Advanced Automation Technology Using PLC Helped for Transfer of Spent Fuel Rods from the Storage Cooling Pool of Unit 4 at Fukushima Daiichi Nuclear Power Plant

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***Abstract* - Tokyo Electric Power Company (TEPCO) operates the Fukushima Daiichi nuclear power plant complex in the Futaba District of Fukushima which is located in Northern Japan, consisting of six boiling-water reactors constructed between 1971 and 1979. The huge earthquake followed by Tsunami waves generated by the shock damaged the backup generators at the Fukushima Daiichi plant on 11th March 2011. At the time of the nuclear power plant accident at Fukushima, only reactors 1, 2, and 3, were in operation, and reactor 4 served as temporary storage for spent fuel rods. The explosion, along with a fire touched off by rising temperatures in spent fuel rods stored in reactor 4, where the spent fuel rods kept led to the release of higher levels of radiation from the plant. This paper summarizes key findings and conclusions from the study how this Advanced Automation Technology used to Transfer of Spent Fuel Rods from the Storage Cooling Pool of unit.4 at Fukushima Daiichi Nuclear Power Plant with Safety**

***keywords* - Japan Fukushima, NPP, Spent Fuel Pool (SFP), Automation, Removal of 1,533 SF Rods.**

I. INTRODUCTION TO SUSTAINABLE DEVELOPMENT BY ENERGY

Energy and powered devices are an integral part of society and today there is a lot of demand for energy. There are many sources of energy. Wind, solar, power, oil, natural gas, coal, petroleum, etc. all provide electricity and energy for the world. Unfortunately, wind and solar power are difficult to trap and do not produce enough power and unreliable to sustain the modern world and natural energy sources are diminishing, therefore, the world is expecting alternative energy sources for sustainable development. Among sustainable energy sources, nuclear power is the high energy pollution free and the safest form of energy.

II. INTRODUCTION TO ATOMIC ENERGY

At the time of the Second World War, the Japanese met a heavy loss of human areas and the grief enveloped them. To free from their grief the Atomic Energy has rescued them to come up and competent the other world [1, 2]. It pared the way for the economic growth. For their immeasurable growth came by their preference hard work (foiling and moiling) Sincerity and controlled good discipline were there.

The Indians ought learn to know about now the tiny country Japan sprang back to normal and claimed to the peak in the economic growth after the destruction by atom bombs were blasted in the Hirosima and Nagasaki during the 2nd world war. Today the whole world wonders about their unbelievable achievements. Like India, America, China and Poland, Japan did not have the mines of coal and also the Japan did not have oil resources [1].

Atomic energy is energy obtained from the atom. Every atom has particles of energy in it. The core of an atom is the source of the energy and when the atom is splitted by bombarded by another nucleus it generate large amount of energy. The Atomic power plant mostly requires Uranium. It is also called as yellowcake. It is available in plenty in the earth more than, gold and silver. Uranium is a very heavy metal which can be used as an abundant source of concentrated energy. Uranium 235 in the nucleus, when bombarded by a neutron, it becomes uranium 236.

III. CHAIN REACTION TO ACHIEVE NUCLEAR FISSION

The nucleus of the Uranium – 235 atoms comprises 92 protons and 143 neutrons (92 + 143 = 235). When the nucleus of a uranium 235 atom is bombarded by a moving neutron it splits into two fission materials and releases some energy in the form of heat, also three additional neutrons are thrown off. The thrown off neutrons cause the nuclei of other Uranium 235 atoms to split, with the release of further neutrons and helps to achieve fission "Chain Reaction". A large amount of heat is produced due to chain reaction for many million times, from a relatively small amount of Uranium 235. It results in the loss of the equilibrium and separated into two as berets Barium (Ba) and Kripton (Kr). It gives the heat energy long with 3 (neutrons) and the three neutrons create a chain reaction. It gives more heat energy.

The mass difference is accounted for the release of energy according to the equation $\mathbf{E=\Delta mc^2}$: (Einstein Equation):

$$^{236}U \rightarrow {}^{144}Ba + {}^{89}Kr + 3\text{ neutron} + 200\text{ Mev (Energy)}$$

92 56 36

The uranium emits full of high energy emissions **like** α, β **and** γ radiations. These radiations are emitted by radioactive materials. Professional workers working in such environments face serious health hazards.

These, β, and γ radiations are very harmful to human beings, even leading to deaths. As per the international regulations, there is a limitation regarding the time professional workers can spend in such environments. According to Newton's third law of the universe that matter and energy can neither be created nor destroyed. But they can be changed into one form into another form. Matter can be changed into energy.

IV. EARTHQUAKE AND TSUNAMI IN JAPAN

The Japan Sendai huge earthquake followed by Tsunami waves generated by the shock damaged the backup generators at the Fukushima Daiichi plant on 11th March 2011 [3, 4]. Fig.1. shows the location of the Sendai Earthquake and Tsunami on 11th March 2011 at Japan. Immediately, all three of the reactors operating were successfully shut down. But the loss of power caused cooling systems to fail in each of them. The rising residual heat within each reactor's core caused the fuel rods in reactors 1, 2, and 3 to overheat and partially meltdown.

Fig.1. Sendai Earthquake and Tsunami on 11th March 2011 at Japan
Source: Wordpress – Japan earth quake 2011.

V. SPENT FUEL ASSEMBLY AT UNIT NUMBER 4 OF FUKUSHIMA NUCLEAR POWER PLANT

On March 15, a hydrogen explosion occurred in the Unit 4 reactor building where all the spent fuel rods are kept underwater in the Spent Fuel Pool (SFP). At the time of attacking by the Tsunami, unit 4 was inoperative. The spent fuel rods were stored in the upper floor reactor 4 building and the walls of unit 4 are completely damaged by Tsunami. This tank structure contains 1,331 Bundles of used fuel rods and 202 Bundles of New unused Fuel rods and a total of 1533 rods contained uranium were placed safely and kept there. The spent fuel assemblies were kept in a pool of water to prevent the radioactive particles, escaping from the pool. The pool height is 20 meters above the ground level. Unit.4 was damaged by hydrogen explosion on15th, March 2011 [8-12]. Experts from IAEA visited the Fukushima Daiichi Nuclear power plant and also visited the damaged reactor unit 4 Fig.2. TEPCO engineers want to remove the fuel as soon as possible from the damaged building.

Fig.2. IAEA Experts at Fukushima Daiichi NPP Unit 4.Source: Wikipedia

As there was no electricity the uranium contained fuel (1533) tank meter began to decrease down. The rods filled with uranium showed their top ends above the water level. The heat was increasing highly. The building is so dangerous condition and it may collapse at any time which causes another nuclear accident unless all the 1,533 fuel rods have to remove and transported to another place. The Reactor Unit No.4 spent fuel pool contains an estimated 400 tons of uranium and plutonium oxide, compared with just 6.2 kilograms of plutonium inside Fat Man, the hydrogen bomb that obliterated Nagasaki in 1945. The radiation from the 1533 rods is so dangerous which is 14,000 times more than what was released during the 1945 Hiroshima bombing.

VI. REMOVAL OF 1,533 SPENT FUEL RODS

Therefore, these 1,533 spent fuel rods have to be shifted safely from the damaged building, and this building structure has to be strengthened for the transfer purpose. A special steel girder framed structure was erected to support a fuel handling equipment and an overhead traveling for crane above the unit 4 building. The new crane structure, 69m long by 31m wide by 53m high, took about a year to install for operation. The fuel handling system installed in 2012. Tepco has done extensive rebuilding, including erecting a new steel framework around the building, to provide support and strengthen the structure of the reactor building in preparation for the removal of the fuel assemblies. Also, a crane-hung camera has taken photographs of the Fukushima Daiichi.

Fig.3. Advanced Automation Technology Using PLC Helped for Removal of Spent Fuel Rods from Unit 4.
Source: Tepco/Japan

The delicate rod-removal procedure requires the lowering of a steel cylinder, called a transfer cask, into a corner of the pool and then using the crane to lift the 300-kilogram fuel assemblies one at a time from the vertical array of rods up and then down into the cask. Lifting the 1,533 fuel bundles is to be carried out carefully to avoid danger. TEPCO is preparing to begin the dangerous task of transferring 1,533 nuclear fuel rods from Japan's Fukushima nuclear plant (13). Also, it says it will take one year to complete the removal of fuel assembly from the number 4 reactor building. Tepco wants to extract all the fuel assemblies from the pool. The three main objectives of pool storage of spent fuel are cooling the fuel assemblies, shielding the workers, and the public from radiation emitted from the fission products present in the fuel and to avoid criticality accidents (14). Dry casks were first used in 1986 at the Surry power plant as a temporary solution until a permanent destination was defined. However, no permanent solution was ever put in practice by the majority of operators (15, 16).

VII. ADVANCED AUTOMATION TECHNOLOGY USING PLC FOR TRANSFER OF SPENT FUEL RODS

Automation is a technology that is concerned with the use of Mechanical, which is connected to material handling equipments (Cranes), Electronics with sensors and Programmable Logic Con trol by using Computerized Numerical Control (CNC) system used in the operation and the control of Nuclear Power Plant to Transfer of Spent Fuel Rods from the Storage Cooling Pool of Fukushima Daiichi Nuclear Power Plant (17). The cranes are designed to lift the fuel from the storage rack in the pool before placing it into a protective cask. Fig.3. shows how the Advanced Automation Technology using PLC was used for Removal of Spent Fuel Rods from Unit 4. Workers are remotely operating a crane built underneath the roof cover from a control room located about 500 meters away.

Fig.4. Photo taken by Tokyo Electric Power shows the work progress at the damaged No. 4 reactor building at the Fukushima Daiichi nuclear-power plant
Source: EUROPEAN PRESSPHOTO AGENCY/TEPCO.

On 18th November the fuel rods removal was started from the **spent fuel** pool and transferred to the common pool and the transfer work was **completed** on 22nd December 2014, by transferring all "**1533**" assemblies from the reactor unit 4. Fig.4. shows the photo of Tokyo Electric Power when the work progress at the damaged No. 4 reactor building at the Fukushima Daiichi nuclear power plant. Fig.5. shows the Schematic Diagram of Removal and Transportation of Spent Fuel Rods. In the history of International **Atomic Energy** the **TEPCO** has achieved by removing **all the 1,533 spent fuel rods** from the damaged cooling pool of Fukushima Daiichi Nuclear Power Plant of unit 4. TEPCO transported all the assemblies of **used fuel rods out of 1331 assemblies** (18). Also, TEPCO transported 22 assemblies of new unused rods out of 202. **71 times the transportation** was taken by the trailer for the transportation of the 'CASK' for complete transfer of 1,533 spent fuel rods (18).

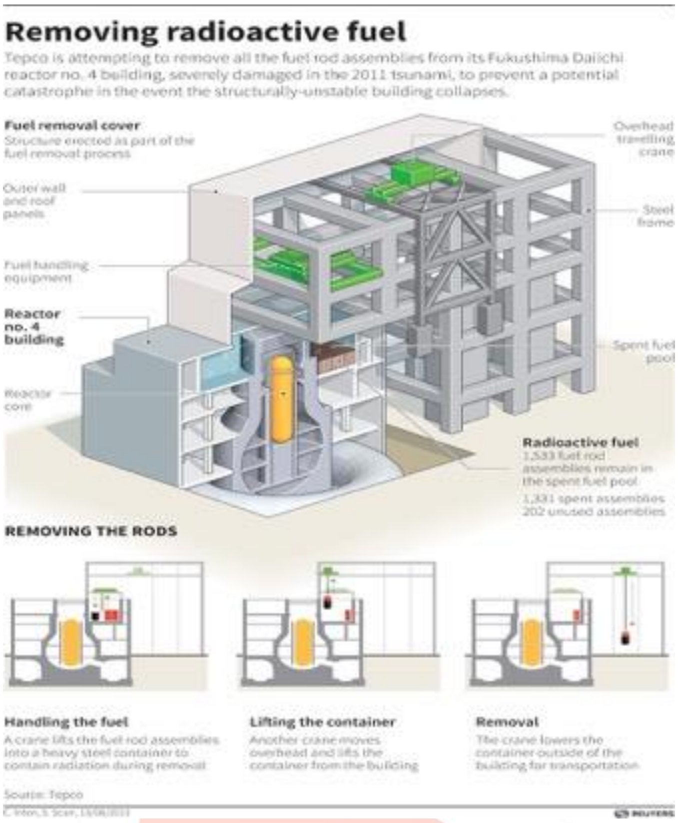

Fig.5. Schematic Diagram of Removal and Transportation of Spent Fuel Rods.
Source: TEPCO, Japan.

VIII. CONCLUSION

In this paper, a detailed analysis was presented for transfer of spent fuel rods of unit 4 followed by the 11th March 2011 accident. The removal and transportation of 1,533 Spent Fuel rods from the damaged cooling pool of Fukushima Daiiachi Nuclear Power Plant was started on November 18, 2013 and the transfer work was completed on 22nd December 2014 which is the **first time in the history** of Atomic Energy which is considered as **Milestone** in the history. After the removal of fuel rods from the spent fuel pools of reactor number 4, it is believed that it is a great step towards the stability and decommissioning of Fukushima Daiichi Nuclear Power Plant. It is concluded that there would have been no large leakage in the spent fuel cooling pool.

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