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Nuclear Energy: Clear and Clean Energy for Safe and Sustainable Development.

KEYWORDS: Nuclear energy, fission; fusion; chain reaction; Nuclear Bomb; Nuclear Reactor; Nuclear Power Plant; Uranium; Thorium; Plutonium; PHWR; FBR; Indian Nuclear Program

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ABSTRACT *Till Second World War, for the need of energy man never looked for nuclear energy on the earth, but it was by product of scientific activity originated in curiosity and political circumstances during that time. Invention of fission process and chain reaction lead to development to nuclear bomb. After the world war, people realized that the bombs are destructive and its use must be avoided, but the nuclear energy can be used for other useful purpose. This lead to peaceful use and sustainable development. India has the highest reserve of Thorium-232 in the world. Based on this consideration, Dr. Homi Bhabha conceived unique sequential three stage Indian Nuclear Program. This program multiplies the energy potential of the fuel available in India and also reduces the waste. India has achieved commercial maturity in stage one and two and working for the development of stage three.*

1. HISTORY OF NUCLEAR ENERGY

In development stage of the human beings, only muscle power was the form of power either self-muscle power or the muscles of animals. It is derived from carbon in the food. After the invention of fire, the source of energy was carbon atom. Energy was available by burning of wood-sticks, dry leaves etc. in the 17th and 18th century, they found coal and mineral oil from which they could obtain more chemical energy. When they found electricity, these coal and mineral oil were used to generate electricity. In addition of this, potential energy of water was also used to generate energy in hydroelectric plant. Hydro electricity is also derived from the energy of Sun. the solar energy is also a nuclear energy. It is derived by nuclear fusion of hydrogen into helium. In fact for the need of energy man never looked for nuclear energy on the earth, but it was by product of scientific activity originated in curiosity and political circumstances during Second World War.

2. NUCLEAR ENERGY IN PERSPECTIVE

An element at the higher end of periodic table like Uranium would gain stability if it splits to make elements on the lower side of mass numbers. Due to this the total mass of two pieces would be lesser than that of the parent atom. According to Einstein's famous equation $E=mc^2$, this breakup process releases energy and we utilize this energy to generate electricity.

CHAIN REACTION

The structure of atom proposed by Rutherford in 1912. In 1932, British physicist Chadwick discovered a nuclear particle Neutron. This practice turned out to be a potent tool for further exploring the atom and its nucleus. The process of breaking of atom was discovered in Germany by Hawn and Strassman in 1938. A Jew scientist working in Hawn's institute gave exact explanation of fission process. If the Uranium atom gave out two neutrons while breaking, then these neutrons can break two more atoms and then for new neutrons from there can break four uranium atoms and so on. This continuous process is called a chain reaction. There will be a billion of fissions as a result of this chain reaction. Meitner also shown that some energy is released during each fission. Thus this amounted to abundant release of energy.

REACTOR HISTORY

Curie-Joliot's team in France looked for controlled chain reaction, which would eventually give a nuclear reactor. Whereas other group who were hurt by dictators and had migrated to USA looked for fast chain reaction in uranium for blast purpose. On 2nd December 1942, practical demonstration of chain reaction was done in Chicago University. 50 tons of uranium and uranium oxide lumps with 500 tons of graphite were used for this reactor. This small reactor had a full power of 200 watts only! Based on this model, they designed another reactor- Oak Ridge reactor and started in November 1943. In December 1943, plutonium extraction plant was started. Because of the war condition and fear of the Germany, the invention from chain reaction to reactors to plutonium extraction to bombs manufacturing were done with remarkable speed- only within two and half years. A trial bomb was exploded in New Mexico desert on 16th July 1945. Hiroshima blast occurred on 6th August and Nagasaki on 9th August 1945.

3. POST WAR DEVELOPMENT FOR PEACEFUL USE OF NUCLEAR ENERGY

After the world war, the people realize that the bombs are for destructive purpose and its use must be avoided, but the nuclear energy can be used for peaceful use. In the 1st decade after world war, so many research reactors were developed.one team of scientist escaped from France to Canada and developed Heavy water Reactor. Which was using natural uranium as a fuel. The US scientist were able to enrich the uranium. They used light water for moderation and cooling purpose. Britain and initially Russia also used graphite as moderation and gas for cooling. In 1954, Obnisk of Russia and in 1956, Calder Hall of Britain were started producing electricity for grid. Nuclear propelled ice-breaker ship Nautilus was floated in 1954. First time in Asia, outside Russia, India came into the picture with her first nuclear reactor Apsara in 1956. At present there are so many reactors operating in the world.

4. OTHER USES OF NUCLEAR ENERGY

Nuclear energy can be used for ships and submarines for propulsion. In cold countries, it can supply steam for heating the walls of building and complexes. Steam from nuclear plant can be used for desalination water from brackish source.

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Nuclear energy can be used to electrolyze water to obtain hydrogen. Along with electricity generation, nuclear reactor can be used for producing nuclear species which do not exist in nature. Production of new fissile isotopes U-233, Pu-239 and Pu-240 can be produced which can be used in medicine, industry and agriculture. Cobalt-60 is popular for cancer treatment. Some isotopes help in research.

5. NUCLEAR POWER PLANT IN INDIA

India has vast available energy resources like coal 186 billion tones, lignite 5060 million tones, crude oil 728 million tons, natural gas 686 billion cu-meter, uranium 78,000 tones and thorium in vast quantity 3,63,000 tones.

Total Nuclear Power Plant Capacity of 4780 MWe is as listed in table below:

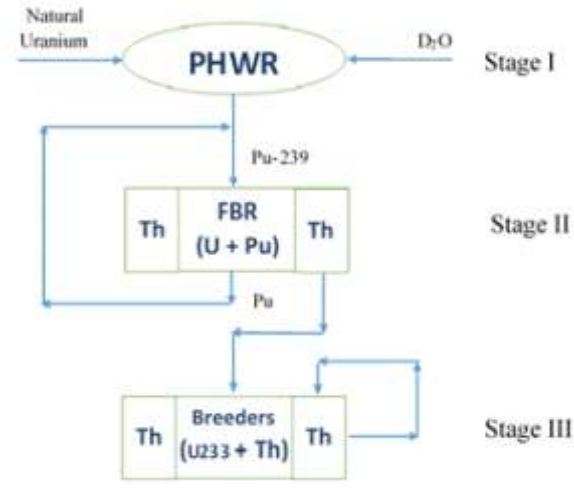
Plant	Unit	Type	Capacity (MWe)	Date of Commercial operation
Tarapur Atomic Power Station (TAPS), Maharashtra	1	BWR	160	Oct 28, 1969
	2	BWR	160	Oct 28, 1969
	3	PHWR	540	Aug 18, 2006
	4	PHWR	540	Sept 12, 2005
Rajasthan Atomic Power Station (RAPS), Rajasthan	1	PHWR	100	Dec 16,1973
	2	PHWR	200	April 1,1981
	3	PHWR	220	June 1, 2000
	4	PHWR	220	Dec 23, 2000
	5	PHWR	220	Feb 4, 2010
	6	PHWR	220	Mar 31, 2010
Madras Atomic Power Station (MAPS), Tamilnadu	1	PHWR	220	Jan 27,1984
	2	PHWR	220	Mar 21,1986
Kaiga Generating Station (KGS), Karnataka	1	PHWR	220	Nov 16, 2000
	2	PHWR	220	Mar 16, 2000
	3	PHWR	220	May 6, 2007
	4	PHWR	220	Jan 20, 2011
Narora Atomic Power Station (NAPS), Uttarpradesh	1	PHWR	220	Jan 1,1991
	2	PHWR	220	Jul 1,1992
Kakrapar Atomic Power Station (KAPS), Gujarat	1	PHWR	220	May 6, 1993
	2	PHWR	220	Sept 1, 1995

Nuclear Power Generation in India from 2006-07 to 2012-13 is listed in table below

Year	Gross Generation (MUs)	Capacity Factor (%)	Availability Factor (%)
2012-13	32863	80	90
2011-12	32455	79	91
2010-11	26472	71	89
2009-10	18803	61	92
2008-09	14927	50	82
2007-08	16930	54	83
2006-07	18634	63	85

6. INDIAN NUCLEAR PROGRAM

The Indian Nuclear Program was conceived by Dr. Homi J. Bhabha based on unique sequential three stage and associated technologies essentially to aim at optimum utilization of locally available nuclear resources of modest uranium and abundant thorium. This three stage program is based on closed fuel cycle where the spent fuel of one stage is processed to produce fuel for the next stage. It multiplies the energy potential of the fuel and also reduces the waste.



STAGE I

The first stage comprises of Pressurized Heavy Water Reactor with natural uranium as fuel. Natural uranium contains only 0.7% of Uranium-235. The remaining 99.3% is Uranium-238 which is not fissile, but fertile. By transmutation of Uranium-238, Plutonium-239 is extracted. The first stage consisting of PHWR has reached a state of commercial maturity.

STAGE II

The second stage comprises of Fast Breeder Reactors. FBRs are fuelled by mixed oxide of Uranium and Plutonium, recovered by reprocessing of first stage spent fuel. In FBRs, Plutonium-239 undergoes fission process and produce energy. It also produces Plutonium-239 by transmutation of uranium-238. Thus the FBRs produce energy and fuel and hence it is considered as Breeders. FBRs produce more fuel than they consume.

Thorium-232 reserve in India is the highest in the world. Thorium-232 is not fissile. It is converted to fissile material Uranium-233 by transmutation in FBR. The second stage of FBR has been commercially launched with the construction of 500 Mw FBR at Kalpakkam.

STAGE III

Stage three will be based on Thorium-232 and Uranium-233 cycle. Breeders will use Uranium-233 as a fuel and will also produce Uranium -233 by irradiation of Thorium-232. Thus potentially utilizing Thorium for power generation. The development work for third with Thorium is in progress.

Japan has decided to restart its nuclear program even after the 2011 Fukushima meltdown. It shows that nuclear power continuous to be an important source of clean energy. The Fukushima disaster had forced Japan to shut down all 50 of its nuclear reactor, but completely shifting to renewable sources such as solar and wind simply is not feasible.

Both solar and wind are less efficient than nuclear power because sufficient sunshine and wind are not always available to

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meet energy demands. This means for solar and wind to completely replace dirty fossil fuels, one would have to cover large portion of the earth with solar panels and wind turbines. Thus much like hydro projects, would lead to massive displacement of people from their lands.

In contrast, nuclear power plants take up much less land, ensure steady base load power supply and emit zero greenhouse gases. It is true that Chernobyl in Russia and Fukushima in Japan happened. But such nuclear disaster are rare. With best safety standards, nuclear power can be used as clear and clean energy for peaceful use like electricity generation and sustainable development.

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