India's Expansion in the Nuclear Power Sector and Its Effects

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Abstract-In the past few years India has seen a tremendous increase in investment and expansion in the nuclear power sector. The reason being the Nuclear Suppliers' Group agreement which was achieved in September 2008. India has a flourishing and largely indigenous nuclear power program and expects to have a capacity of 14,600 MWe by 2020. It aims to supply 25% of electricity from nuclear power by 2050. India is outside the Nuclear Non-Proliferation Treaty due to its weapons program,and hence it was largely excluded from trade in nuclear plant or materials for 34 years , which has hampered its development of civil nuclear energy until 2009.Due to these trade bans and lack of indigenous uranium, India has uniquely been developing a nuclear fuel cycle to exploit its reserves of thorium. Now, foreign technology and fuel are expected to boost India's nuclear power plants considerably. India has a vision of becoming a world leader in nuclear technology due to its expertise in fast reactors and thorium fuel cycle.

This research paper is trying to give a detailed report of India's development in the nuclear power sector and its impact on the power sector in India.

Index Terms- Nuclear Power, India's development, Thorium Fuel Cycle,Treaty with NSG, Future projects,Regulation and control, Effects, Challenges.

1.0 INTRODUCTION

Nuclear fission in a chain process produces tremendous amount of heat and electricity that can be utilized for the generation of nuclear power. 2012 survey reveals that approximately 5.7% of the global energy and 13% of the global electricity requirements in particular, were met by nuclear power plants.

Splitting of atoms of certain heavy unstable elements like uranium, plutonium, and thorium etc. into lighter elements; because of bombardment of neutrons results in the production of massive energy. In a nuclear reactor, this released energy is monitored and harnessed as heat in gas or water based reactor for producing steam that later drives turbines and electricity is generated. All nuclear reactors utilize the same principle for conversion of nuclear power to electrical energy.

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The foremost nuclear power station for commercial electricity production was set up at Obninsk, Russia in 1954 whose output was 5MW(e). The reactor used in this plant was graphite moderated, light water cooled reactor. In 1956, four 50MW (e) graphite moderated and gas (carbon dioxide) cooled reactors were set up in UK. In 1957,for the very first time, pressurized light water reactor (PWR) for electricity production with an output of 60 MW(e) commenced in USA. Many nations succeeded in this novel trend of electricity production using nuclear energy and subsequently, 436 nuclear reactors began functional across the globe with a cumulative capacity of 370 GW(e).

The components of a nuclear reactor comprise of fuel, moderator, control rods, coolant, steam generator, pressure vessel or pressure tubes and containment.

The nuclear reactors can be categorized as Pressurized water reactor, Pressurized heavy water reactor (CANDU), boiling water reactor, fast breeder reactor (neutron reactor), Light water graphite reactor (RBMK) and Gas cooled reactor (AGR).

2.0 INDIA'S DEVELOPMENT IN NUCLEAR POWER SECTOR

Nuclear power for civil use is well established in India. Its civil nuclear strategy has been directed towards complete independence in the nuclear fuel cycle, necessary because it is excluded from the 1970 Nuclear Non-Proliferation Treaty (NPT) due to it acquiring nuclear weapons capability after 1970. Hence, India didn't receive any external help for development of nuclear energy. The technology that India implemented for nuclear power generation was crude and primitive till mid-1990s. However, it saw an amazing growth between 1995 and 2002. This figure again plummeted in 2008-10 due to scarcity of uranium fuel.

For becoming self-reliant, India explored its uranium reserves and started extensive mining. It also began with fuel fabrication, production of heavy water, designing and constructing reactors, reprocessing and management of waste generated. India is also thinking of using thorium as an alternative to uranium (nuclear fuel) because of its copious reserves. India is developing the existing small fast breeder reactor that it has.

The Atomic Energy Establishment was set up at Trombay, near Mumbai, in 1957 and renamed as Bhabha Atomic Research Centre (BARC) in 1967. India's first research nuclear reactor and its first nuclear power plant were built with assistance from Canada. Research reactor of 40 MW was handed over to India by signing an agreement specifying that India won't use it for military or war operations.The first Pressurized Heavy Water Reactor (PHWR) - Rajasthan-1, which had Canada's Douglas Point reactor as a reference unit, was built as a collaborative venture between Atomic Energy of Canada Ltd (AECL) and National Power Corporation of India Ltd (NPCIL) in 1972.

The NPCIL along with public sector and private corporations are aiming to expand the nuclear power industry.

Table 1 shows the existing 20 reactors producing 4780 MWe approximately. *Source: NPCIL website.*

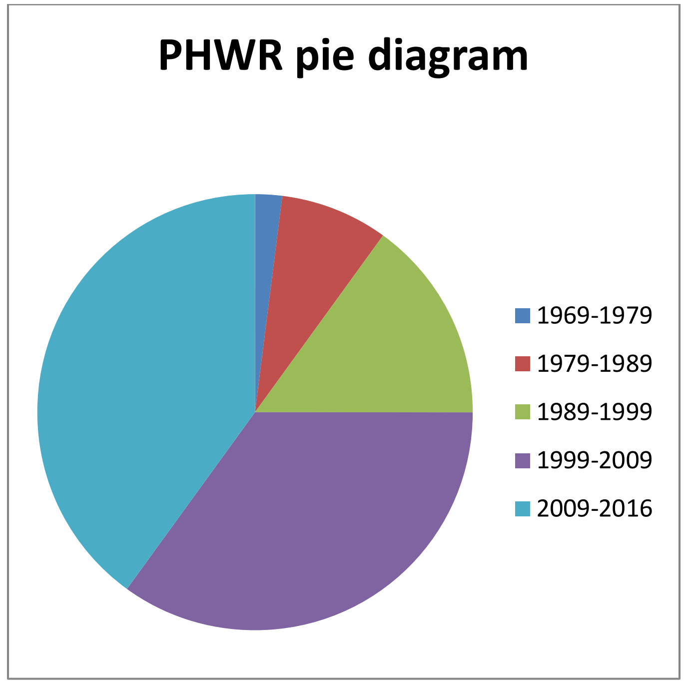
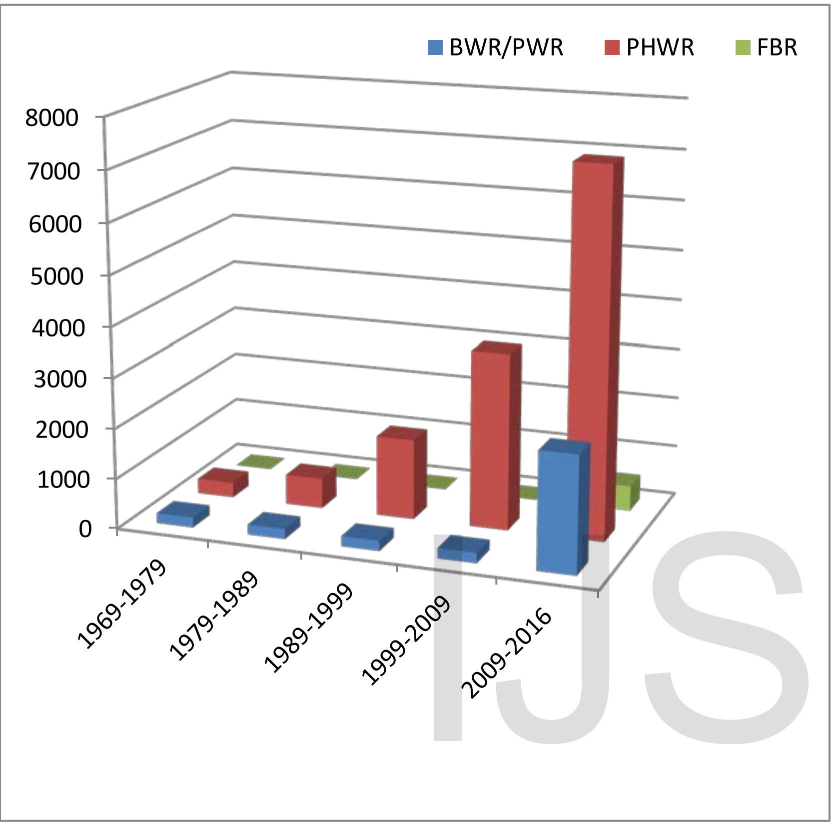


Table 1: India's operating nuclear power reactors

Reactor	State	Type	Total Capacity MWe, each	Commercial operation
Tarapur 1 & 2	Maharashtra	BWR	160	1969
Tarapur 3 & 4	Maharashtra	PHWR	540	2006, 05
Kakrapar 1 & 2	Gujarat	PHWR	220	1993-95
Kalpakkam 1 & 2	Tamil Nadu	PHWR	220	1984-86
Kaiga 1 & 2	Karnataka	PHWR	220	2000
Kaiga 3 & 4	Karnataka	PHWR	220	2007,2011
Rawatbhata 1	Rajasthan	PHWR	100	1973
Rawatbhata 2	Rajasthan	PHWR	200	1981
Rawatbhata 3 & 4	Rajasthan	PHWR	220	2000
Rawatbhata 5 & 6	Rajasthan	PHWR	220	Feb & March 2010
Narora 1 & 2	Uttar Pradesh	PHWR	220	1991-92

In 2011 there were 20 well established fully functional nuclear reactors across India; however; the figure is expected to rise to 27 by 2016 as projected by the following bar graph.



Note: Y axis denotes Net Nuclear Capacity in MWe.

BWR-Boiling Water Reactor. PWR-Pressurised Water Reactor. PHWR-Pressurised Heavy Water Reactor. FBR-Fast Breeder Reactor.

2.1 Thorium Fuel Cycle Development in India

India has done a great amount of work in the development of Thorium Fuel Cycle. It has been striving towards the development of an advanced Heavy Water Thorium Cycle. This process consists of 3 stages. In the first stage PHWRs are used which work on natural uranium and light water reactors to produce plutonium. In stage 2, fast neutron reactors burn plutonium to get U-233 from thorium. Thorium in combination with Uranium will serve as a blanket around the core, so that further plutonium (ideally high-fissile Pu) is produced. Finally, in stage 3, U-233 will be burnt by advanced heavy water reactors (AHWRs) and this process generates power out of which two- thirds is from thorium.

The fast breeder reactor at Kalpakkam with an output of 500MWe was expected to be ready by 2012. By 2020, six more fast reactors of 500MWe are going to be functional. The reprocessing center for thorium fuels has also been established at Kalpakkam.

Indian President A.P.J.Abdul Kalam, stated while he was in office, that "energy independence is India's first and highest priority. India has to go for nuclear power generation in a big way using thorium-based reactors. Thorium, a non-fissile material is available in abundance in our country"

2.2 Radioactive Waste Management in India

Radioactive wastes from the nuclear reactors and reprocessing plants are treated and stored at each site. Waste immobilization plants are in operation at Tarapur and Trombay and another is being constructed at Kalpakkam. Research on final disposal of high-level and long-lived wastes in a geological repository is in progress at BARC.

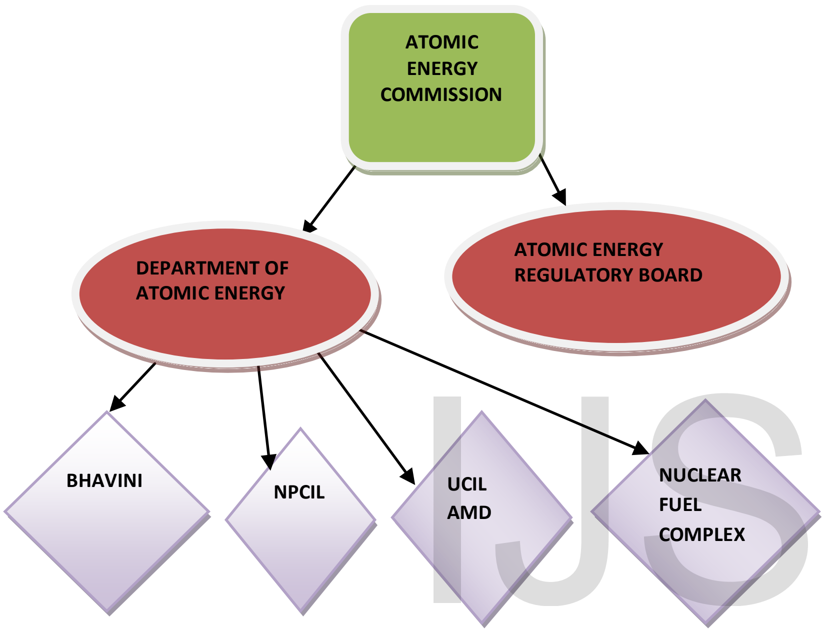
2.3 Regulation and Control

The Atomic Energy Commission (AEC) was established in 1948 under the Atomic Energy Act as a policy body. Then in 1954 the Department of Atomic Energy (DAE) was set up to facilitate research, technology development and commercial reactor operation. The current Atomic Energy Act, 1962 permits only government-owned enterprises to be involved in nuclear power.

The DAE includes Nuclear Power Corporation of India Ltd.(NPCIL), Uranium Corporation of India Ltd. (UCIL, mining and processing), Atomic Minerals Directorate for Exploration and Research (AMD, exploration), Electronics Corporation of India Ltd (reactor control and instrumentation) and Bhartiya Nabhikiya Vidyut Nigam Ltd.,BHAVINI (for setting up fast reactors). The DAE also controls the Heavy Water Board for production of heavy water and the Nuclear Fuel Complex for fuel and component manufacturing.

The Atomic Energy Regulatory Board (AERB) was formed in 1983 and comes under the AEC but is independent of DAE. It is responsible for the regulation and licensing of nuclear facilities and their safety and carries authority conferred by the Atomic Energy Act for radiation safety and by the Factories Act for industrial safety in nuclear plants.

HIERARCHY OF NUCLEAR ORGANIZATION IN INDIA



Atomic energy regulatory Board (AERB) is mainly concerned of regulation. Bhavini is responsible for FBRs, NPCIL for most of the power, UCIL AMD for uranium and Nuclear Fuel Complex for Fuel Cycle.

3.0 INDIA's TREATY WITH NSG(NUCLEAR SUPPLIERS GROUP) AND ITS EFFECTS

Following the Nuclear Suppliers' Group agreement which was achieved in September 2008, the scope for supply of both reactors and fuel from suppliers in other countries opened up. Civil nuclear cooperation agreements have been signed with the USA, Russia, France, UK, South Korea and Canada, as well as Argentina, Kazakhstan, Mongolia and Namibia.

On the basis of the 2010 cooperation agreement with Canada, in April 2013 a bilateral safeguards agreement was signed between the Department of Atomic Energy (DAE) and the Canadian Nuclear Safety Commission, allowing trade in nuclear materials and technology for facilities which are under International Atomic Energy Agency(IAEA) safeguards. A similar agreement is being negotiated with Australia.

NPCIL had meetings and technical discussions with three major reactor suppliers - Areva of France, GE-Hitachi and Westinghouse Electric Corporation of the USA for supply of reactors for these projects and for new units at Kaiga. Since 2007 the Government of India along with the Atomic Energy Regulatory Board have approved the construction of more than 15 Atomic Reactors and many more have been proposed.(see Table 2 and 3)

Table 2: Power reactors planned

Reactor	Type	MWe gross each	Start construction	Start operation
Kudankulam 3	PWR	1050	2014	2019
Kudankulam 4	PWR	1050	2014	2020
Kudankulam 5 & 6	PWR x2	1050-1200	2014	2019-21
Kalpakkam 2 & 3	FBR x 2	500	2014	2019-20
Jaitapur 1 & 2	PWR x 2	1700	2013	2018-19
Banswada	PHWR x 2	700	2014	N/A
Kaiga 5 & 6	PHWR x 2	700	2012	N/A
Gorakhpur 1 & 2	PHWR x 2	700	2013-14	2018-19
Bheempur 1 & 2	PHWR x 2	700	2014	N/A
Chutka 1 & 2	PHWR x 2	700	2014	N/A
Subtotal planned	**18 units**	**15,100 - 15,700 MWe**		

Source: World Nuclear Association.

The next big milestone was the proposal by NPCIL to establish five "Nuclear Energy Parks" whose capacity would be 1000 MWe each. 40-45 Gwe nuclear power was expected to be generated from these nuclear parks.The eight proposed parks are Kudankulam, Jaitapur, Mithi Virdi, Kovvada, Haripur, Kumharia, Bargi and Markandi.

India's largest power company, National Thermal Power Corporation (NTPC) in 2007 proposed building a 2000 MWe nuclear power plant to be operational by 2017. NTPC is reported to be establishing a joint venture with NPCIL and BHEL to export India's native 220 MWe heavy water power reactor units particularly to Namibia and Mongolia in return of uranium..

National Aluminium Company (Nalco) with NPCIL has got into an agreement of a 1400 MWe nuclear power plant in Orissa.

India's prestigious oil company Indian Oil Corporation Ltd (IOC) in 2009 along with partner NPCIL has plans to establish revenue generating nuclear power plants with an output exceeding 1000MWe. NPCIL is holding 51% whereas IOC has 49%. Oil and Natural Gas Company (ONGC) too has similar plans.

To fulfill power requirements, Indian Railways is in talks with NPCIL to build two 500 MWe PHWR nuclear plants on railway land.

The Steel Authority of India Ltd (SAIL) and NPCIL are discussing a joint venture to build a 700 MWe PHWR plant mostly on the west coast (Gujarat).

Table 3: Power reactors firmly proposed

Reactor	Type	MWe gross each	Start construction	Start operation
Jaitapur 3 & 4	2 x PWR	1700	2016	2021-22
Jaitapur 5 & 6	2 x PWR	1600	N/A	N/A
Mithi Virdi 1-2	2 x PWR	1250	2013	2019-20
Mithi Virdi 3-4	2 x PWR	1250	2015	2020-21
Mithi Virdi 5-6	2 x PWR	1250	2023-24	N/A
Kovvada 1-2	2 x ESBWR	1350-1550	2014	2019-20
Kovvada 3-4	2 x ESBWR	1350-1550	N/A	N/A
Pulivendula	2 x PWR 2x PHWR	1000 700	N/A	N/A
Nizampatnam 1-6	6x N/A	1400	N/A	N/A
Markandi	PWR	6000	N/A	N/A
Haripur 1-2	4 x PWR	1200	2014	2019-21
Haripur 3-4	4 x PWR	1200	2017	2022-23
Chutka 3-4	2 x PHWR	1400	N/A	N/A
Subtotal proposed	**approx. 35**	**45,000 MWe approx.**		

Source: World Nuclear Association. *N/A- Not Available.*

The Government of India has plans to make amendments to the law that allows private companies to get involved in the nuclear power generation and processes like fuel cycle.

In anticipation of this, Reliance Power Ltd, GVK Power & Infrastructure Ltd and GMR Energy Ltd are reported to be in discussion with overseas nuclear vendors including Areva, GE-Hitachi, Westinghouse and Atomstroyexport.

In September 2009 the AEC announced a version of its planned Advanced Heavy Water Reactor (AHWR) designed for export.

In August and September 2009 the AEC reaffirmed its commitment to the thorium fuel cycle, particularly thorium-based FBRs, to make the country a technological leader.

3.1 IMPACT ON INDIA'S ELECTRICITY SECTOR

As of May 2013, the electricity sector in India has an installed capacity of 225GW; fifth across the globe. This production is obtained by both renewable and non-renewable sources. Coal and lignite produce 57% of the total; whereas hydro-electricity accounts for 19%. On the other hand, nuclear power constitutes 3%. The remaining is met by newer renewable sources like solar energy, tidal energyand wind energy. Etc

Nuclear power stands fifth in electricity production. As of 2012, India has 20 nuclear reactors in operation in six nuclear power plants, generating 4,780 MWwhile seven other reactors are under construction and are expected to generate an additional 5,300 MW.

In spite of producing close to 225 GWe; India is still falling short of electricity for a population exceeding 1.21 Billion. The reason behind this shortfall is the ever increasing population and along with it, the increasing demand for electricity. The 960 billion kilowatt hours gross produced in 2010 was more than triple the 1990 output, though still represented only some 750 kWh per capita for the year. As per the 2010 statistics, 211 TWh was lost in transmission leaving 693 billion kWh for consumption. The per capita electricity consumption figure is expected to double by 2020, with 6.3% annual growth, and reach 5000-6000 kWh by 2050, requiring about 8000 TWh/yr. then. There is an acute demand for more and more reliable power supplies. One third of the population is not connected to any grid.

This scenario can be changed by investment in nuclear power.

Nuclear power supplied 20 billion kWh (3.1%) of India's electricity in 2011 from 4.4 GWe (of 180 GWe total) capacity and after a dip in 2008-09 this is increasing as imported uranium becomes available and new plants come on line. India's fuel situation, with shortage of fossil fuels, is driving the nuclear investment for electricity, and 25% nuclear contribution is the ambition for 2050, when 1094 GWe of base-load capacity is expected to be required.

It can be foreseen that as the percentage of nuclear energy in the total energy produced rises, the percentage of non-renewable sources like coal and natural gas will drop down. Coal can be used for steel generation, cement generation or export in order to generate revenue. Most importantly, it can be preserved for future use in technologies where coal is the ultimate choice. Moreover, Coal-fired electric power generation emits around 2,000 pounds of carbon dioxide for every MWh generated, which is almost double the approximately 1100 pounds of carbon dioxide released by a natural gas-fired electric plant per MWh generated.

Nuclear energy has high output. Nuclear power plants produce electricity with about 66g equivalent lifecycle carbon dioxide emissions per kWh, while renewable power generators produce electricity with 9.5-38 g carbon dioxide per kWh.

Nuclear power is constant and chances of failure are comparatively lower .Hence the development in nuclear power will definitely help in meeting the ever increasing demand of electricity in India.

4.0 Challenges

There is an ongoing debate about the use of nuclear energy. Proponents, such as the World Nuclear Association, the International Atomic Energy Agency and Environmentalists for Nuclear Energy contend that nuclear power is a sustainable energy source that reduces carbon emissions. Opponents, such as Greenpeace International and Nuclear Information and Reserve Service, believe that nuclear power poses many threats to people and the environment.

Some of the challenges that India has to face include nuclear decommissioning, high level radio-active waste generation and possibility of occurrence of disasters if not handled appropriately.

Nuclear power plants have their life-span beyond which they need to be decommissioned. Decommissioning costs are as much as 60% of the costs of establishing a nuclear power plant, apart from it being a time-consuming process.

The radioactive waste that is generated as a by-product in nuclear power production is extremely dangerous as the by-products are radioactive isotopes. For instance, Technetium-99(half-life 220,000 years) and Iodine-129 (half-life 15.7 million years), which are toxic and result in mutations in the off springs. Also, these radioactive products need to be stored for a long time before being disposed at a far off place.

The Chernobyl explosion, Fukushima disaster, Three Mile Island accident are historic illustrations of ill-effects of negligence in utilization of nuclear energy.

5.0 Conclusion

Energy plays a vital role in economic growth and serves as a backbone for industrial development in a country. Nuclear energy is a promising , and at present, the fastest source to overcome the energy deficit. India is making rapid progress in the field of nuclear energy. Practically speaking; India has a long mile to go before it becomes self-sufficient with nuclear power. Despite the challenges and other issues; nuclear energy has the potential to overcome the energy crisis that India is dealing with.

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