Current Status and Development of Nuclear Power in India

1. The Indian Nuclear Power Programme

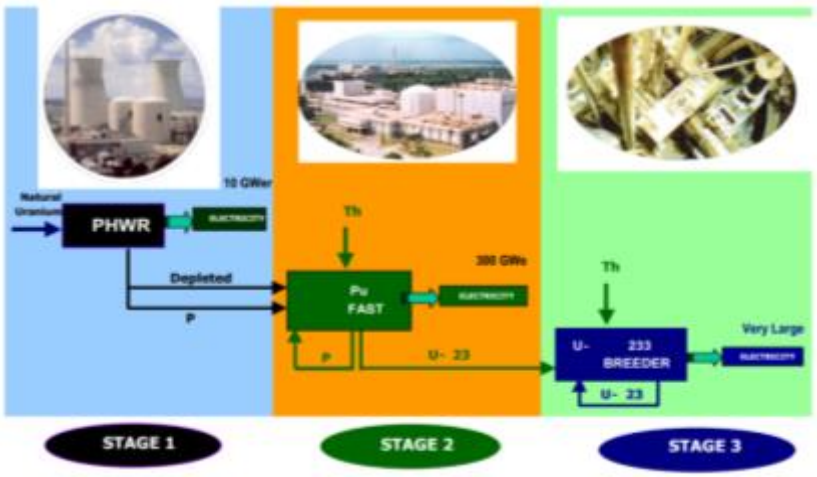
The Indian nuclear programme was conceived based on, unique sequential three-stages and associated technologies essentially to aim at optimum utilization of the indigenous nuclear resource profile of modest Uranium and abundant Thorium resources. This sequential three-stage program is based on a closed fuel cycle, where the spent fuel of one stage is reprocessed to produce fuel for the next stage. The closed fuel cycle thus multiplies manifold the energy potential of the fuel and greatly reduces the quantity of waste generated.

The first stage comprises Pressurized Heavy Water Reactors (PHWR) fuelled by natural Uranium. During this stage the Uranium-238 contained in natural Uranium is converted to fissile element Plutonium-239.

The second stage, comprising Fast Breeder Reactors (FBRs) are fuelled by mixed oxide of Uranium-238 and Plutonium-239, recovered by reprocessing of the first stage spent fuel. In FBRs, Plutonium-239 undergoes fission producing energy, and producing Plutonium-239 from Uranium-238. Thus the FBRs produce energy and fuel, hence termed Breeders. Also non-fissile Thorium-232, which constitutes world's third largest reserves in India, is converted to a fissile material, Uranium-233, by transmutation in a fast breeder reactor.

In the third stage, Uranium-233 based reactor would be used to covert non-fissile Thorium-232 into Uranium-233, which would be a closed cycle.

Three-Stage Nuclear Power Program



2. Operating Nuclear Power Plants – Current Status

Presently in India, there are 19 Nuclear Power Plants (NPPs) in operation with an installed capacity of 4680 MWe. The list of NPPs in operation is given in Table-1.

Table – 1: Operating NPPs in India

Plant	Unit	Type	Capacity (MWe)	Date of Commercial Operation
Tarapur Atomic Power Station (TAPS), Maharashtra	1	BWR	160	October 28, 1969
	2	BWR	160	October 28, 1969
	3	PHWR	540	August 18, 2006
	4	PHWR	540	September 12, 2005
Rajasthan Atomic Power Station (RAPS), Rajasthan	1	PHWR	----	December 16, 1973 **(currently defueled)**
	2	PHWR	200	April 1,1981
	3	PHWR	220	June 1, 2000
	4	PHWR	220	December 23, 2000
	5	PHWR	220	February 4, 2010
	6	PHWR	220	March 31, 2010
Madras Atomic Power Station (MAPS), Tamilnadu	1	PHWR	220	January 27,1984
	2	PHWR	220	March 21,1986
Kaiga Generating Station (KGS), Karnataka	1	PHWR	220	November 16, 2000
	2	PHWR	220	March 16, 2000
	3	PHWR	220	May 6, 2007
	4	PHWR	220	January 20, 2011
Narora Atomic Power Station (NAPS), Uttarpradesh	1	PHWR	220	January 1,1991
	2	PHWR	220	July 1,1992
Kakrapar Atomic Power Station (KAPS), Gujarat	1	PHWR	220	May 6, 1993
	2	PHWR	220	September 1,1995

The first NPP in the country, TAPS Units 1&2, based on Boiling Water Reactors (BWR), supplied by General Electric, USA, became operational in the year 1969. After completion of 30 years of operation, these plants underwent safety assessments for continued long term operation. Based on the review, during the years 2000 to 2006, a number of safety upgrades were implemented during the refueling outages of individual units and in a simultaneous long shutdown of both the units during November 2005 to January 2006.

The mainstay of India's nuclear power programme has been the PHWR. Two 200 MWe units (RAPS 1&2) were established in the 1970s, at Rawatbhata in Rajasthan, with the technical cooperation of AECL (Canada). Subsequently, in 1980s, two 220 MWe PHWRs (MAPS-1&2) were constructed at Kalpakkam in Tamilnadu, with indigenous efforts.

Among these, RAPS Unit-2 and MAPS Units 1&2 have undergone extensive safety upgrades during enmasse coolant channel replacement and/or enmasse feeder replacement.

Subsequently, India developed a standardized design of 220 MWe PHWRs. This design incorporated state of the art features viz. integral calandria & end shields, two independent fast acting shut down systems, high pressure Emergency Core Cooling System (ECCS), water filled calandria vault and provision of double containment with passive vapour suppression pool. Four reactors of this standardized design were built, two each at Narora in Uttar Pradesh (NAPS 1&2) and Kakrapar in Gujarat (KAPS 1&2). These plants became operational through the 1990s. Subsequently eight more units of standardized 220 MWe PHWRs were built, four each at Kaiga in Karnataka (KGS units 1-4) and Rawatbhata in Rajasthan (RAPS Units 3-6). Over and above the basic standardized 220 MWe PHWR, this design has more compact site layout and incorporated further improvements in safety features and containment.

In 1990s, India undertook the design and development of 540 MWe PHWR. Two reactors based on this design became operational in 2005-2006 at Tarapur (TAPS Units 3&4).

3. Nuclear Power Projects – Current Status

Program of ongoing, planned and future Nuclear Power Projects (NPPs) includes indigenous PHWRs (700 MWe), Fast Breeder Reactors (FBRs) and imported Light Water Reactors (LWRs). Presently, there are 7 NPPs under various phases of construction in India, with rated capacity of 5300 MWe. In addition, a number of new NPPs are planned to significantly increase the nuclear power base from the current levels. The list of Ongoing NPPs is given in Table - 2.

Table - 2: Ongoing Nuclear Power Projects in India

Project	Unit	Type	Capacity (MWe)	Status
Kudankulam Nuclear Power Project (KK NPP), Tamilnadu	1	VVER	1000	Commissioning in progress
	2	VVER	1000	Construction nearing completion
Kakrapar Atomic Power Project (KAPP), Gujarat	3	PHWR	700	Civil construction started
	4	PHWR	700	Civil construction started
Rajasthan Atomic Power Project (KAPP), Rajasthan	7	PHWR	700	Civil construction started
	8	PHWR	700	Civil construction started
Prototype Fast Breeder Reactor (PFBR), Tamilnadu	1	FBR	500	Construction nearing completion

Brief description of the ongoing projects is given below;

2 x 1000 MWe VVER

For faster nuclear power capacity addition, in parallel to the indigenous three stage program, additionalities based on imports have been introduced. India has setup two VVER based NPPs (2X1000 MWe), at Kudankulam (KK-1&2) in Tamilnadu, with the co-operation of Russian Federation. These reactors incorporate philosophy of four train redundancy for achieving the safety function reliably. Also many advanced safety features both passive and active have been introduced in these reactors.

The commissioning activities are at advanced stage in KK Unit-1 and construction of Unit-2 is almost complete. After satisfactory safety review and clearance of sub-stage activities, Initial Fuel Loading in KKNPP Unit # 1 was completed. The Unit is expected to attain its first criticality by July 2013. With regard to KKNPP Unit # 2, the pre-commissioning activities are under progress.

500 MWe Prototype Fast Breeder Reactor (PFBR)

A 500 MWe Prototype Fast Breeder Reactor (PFBR) is in advanced stage of construction at Kalpakkam, Tamilnadu. The PFBR is being built with the design and technology developed at the Indira Gandhi Centre for Atomic Research (IGCAR) and is the forerunner of the future fast breeder power reactors. The construction activities are almost complete and pre-commissioning activities are expected to be started soon.

4 x 700 MWe Pressurized Heavy Water Reactors (PHWRs)

Evolving on the 540 MWe PHWR design, India has developed a 700 MWe design with limited boiling at the outlet of coolant channels. Four PHWRs units of 700 MWe each are under construction, two units at Kakrapar, Gujarat and other two units at at Rawatbhata, Rajasthan.

4. Regulatory Process

AERB has evolved a robust procedure for safety review and issue of consents at various stages of setting up of nuclear and radiation facilities in India in line with the best international practices and IAEA guidelines. The major safety regulations of AERB are issued in the form of safety standards comprising of safety codes and safety guides. Developing and updating of safety regulations is a continuing process at AERB. The regulatory standards in India are developed with safety concepts, requirements and methodologies derived from IAEA safety standards and other international nuclear safety regulations, which collectively represent enormous experience in design, construction and operation of NPPs.

The consenting process of NPPs is based on the well established multi-tier safety review process specified in AERB's Safety Codes and Guides. The main consenting stages for nuclear power plants are Siting, Construction, Commissioning, Operation and

Decommissioning. Depending on the complexity, sub-stages are also adopted for each stage.

At each stage a comprehensive review in a multitier structure of safety committees is carried out before issue of consent. At first Tier, safety review in each specific area is carried out by group of experts in that specific field. At Tier-II, the Advisory Committees carry out safety review of the Utility submissions and review reports of Tier-I expert groups. The Application submitted by Utility and recommendations of Advisory Committees are then discussed in the Board of AERB and consents are issued by Chairman, AERB.