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SAFETY AND PERFORMANCE ACHIEVEMENT OF INDIAN NUCLEAR POWER PLANT

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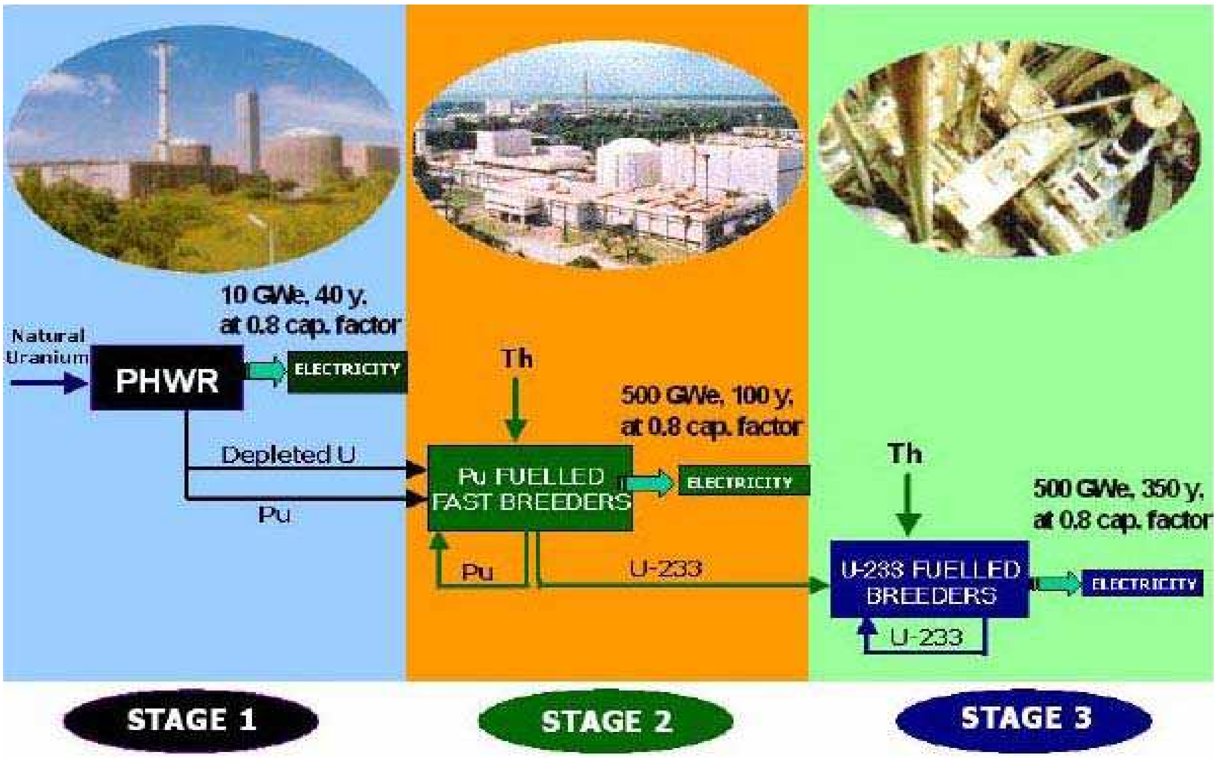
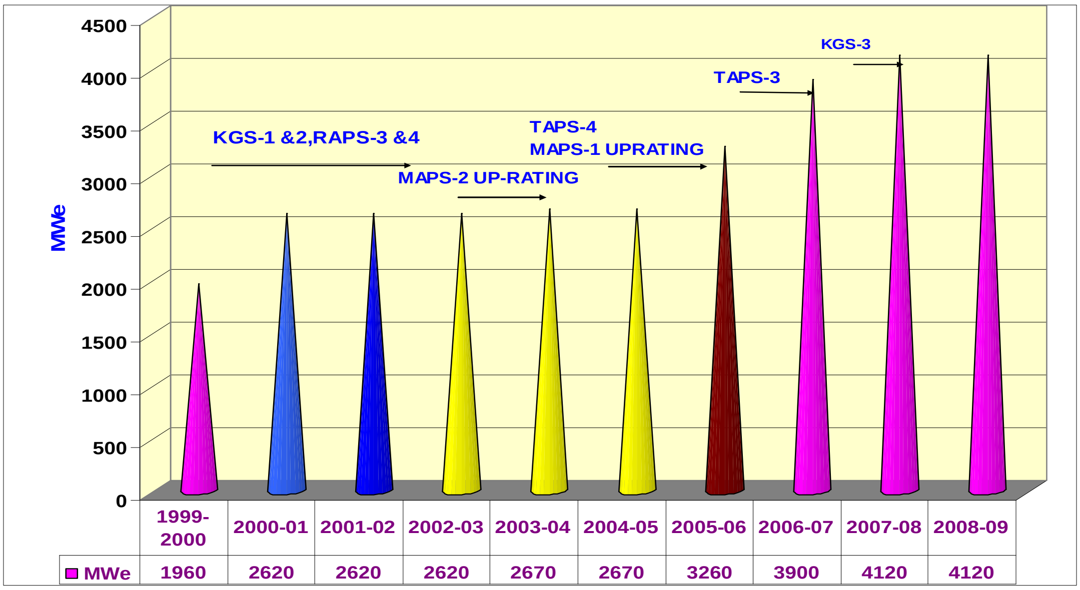
The Nuclear Power Programme in India is based on three stage. The first stage is based on setting up of Pressurized Heavy Water Reactors (PHWRs) using indigenously available natural uranium producing electricity and plutonium. This will be followed by the second stage by plutonium fuelled Fast Breeder Reactors (FBRs) producing electricity and additional quantity of plutonium and also uranium 233 from thorium. The third stage of reactors will be based on thorium uranium 233 cycle.

THREE STAGE OF INDIAN NUCLEAR POWER PROGRAMME



The construction of India's first Nuclear Power Station at Tarapur consisting of two Boiling Water Reactors (BWRs) by General Electric, USA on a turnkey basis, was commenced in 1960s. This was essentially to establish the technical and economic viability of nuclear power in India and to gain valuable experience of Nuclear Power Plant operation. In parallel, the work on construction of PHWRs was also commenced at RAPS 1&2 with technical cooperation of AECL (Canada). Subsequently, in 1980s two 220 MWe PHWRs (MAPS-1&2) were constructed near Madras with indigenous efforts. After gaining experience in setting up of RAPS and MAPS, a standardised design of 220 MWe reactor was developed. This incorporated major design modifications in terms of two independent fast acting Shut Down Systems, High Pressure Emergency Core Cooling System, integral Calandria & End Shields, water filled Calandria vault, elimination of dumping and provision of double containment with modified vapour suppression pool. Four such reactors, two each at Narora, Uttar Pradesh and Kakrapar, Gujarat were set up. Four more 220 MW PHWRs, with some more modifications such as locating the steam generators fully inside the Primary Containment, complete pre-stressed concrete construction for Primary Containment and a compact site layout were set up at Kaiga and Rawatbhata subsequently. These reactors (Kaiga-1&2 and RAPS-3&4) commenced operation in the year 2000. In addition, four similar PHWRs (Kaiga-3&4 and RAPS-5&6) of standard 220 MW design were taken up for construction at same sites in 2002. The first among these, Kaiga-3 has become operational in April 2007 and the other three are planned for completion sequentially by end of 2009 or beginning of 2010. Thus apart from the first two BWR Units at Tarapur which are in operation since 1969, twelve PHWR 220 MWe Units with two Units at each of the four locations Kalpakkam (MAPS), Narora (NAPS), Kakrapar (KAPS) and Kaiga (KGS), and four Units at Rawatbhata (RAPS-1&2 and RAPS-3&4) are now in operation.

NPCIL CAPACITY ADDITION



In parallel, design and development of larger size 500 MWe PHWR Unit was taken up in 1990s. The experience of design, construction and operation of 220 Mwe Units provided significant inputs in the design, which was later, scaled up to 540 Mwe capacity. The construction of two 540 MWe Units at Tarapur was commenced in the year 2000 and the Units became operational in 2005 and 2006 respectively. Some of significant improvements in the design of 540 Mwe reactors are as follows: -

- The Safety Systems have been divided in to two groups to the extent possible. These groups are physically seperated so that any common mode incident either inside or outside the reactor building would not disable more than one of these groups. Each group of safety system should meet the requirements of shutdown reactor, remove decay heat from the fuel subsequent to shutdown, prevent any subsequent escalation of failures, minimise the escape of radioactivity, supply necessary information to the operators for assesment of the state of the plant. Group-1 is first line of defence safety systems i.e Shut Down System-1 (SDS-1), Emergency Core Cooling System (ECCS) and all Process Water Systems including shutdown cooling. Group-2 is the second safety systems i.e Shut Down System-2 (SDS-2), Containment Isolation, Moderator Cooling, Emergency water supply (Fire Fighting Water with diesel driven pump) through Steam Generator. Status of the plant is monitored and controlled from Main Control Room (MCR) and it is done from Supplementry Control Room (SCR) in case of MCR becomes inaccessible.

- The trip parameters of reactor are so choosen that for severe transients, both SDS-1 and SDS- 2 actuate, either simultaneously or their actuation is staggered by different set points. For all postulated accidents, it is ensured that at least one main and back-up trip parameter is available on each SDS- 1 and SDS- 2 independently, thereby ensuring defence in depth.

- Primary Heat Transport (PHT) system is split into two halves to limit voiding in case of Loss Of Coolant Accident(LOCA). A pressuriser is provided for the necessary vapour cushion for the PHT main circuit to reduce pressure variation due to transients involving swell and shrinkage in the main PHT circuit.

- Entire standby power supply system i.e. Class-III, Class-II and Class-I are divided in to two independent and physically seperated divisions, called Division- I and Division- II . The redundant loads are so distributed that each division can independently meet the emergency load requirements. Power supply equipment of Division- I and Division II are located in physically separate buildings , to avoid the possibility of common–cause failures.

- Control power supply system is divided into Main and Supplementary control power supply system. Main control power supply feeds to all plant instrumentation and control loads except SDS#2 instrumented trip channel- G,H and J, which are supplied by supplementary control power supply.

- Intrument Air (IA) for valve actuation, measurement, signal transmission, etc. is divided in to two group i.e. Class-III and Class-IV Instrument Air System. All Safety System under all plant condition is supplied from Class-III Compressed Air System. IA is supplied to Reactor Building (RB) through two independent lines to ensure reliability of supply and each line is provided with isolating valve to isolate the affected line in case of accidental pipe rupture inside RB.

- Service Water System, the ultimate heat sink is segregated in such a way that leak at one point will not lead to complete unavailability of system.

- Turbine Buildings are so located such that systems and equipments important to Reactor Safety are protected from missiles,which could emanate from failure of rotating turbines.

In the earlier design of PHWRs used at RAPS-1&2, MAPS-1&2, NAPS-1&2 and KAPS-1 a zirconium alloy (zircalloy-2) was used for coolant channel. It was considered best available material at that time. However, in pile of experience brought out, the requirement of replacement of coolant tubes after 10 to 12 effective full power years in view of the modification of material characterstics especially the reduction in mechanical strength due to hydriding under radiation during service. These coolant channels of RAPS-2, MAPS-1&2 and NAPS-1 were replaced by zirconium-2.5% niobium. At present NAPS-2 & KAPS-1 En-masse Coolant Channel Replacement is in progress. Although in Indian PHWR, no significant thinning was observed in feeder pipe and elbow, but as a precautionary measure, En-masse Feeder Replacements with modified material was carried out at RAPS-2, MAPS-1&2 and NAPS-1. The long shutdown of EMCCR/EMFR were used to carry out safety upgrades in parallel. Several major equipment, like replacement of Steam Generators in MAPS 1&2, replacement of Control Motor Generator Sets by Control UPS and replacement of all CTM RTDs in NAPS 1 & 2 to enhance the life of the plant and performance of equipment during these upgrades.

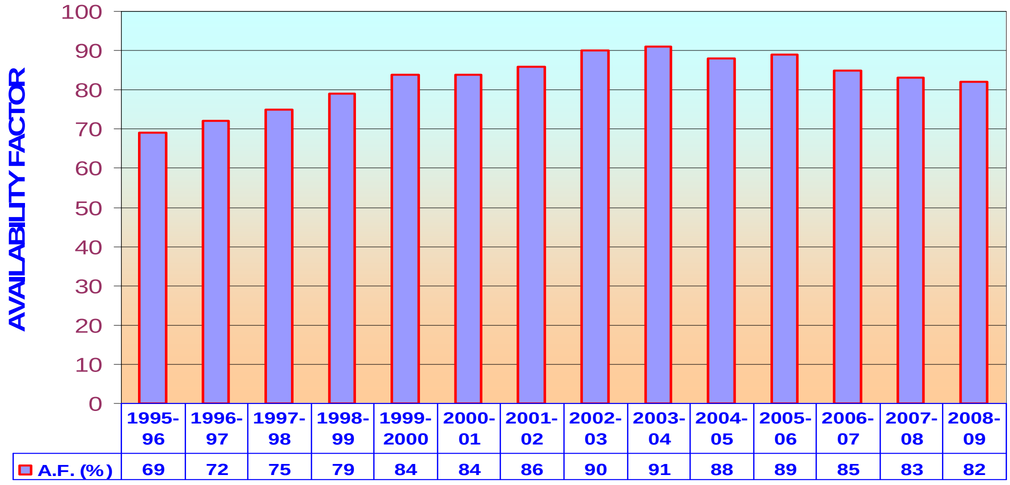
TAPS 1&2 were commisioned in the year 1969.In the year 1993, a comprehensive assesment of the safety performance, operating experience and material condition of the station was done. NPCIL developed and carried out Probabilistic Safety Analysis (PSA) of TAPS1&2, which found that the reactor were operating in the safe regime and met the current standards.However, based on the PSA studies, Safety Analysis, operational performance, seismic re-evaluation and ageing management programme, system upgradation and siesmic upgradation were carried out in 2005/2006. These includes following upgradation.

- Unit-wise segregation of the shutdown cooling system and its de-linking from the fuel pool cooling system.
- Unit-wise Segregation of Control Rod Drive (CRD) hydraulic system.
- Replacement of the existing 3x 50% capacity Emergency Diesel Generators (DGs) with 3x100% capacity Diesel Generators.
- Introduction of Supplementary Control Rooms.

After carrying out all system upgradation and siesmic upgradation TAPS 1&2 was synchronised to the grid on Febraury 2006. The performance of the plant system was evaluated during commissioning and subsequent operation of each system and was found satisfactory.

Indian Nuclear Power Plant continued their endeavour to attain excellent operation and safety performance comparable to international benchmark with sustained efforts in operation and maintenance practices, reduced downtime for unshedule outage, development of various quality equipments, full scope simulator facility at new plants and development and nurturing of qualified human resources at various levels. In the year 2002,Kakrapara Atomic Power Station (KAPS) was adjudged the world’s best operating Nuclear Power Plant among the PHWRs world over. Kaiga-2 completed 529 days of safe and continuous operation recently. Prior to Kaiga-2 many Indian reactor viz KAPS-1, NAPS-2, RAPS-4 also registered continous operation of nearly a year. The biennial shutdown duration for In Service Inspection, Containment Testing and other important Surviellance Testing have also been reduced to about 18 to 20 days by effective planning and management of shutdown activities. Nuclear Power Corporation India Limited (NPCIL) Units are operating consistently at high availability factor of about 90%.

PERFORMANCE OF NPCIL



The safety track record of more than 300 reactor years of operation evidences the strong commitment to safety and demonstrates strong safety culture of Indian nuclear industry. The release of radioactivity to the environment from Indian Nuclear Power Station is very small quantities and well within the limit stipulated by AERB. The radiation dose due to actual release is insignificant compared to the dose from the natural background. A person living at the fence post of a Nuclear Power Station recieves a radiation dose in 20 years equivalent to the radiation dose of single chest X-ray indicating the background radiation control of Indian Nuclear Power Plant. It is estimated that annual average maximum individual exposure at a plant boundary of nuclear power station is less then 0.1 mSv/year.Industrial safety record of Indian Nuclear Power Plants are outstanding. In the year 2007 , there were only one reportable injuries causing 20 man day loss out of 1344757 man day worked. Frequency rate and Severity rate are Zero for KAPS-1 and 2 since 2003, KGS-1 and 2 since 2004, RAPS-1 & 2 since 2005 and TAPS- 3 & 4 since 2007.