Status of Fast Reactor Programme in India

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Extended Abstract

In view of high impact on environment due to burning of fossil fuels and escalating oil bills, the nuclear option is being pursued vigorously in India. The three stage nuclear programme, comprises of Pressurised Heavy Water Reactors (PHWRs) in the first stage to exploit the limited uranium resource (~ 100 kt), Fast Breeder Reactors (FBRs) in the second stage to utilize the uranium to the extent of 80 % and thorium-based reactors in the third stage to utilise the vast thorium resources (second largest in the world). The PHWR is technologically matured and mostly indigenous. Its current share is 4780 MWe out of 20 reactors as on Feb 2012. It is expected to have 20,000 MWe capacity by 2020 and 63,000 MWe by 2032 with the addition of imported light water reactors to the maximum extent of 40 GWe

The second stage was started by constructing a 40 MWt / 13.5 MWe capacity Fast Breeder Test Reactor (FBTR), which is in operation at Indira Gandhi Centre for Atomic Research (IGCAR), Kalpakkam, since 1985. To demonstrate techno-economic feasibility of construction and operation of large size power plants, a 500 MWe capacity Prototype Fast Breeder Reactor (PFBR) was launched in Oct 2003 and is under advanced stage of construction. Bharatiya Nabhikiya Vidyut Nigam Limited (BHAVINI), a Government Company was formed for implementing the India's fast reactor projects, starting with PFBR. BHAVINI is planning to construct six more units, similar to PFBR, to commission by the year 2023. Subsequently, a series of 1000 MWe metallic core FBRs would be constructed to realize the targeted nuclear contributions (~25 % by 2050). Towards closing the fuel cycle, a fast reactor fuel cycle facility (FRFCF) will be co-located for recycling the fuel from PFBR, including fuel fabrication & assembly, reprocessing and waste management. FRFCF is planned in such a way that future expansion would be possible to meet the requirements of two more 500 MWe FBRs, that would be built at Kalpakkam site at later date. IGCAR is dedicated to the development of fast breeder reactor and associated fuel cycle science and technology since 1971. It is responsible for design, R&D, manufacturing technology and regulatory clearances.

FBTR uses indigenously developed unique Pu-rich mixed carbide fuel and has performed extremely well crossing a burn-up of 165,000 MWd/t. The fuel discharged at 155,000 MWd/t has been successfully reprocessed. This is the first time that the plutonium-rich high burnup carbide fuel has been reprocessed anywhere in the world. While FBTR is a loop type reactor, PFBR is of pool type with 2 primary and 2 secondary loops with 4 steam generators (SG) per loop. The nuclear heat generated in the core is removed by circulating sodium from cold pool at 670 K to the hot pool at 820 K. The sodium from hot pool after transporting its heat to four intermediate heat exchangers (IHX) mixes with the cold pool. The heat from IHX is in turn transported to eight SG by sodium flowing in the secondary circuit. Steam produced in SG is supplied to turbo-generator. Currently, the reactor assembly components have been manufactured and erected successfully and the remaining systems are under advanced stage of erection. PFBR is scheduled for commissioning by end 2012 or by early 2013.

PFBR design addresses many challenging issues such as: material damage due to high irradiation, sodium leaks and sodium water reactions in the steam generators, high temperature design for a long reliable operation for 40 years, design of mechanisms and rotating equipment operating in sodium & argon cover gas space, complex pool hydraulics to assess thermal striping and thermal stratification problems, gas entrainment in the coolant and core, sodium aerosol deposits in the top shield penetrations, various flow induced vibration mechanisms, seismic behaviour of inter-connected buildings resting on the common base raft, seismic design of thin walled vessels including associated instability mechanisms, pumps and absorber rod mechanisms and in-service inspection of reactor internals within sodium, structural integrity of primary containment under severe accident conditions. These apart, chemistry of cold-trap regeneration for the secondary circuits, development of techniques for decontamination of primary system components and sodium sensors are other issues addressed. Towards these, necessary R&D activities have been carried out at IGCAR and other R&D establishments and academic institutions in the country.

Regulatory clearance for PFBR was obtained based on three tier system of review (Internal safety committee, Project Design Safety Committee and Apex Committee for Plant Safety Review). To assist the

reviews, several specialists groups were formed. Safety criteria for PFBR have been checked with relevant IAEA safety guidelines of water reactors (NS-R-1). Events and incidents in other FBRs as well as thermal reactors for any impact were analysed critically and feedback have been incorporated. Apart from safety, the review covered manufacturing and erection aspects in view of first-of-kind project. Based on the review experiences, safety criteria for future FBRs has been revised, which is under review by regulators

For the future fast reactors beyond PFBR, systematic road map of R&D has been in progress. Adopting twin unit concept, optimum shielding, use of 304 LN in place of 316 LN for cold pool components and piping, 3 SG modules per loop with increased tube length of 30 m (PFBR has 4 modules per loop with 23 m length), 85 % load factor, 60 years design life, reduced construction time (5 y) and enhanced burn up (upto 200 GWd/t to be achieved in stages) are the key aspects of improving the economy. Significant improvements would be introduced in the reactor assembly design. In the domain of safety, passive safety features for the shutdown systems, combination of active and passive decay heat removal systems towards elimination of core disruptive accidents, application of innovations and novel techniques to efficiently handle the sodium fire issues are being studied.

To summarise, India has a vision of becoming a world leader in fast reactors and fuel cycle technologies. The operating experiences of FBTR, design and construction experiences of PFBR, R&D output from well planned activities being carried out for the future reactors to achieve competitive economy and enhanced safety provide high confidence in fulfilling this vision. It is worth to mention that in the Indian context, fast reactors are inevitable at least up to 2050. Beyond 2050, other potential options such as renewable energy solutions, especially for distributed energy resources, thorium based technology, fusion technology, economical and sustainable hydrogen based systems etc. are likely to emerge. Relevant scientific breakthroughs, ever growing high quality human resource, national and international collaborations and deployment of innovative technologies for meeting the challenges of long term energy sustainability through fast reactors are the means for success.