Engineering of Nuclear Power Plants in India: Present and Future

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Integrated energy policy of India considers the role of nuclear energy as vital for long term energy security and sustainable development of the country. To increase the nuclear power capacity in the country, India is pursuing a multi track approach for development and deployment of nuclear power plants.

The strategy adopted under the Indian nuclear power programme optimizes the utilization of the modest uranium reserves and the vast thorium resources available in the country for long term energy security of the country. Pressurised Heavy Water Reactors (PHWRs) which form the mainstay of India's nuclear power production uses natural Uranium as fuel and Heavy water as moderator. The design of PHWRs has evolved continuously with majority of the operating PHWRs belonging to the standard 220MWe twin unit concept, followed by 540MWe twin units. Currently, construction of PHWR based 700MWe design, an evolution of 540MWe model, is in progress.

All nuclear and radiation facilities in India are sited, designed, constructed, commissioned and operated in accordance with strict quality and safety standards. Defence-in-depth, redundancy and diversity are the main principles followed in the design of all NPPs and their systems/components so as to ensure safety under all postulated scenarios. The work towards meeting safety objectives in design starts right from siting stage of an NPP. The siting includes the assessment of impact of site and surrounding environment on the structures and systems of NPP as well as impact of NPP operation on the environment.

For estimation of site related design basis parameters required for an NPP, a detailed evaluation considering natural and human induced events is carried out. The natural events include earthquakes as well as extreme meteorological phenomena such as floods, high winds & cyclones, heavy precipitation etc. Human-induced events include hazards posed by toxic and explosive materials, mining and blasting, etc. For all events with a potential to pose challenge the safety of NPP, a design basis event is established and NPP is engineered accordingly.

Earthquake and flood form two major natural hazards considered for design of NPPs. The seismic design follows two level earthquake philosophy. The entire plant is designed to be operational under a smaller level earthquake, viz. operating basis earthquake (OBE) and the safety related structures and systems are designed to be functional under a larger level earthquake, viz. safe shut down earthquake, SSE. The mean recurrence interval of SSE is of the order of 10,000 years.

Flooding of sites located inland could be caused by heavy precipitation or from the release of large volumes of water due to failure of upstream dams. The dam failure could be initiated by seismic disturbance or dam overtopping. The failure of dams located downstream may also affect availability of cooling water which acts as ultimate heat sink. For coastal sites, cyclones, tsunami and wind waves are the main sources of flooding.

For an external event or combination of events, the choice of values of the parameters upon which the plant design is based, ensures that structures, systems and components important to safety will maintain their integrity and will not suffer loss of function during or after the design basis event.

Despite the measures being adopted during siting and design, there are two incidences in the past wherein Indian NPP sites were affected by floods. During 1994, Kakrapar NPP site located along the banks of Motcher lake in Western India experienced about 470mm rainfall in 15 hours. The Unit#1 was under shutdown condition and Unit#2 was undergoing commissioning. As overflow gates in the Moticher lake became inoperable due to blockage of grass and mud brought-in by the flood, lake level rose and water entered the turbine building area though the cable penetrations and trenches, located below the plant grade level. Apart from identification of several site specific actions, this event also resulted in formulation of operator actions considering progressive unavailability of the safety related equipment due to multiple failures in the flood protection measures. In addition, the penetrations below grade were engineered and also minimised in the subsequent designs.

On December 26, 2004, the Indian Ocean tsunami struck the eastern coastline of India causing severe loss of life and property. Madras Atomic Power Station (MAPS), located on the coastline at Kalpakkam near Chennai was affected by this event. Prior to the event, MAPS unit-2 was operating at full power and MAPS unit-1 was under shutdown. MAPS unit-2 was successfully shutdown after the tsunami but the event caused tripping of Condenser Cooling Water (CCW) pumps. Though the tsunami water level was about 2m below the finished grade level of Prototype Fast Breeder Reactor (PFBR) being constructed at Kalpakkam , the event also resulted in flooding in the excavated pit for construction of foundation raft of PFBR.

The subsequent assessment brought out the need for installation of a tsunami warning system, revision of emergency operating procedures for handling flooding incidents at all coastal sites, and relocation of some equipment to higher elevations. Though the 2004 tsunami levels were below the estimated design basis flood levels for NPP sites, a need for more rigorous treatment in estimation of tsunami hazard was recognised. Present approach for tsunami hazard evaluation follows site specific assessment of worst case scenario tsunamis originating from various tsunamigenic sources around Indian coast. The presentation also covers preliminary outcome of evaluation being undertaken for characterisation of tsunami hazard along entire Indian coast following this approach.

Conventionally, NPPs were designed to cater to loads from normal operating conditions, anticipated transients and design basis events where as the newer designs also consider beyond design basis events. However, evolving scenarios worldwide indicate the need for additional design margins, assessment of design with regard to cliff edge effects and extended station black out scenarios. The vulnerability of NPPs against common cause failures resulting from external events also needs to be evaluated by safety analysis. The gradual changes to environment, caused by climate change, is another factor that has to be assessed and taken into account in design so that the safety margins could be kept above the desired limits throughout the life time of NPP.