**Annex III of Technical Volume 2**
**DETAILED DESCRIPTION OF RELEVANT OPERATING EXPERIENCE**

## III–1. EXTERNAL FLOODING OF LE BLAYAIS NUCLEAR POWER PLANT IN 1999 [III–1, III–2]

The Le Blayais nuclear power plant (NPP), comprising four 900 MW(e) pressurized water reactors (PWRs), is located on the banks of the River Gironde in a swampy area. On the night of 27-28 December 1999, high waves, caused by a combination of tides and exceptionally high winds, moved up the River Gironde and submerged the plant platform. The waves moved the rocks protecting the dike and part of it was washed away down the River Gironde. The water reached a depth of around 30 cm in the northwest corner of the site. Only Units 1 and 2 were severely affected by the incoming water [III–1].

The water ran along the underground gallery of the site, through the panel handling holes above the gallery and in the empty spaces where the metal plating was distorted. This gallery is located outside the buildings and almost completely surrounds them.

The following facilities were flooded in Units 1 and 2:

— Rooms containing the essential service water (ESW) pumps. The ESW system of each unit comprises four pumps on two independent trains, A and B. Each pump is capable of providing the entire throughput required. The ESW system operates during normal operation to cool the reactor auxiliaries and when the reactor is shut down to cool the decay heat removal system during accident situations. In Unit 1, the ESW system pumps of train A were lost as a result of the immersion of their motors.
— Some utility galleries, particularly those running in the vicinity of the fuel building linking the pump house to the platform.
— Some rooms containing outgoing electrical feeders. The presence of water in these rooms led indirectly to the unavailability of some electrical switchboards.
— The bottom of the fuel building of Units 1 and 2 containing the cells of the two low head safety injection (LHSI) pumps and the two containment spray system pumps, which were unavailable [III–1].

At 03:00 on 28 December 1999, the plant emergency response teams were summoned to assist those teams already in place. The level 2 on-site emergency plan was put into operation at 09:00 at the request of the safety authority, and a complete emergency response team was set in place. It was estimated that Unit 1 would have had over 10 hours to take action prior to core meltdown in the event of failure of the emergency feedwater system, which removes the decay heat. This system, which comprises two motor driven pumps and one turbine driven pump — only one pump is needed to cool the reactor — showed no signs of failing during operation. The situation was managed in four stages:

— Shutdown of Units 1 and 2;
— Identification of all the paths by which water was entering the site and pumping out of flooded rooms;
— Recovery of train A of the essential service water system of Unit 1;
— Repair of one safety injection pump and one containment spray pump for each unit on 4 January 2000.

To remove the water from the flooded rooms, the NPP used its own pumps and those of the fire services in the vicinity. Flooding spread mainly through the general site gallery, doors, pipe penetrations in masonry structures and hoppers. This incident showed that rooms containing safety significant systems should be adequately protected against flooding. One lesson was that while flooding and loss of off-site power could occur simultaneously, very few of the drainage pumps were supplied by emergency power supplies.

The flooding which occurred at the Le Blayais NPP revealed a weakness by which the safety of all the units at the site could be jeopardized. This incident, and the main lessons learned, was communicated at the international level.

## III–2. EXTERNAL FLOODING OF THE MADRAS NUCLEAR POWER PLANT IN 2004 RESULTING FROM A TSUNAMI [III–3 TO III–6]

On 26 December 2004, an earthquake of magnitude 9.1 occurred off the western coast of Sumatra in the Indian Ocean and generated a transoceanic tsunami which devastated the coastline, with a maximum runup of 50.9 m at Labuhan on the northwest coast of Sumatra. The tsunami caused approximately 300 000 deaths, travelling across the Indian Ocean, and affecting several countries, including India (which experienced a maximum runup of 9.56 m). It also caused unprecedented damage in countries around the Indian Ocean.

On 26 December 2004, Unit 2 of the Madras Atomic Power Station (MAPS), located near Chennai, in Tamil Nadu, India, was operating at full power. Unit 1 was under long shutdown. When the tsunami struck, the condenser cooling pumps of Unit 2 at the installation were affected due to flooding of the pump house and subsequent submerging of the seawater pumps. Following this, the reactor tripped automatically and the reactor was brought to cold shutdown using the emergency operating procedure.

The pump house operating floor is located about 2.5 m above mean sea level, about 2 m below the level of the main plant buildings, and is connected by a submarine tunnel about half a kilometre long to the intake well. The increase in water level in the pump house during the tsunami rendered all the seawater pumps located in this area inoperable except for one process seawater pump. This pump was used to cool the NPP’s loads in the initial period following reactor shutdown.

Later, this pump also became unserviceable due to clogging of the travelling water screen in the seawater pump house due to the ingress of large quantities of debris from the tsunami. Furthermore, cooling of MAPS Unit 1 and different loads were achieved by using the firewater system. Though the off-site power remained available throughout the event, emergency diesel generators were started and were kept running as a precautionary measure. The plant declared an emergency alert at 10:25 on 26 December 2004, which was lifted at 21:43 on 27 December 2004. The tsunami did not affect MAPS Unit 2, which shut down.

The vital areas of the plant such as the reactor building, turbine building, service building, switchyard and ancillary systems were unaffected by the tsunami. The damage caused by the tsunami was limited to the peripheral areas, such as damage to the cement-brick wall at the plant periphery on the sea side and inundation of roads on the east side of the turbine building. A part of the cement–brick enclosure provided over the discharge line on the southern side of the jetty structure was washed away.

After restoration of the affected areas, the unit was restarted on 1 January 2005. The tsunami highlighted some important issues which needed detailed review and follow-up. The telecommunication links to MAPS and the nearby Kalpakkam site had suffered severe degradation. In the light of this experience, the Nuclear Power Corporation of India Limited (NPCIL) was asked to augment the communication facilities at Kalpakkam and examine the need for providing diverse and reliable communication channels at NPP sites.

The event was reviewed in detail and the following corrective actions were recommended:

— Improvement of the means of communication;

- Improvement of external protection against tsunami waves to reduce the energy and height of the waves;
- Improvement of emergency operating procedures for flooding incidents at coastal sites;
- Relocation of some equipment above the maximum flood levels (including diesel driven fire fighting pumps and new uninterruptible power system);
- Installation of a tsunami warning system;
- Provision of new mobile air cooled power packs;
- Provision of battery operated measurement provisions for key instrumentation;
- Revision of Atomic Energy Regulatory Board design requirements for nuclear facilities at coastal site.

This event showed that external flooding (in particular from tsunamis) can lead to the loss of the ultimate heat sink and create further common cause failures if the flooding level is above the design basis flood. Moreover, it showed that external events can affect simultaneously several units at the same site, and can bring additional issues when the infrastructure is destroyed.

This event was reported at the international level.

## III–3. EARTHQUAKE NEAR THE KASHIWAZAKI-KARIWA NUCLEAR POWER PLANT IN 2007 [III–7]

At 10:13 on 16 July 2007, a strong earthquake measuring magnitude 6.6 struck the Chuetsu area of Japan, resulting in the automatic shutdown of Units 2–4 and 7 of the Kashiwazaki-Kariwa NPP. The NPP was located approximately 9 km from the epicentre. Unit 2 was under startup operation when the reactor was shut down. Units 1, 5 and 6 were out of service for annual outage work when the earthquake occurred. The maximum acceleration observed at the station was 680 gals, which was above the design acceleration of 273 gals. Although the earthquake was above the design values, the operating reactors were shut down under control and brought safely to cold shutdown condition.

Due to the earthquake, a fire broke out at the house transformer of Unit 3, which was extinguished in about two hours, at 12:10. The transformer, installed beside the turbine building, supplies electricity, generated at the unit, to equipment on the same premises. The base of the transformer's main unit is secured to the rock foundation, and the turbine building on the supply side is also fixed to the rock bed. However, the support structure for the secondary connecting bus duct linking the two facilities did not have rock-bed reinforcement. There is a possibility that when the quake caused the ground underneath the support structure to sink (by approximately 30 cm), the conductor came in contact with the duct, triggering a short circuit and igniting leaked oil.

Water in the spent fuel pool of Unit 6 leaked into a non-radiation controlled area and was discharged to the sea through a discharge channel. The amount of water discharged to the sea was estimated at about 1.2 $m^3$, containing 90 kBq radioactivity in total. Because the water was diluted far below the legal limit of the activity concentration for discharge water, it was estimated that there was no impact on the environment. The pool itself was undamaged.

The earthquake also damaged some piping of the fire protection system, installed outside the reactor combination building for Unit 1. Water leaked from the piping and seeped into the composite reactor building through the gaps in the piping housing. This left a pool of muddy water, approximately 48 cm deep, on the fifth basement of the reactor combination building. This basement houses numerous devices associated with waste processing. However, unlike the basement of the reactor building, it did not contain important equipment in terms of reactor safety.

In addition, hundreds of drums of solid low level radioactive waste (LLW) in the plant's solid waste storage facility fell from their position. The lids of dozens of these were found open. LLW is typically composed of paper, filters, lightly contaminated clothing and tools. The LLW drums in the facility contained either ash resulting from the incineration of flammable LLW items, the flammable items prior to incineration, or inflammable items themselves.

The roof of the NPP's administration building collapsed, making it impossible to perform work there. The door to the emergency response office, set up in the administration building, was initially jammed, denying access to workers who tried to use the emergency phones there that had direct connections to the local government and local fire department.

Outside the NPP, several road sections collapsed during the earthquake and complicated the access to the site.

This event offered numerous lessons that were implemented in Japan, and increased the seismic robustness of NPPs. These improvements led to the greater resiliency of NPPs in Japan during the 2011 Tohoku earthquake. As such, it is a good example of how operating experience can be used to improve safety.

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