ABSTRACT

Two Boiling Water Reactors (BWR) of 210 MWe each at Tarapur Atomic Power Station, Units-1&2 (TAPS-1&2) were commissioned in the year 1969. The safety related civil structures at TAPS had been designed for a seismic coefficient of 0.2g and other structures for 0.1g. The work of seismic re-evaluation of the TAPS-1&2 was taken up in the year 2002. As two new Pressurized Heavy Water Reactor (PHWR) plants of 540 MWe each, Tarapur Atomic Power Project Units-3&4 (TAPP-3&4), are coming up in the vicinity of TAPS-1&2, detailed geological and seismological studies of the area around TAPS-1&2 are available. The same free-field ground motion as generated for TAPP-3&4 has been used for TAPS-1&2. The seismic re-evaluation of the plant has been performed as per the procedure given in IAEA, Safety Reports Series entitled “Seismic Evaluation of Existing Nuclear Power Plants”, and meeting the various codes & standards, viz., ASME, ASCE, IEEE standards etc. The Safety Systems (SS) and Safety Support Systems (SSS) have been qualified by adopting detailed analysis and testing methods. The equipment in the SS and SSS have been qualified by conducting a walkdown as per the procedure given in Generic Implementation Procedure, Dept. of Energy (GIP–DOE), USA. The safety systems include the systems required for safe shutdown of the plant, one chain of decay heat removal and containment of activity. The safety support systems viz., Electrical, Instrumentation & Control and systems other than SS & SSS have been qualified by limited analysis, testing and mostly by following the procedure of walkdown. The paper brings out the details of the work accomplished during seismic re-evaluation of the two units of BWR at Tarapur.

Keywords: Older generation plants, seismic re-evaluation, walkdown, Generic Implementation Procedure

1. INTRODUCTION

Nuclear power plants designed in India since 1975 have been designed for earthquake loading. Designers and equipment suppliers are therefore required to consider seismic loading as a major load case in the design. In India, 14 Nuclear Power Plants (NPPs) viz., Narora Atomic Power Station-(NAPS 1&2), Kakrapar Atomic Power Station (KAPS-1&2), Kaiga Atomic Power Station (KAIGA-1,2,3&4), Rajasthan Atomic Power Station (RAPS-3,4,5&6) and TAPP-3&4 have been seismically qualified using state of the art techniques, involving both seismic analysis and testing. The older generation plants viz., TAPS-1&2, RAPS-1&2 and MAPS-1&2 were seismically designed according to the standards prevailing at the time of their construction but not designed to the rigour of the current design practice.

These plants are being re-evaluated for seismic loading as per IAEA Safety Standard [1] which has been followed for re-evaluation of older generation plants in Eastern European countries. The two units of Tarapur Atomic Power Station (TAPS-1&2) are the first units taken up for such a seismic re-evaluation in India. The Tarapur Atomic Power Station consists of twin Boiling Water Reactors of 210 MWe each, now operating at 160 MWe each, as the secondary steam generators have been taken out of operation. These plants were built by General Electric, USA as a turnkey Project. The constructions of these plants commenced in the year 1964 were commissioned in the year 1969. These plants were designed for seismic loading by using equivalent static
coefficient method [2]. As these plants were not designed as per the state of the art technology, which is being used in the seismic design of the new Nuclear Power Plants, the seismic re-evaluation of these plants has been undertaken. The Safety Systems (SS) and Safety Support Systems (SSS) have been qualified by adopting a detailed analysis and testing methods. The equipment in the SS and SSS have been qualified by conducting a walkdown as per the procedure given in Generic Implementation Procedure, Dept. of Energy (GIP – DOE), USA. The safety systems include the systems required for safe shutdown of the plant, the systems required for one chain of decay heat removal and the systems required for the containment of activity. The safety support systems viz. Electrical, Instrumentation & Control (I&C) and systems other than SS & SSS have been qualified by limited analysis, testing and by following the procedure of plant walkdown. The paper brings out the details of the work accomplished during seismic re-evaluation of the two units of BWR at Tarapur.

2. SEISMIC DESIGN OF THE STRUCTURES, SYSTEMS AND EQUIPMENT (SS&E) AS DONE BY GENERAL ELECTRIC (GE) IN 1965

The seismic design of the Structures, Systems and Equipment (SS&E) in TAPS-1&2 has been carried out by GE using equivalent static coefficient method way back in 1965. The Class I and Class II civil structures were designed for a horizontal seismic coefficient of 0.2g and 0.1g respectively [2]. The Class I structures were designed as per the provisions of ACI 318. The piping systems were designed for 0.5% damping free field ground spectrum by equivalent static analysis method as per ANSI B31.1 and B31.3 codes.

3. SEISMIC RE-EVALUATION OF SS&E

The seismic re-evaluation of TAPS-1&2 has been taken up in the year 2002. The seismic re-evaluation has been carried out as per the guidelines given in IAEA Safety Standard [1]. The steps involved in the seismic re-evaluation of older generation plant are to arrive at the ground motion, to classify the structures, systems and equipment in the power plant for their safety, to re-evaluate the class-I safety structures by response spectrum analysis and to perform time history analysis of the same to generate floor time histories & floor response spectra and re-evaluate the SS&E in the safety system which perform the role in shutting down the plant, decay heat removal & containment of activity and also the safety support systems which perform a supporting role in the above functions. The details of the seismic re-evaluation carried out are given below:

3.1. Design Basis Ground Motion (DBGM)

As two new PHWR plants of 540 MWe each, TAPP-3&4, are coming up in the vicinity of these plants, detailed geological and seismological studies of the area around TAPS-1&2 are available. As such, the DBGM of TAPP3&4 has been used for the seismic re-evaluation of SS&E of TAPS-1&2 (Figure-1). The DBGM compatible artificial time history has been used for time history analysis of safety structures to generate the floor time histories and floor response spectra which are further used for the seismic re-evaluation of SS&E.

3.2. Seismic re-evaluation of various Safety Related Civil Structures

The important safety related civil structures of TAPS-1&2 are Reactor building, Service building, Turbine building, Intake Structure and Stack.

3.3. Seismic Re-evaluation of various mechanical, electrical, I&C systems and equipment

In case of a new NPP, all the safety systems and the safety support systems are qualified for earthquake resistance by way of analysis and testing to demonstrate their structure integrity, pressure boundary integrity and functional operability. However, in case of an older generation plant like TAPS-1&2, only the following Safety Systems (SS) and the Safety Support Systems (SSS) have been evaluated for their earthquake resistance.
3.3.1. Safety System (SS)

(1) Systems required for the shutdown of the plant: Control Rod Drive (CRD) System.
(2) Systems required for decay heat removal: Reactor Pressure Vessel (RPV), re-circulation piping, emergency condenser piping, Shut Down (S/D) cooling piping, Reactor Building Cooling Water (RBCW) system, Salt Sea Water (SSW) system
(3) The systems required for containment of activity: box-up system and the containment.

3.3.2. The Safety Support Systems (SSS)

(1) Electrical systems: Diesel Generator (DG), Motor Generator (MG) & Battery banks
(2) Instrumentation systems: All control & instrumentation in relation to above safety and safety support systems.

3.4. Seismic re-evaluation Methodology

The safety systems and safety support systems are to be evaluated by performing analysis & testing depending on the functional requirements. The Structures Systems and Equipment (SS&E) have been qualified by Seismic Margin Assessment method (SMA). Seismic Margin Assessment is based on deterministic method, where in the structure or piping responses, have been calculated by usual response spectrum method, time history method or equivalent static analysis method with due justification for the method used. While calculating the response, the damping and the ductility reduction factor as given in IAEA Safety Standard [1] have been used. The subsequent design check has then been conducted using ASME code for piping and ACI 349 code for civil structure. The equipment in the safety system and safety support system, have been qualified by a walk down. This walk down has been conducted as per the guidelines given in IAEA safety standard [1].

4. SYSTEM RE-EVALUATION

4.1. Reactor Pressure Vessel

The Reactor Pressure Vessel (RPV) along with secondary steam generator, re-circulation piping, re-circulation pump have been modeled and coupled with the primary civil structure, i.e. Reactor Building - Service Building is shown in Figures-2a & 2b. The seismic induced stresses in the RPV and its connected equipment have been combined with the operating stresses and they meet the ASME codal requirements.
4.2. Seismic Re-evaluation Piping System

While carrying out the re-evaluation of the piping system, damping value and ductility reduction factor as given in IAEA Safety Standard [1] have been used. The re-circulation piping, emergency condenser steam piping & condensate piping, shutdown cooling piping, Reactor Building Circulating Water (RBCW), Salt Service Water (SSW) and Control Rod Drive (CRD) System piping have been analyzed by response spectrum method for the enveloped and broadened floor response spectra and the seismic anchor movement experienced by the piping system. The systems have been qualified for the level-D requirements of the ASME-Section-III Sub-Section NB & NC for a load combination of dead weight, pressure, high velocity induced momentum loads and seismic loading due to inertia & seismic anchor movement.

4.3. Seismic re-evaluation of equipment by walk down
4.3.1. The methodology of seismic re-evaluation of SS&E by walk down

The seismic re-evaluation of the Mechanical, Electrical, Instrumentation & Control (I&C) equipment and Civil Structures (Unreinforced Masonry Walls), was conducted using the Generic Implementation Procedure (GIP) given in US-DOE document DOE/EH0545 titled “Seismic Evaluation Procedure for equipment in US DOE facility” [3].

Most of the equipment in a NPP are similar to the equipment used in the industries and conventional power plants, which had experienced the earthquake. If a free field response spectrum (DBGM) at NPP site is lower than the bounding spectrum [3], the equipment in a NPP up to 13-meter elevation is considered to have met the seismic requirement. For equipment located on floor higher than 13 meter elevation, it is essential that the floor response spectra is enveloped by the bounding spectrum increased by a factor of 1.5 (equal to Reference Spectrum), if not, then qualification of equipment by detailed analysis and / or testing is required.

However, before the equipment is seismically evaluated by the above procedure, it is essential to demonstrate that the equipment is well anchored to the floor. For this, it is essential that the capacity of anchorage of equipment is higher than the seismic demand on the anchorage of the equipment. The demand has been calculated by using the accelerations from the Floor Response Spectra (FRS) corresponding to the frequency of the equipment and the damping of the equipment. Furthermore, it is also essential to demonstrate that the equipment has construction features similar to the one that had experienced the real earthquake. These details are compared with the caveats given in the Seismic Evaluation Worksheets (SEWS) for individual equipment as prepared and given in GIP-DOE [3]. The SEWS also cover the spatial interaction of any lower safety class equipment with the equipment under review.

4.3.2. The various Mechanical, Electrical, Instrumentation & Control and Civil Structures evaluated by walk down

Following is the list of various Mechanical, Electrical, Instrumentation & Control and Civil Structures, which have been evaluated by walk down.

- Batteries on Racks, Motor control centers, Low Voltage switchgear, Medium voltage switchgear, Distribution panels, Transformers, Battery chargers and Inverters, Instruments on Racks, Temperature Sensors, Fluid Operated/Air operated valves, Motor Operated valves, Solenoid operated valves, Horizontal pumps, Vertical pumps, Chillers, Air Compressor, Motor Generators, Engine Generators, Air Handlers, Fans, Horizontal Tanks and Heat exchangers, Cable and conduit raceway systems, Piping, HVAC ducts, Vertical tanks, Gas cylinders, Un-reinforced Masonry (URM) walls, Raised floors, Storage Tanks, Relays etc.

4.3.3. Seismic re-evaluation of SS&E by walk down

As brought out above, the safety related SS&E of TAPS-1&2 have been re-evaluated by conducting a detailed walk down of the plant in April and May 2003. Many of the equipment met the GIP-DOE requirement. However, some of the SS&E had some deficiencies and were recommended for retrofit to increase the seismic resistance or were recommended for maintenance type of modification to overcome the interaction effects. Few of the recommendations have been implemented.

4.3.4. Seismic up-gradation

Some of the Recommendations for Seismic Upgradation are given below:

4.3.4.1. Shutdown Cooling and RBCW Heat Exchangers

The shutdown heat exchangers are mounted one above the other in three tier, held with each other by four bolts. The total load on the anchor bolts is a cumulative load from all the three heat exchangers. In case of RBCW heat exchangers, two of them are mounted one above the other and connected to each other by 8 numbers of bolts. The allowable shear & pullout loads of anchor bolts are inadequate to meet the seismic demand i.e. the demand is more than the capacity.
After detailed study, lateral supports from wall have been provided.

### 4.3.4.2 Condensate Storage Tank (T1A) & (T1B)

For the condensate storage tank, it is observed that the distance between center of the anchor bolt to the concrete edge is less than the required minimum edge distance, hence, additional concrete blocks connected to foundation raft having dimensions 0.6 x 0.3 x 1.0 m deep around the bolts have been designed.

### 4.3.4.3 Reactor Protection Panel

The weld details of the protection panel have been inspected during the annual shutdown and additional plug welding has been provided.

### 4.3.4.4 Control Room Panels

It is observed that in the main control room after the last row of control panels, there are many unanchored lockers. These lockers may slide and overturn on to the instrumentation panels, which may result in damage to the main control room panels in the last row. There are suitcases on the lockers, which contain air masks. These suitcases may slide and drop on to the control panels in the last row.

The suitcases of air masks have been shifted. Anchorage for the lockers to the rear concrete wall have been designed.

### 4.3.4.5. Battery Bank # 1 and # 2

Battery Bank no # 1, which is located in the Battery Bank Room of Service Building, is mounted on wooden stands. Battery Bank no #2 which is located in Service Building Corridor is being relocated and replaced.

The seismically designed battery banks with stands and cells which are tested on shaketable are being installed.

### 4.3.4.6. Emergency Diesel Generator

Emergency DG Sets presently located in Service Building (SB) will be replaced by new ones and relocated in seismically designed DG Building. These DG sets and their auxiliaries have been designed for seismic resistance.

### 4.3.4.7. Unreinforced Masonry Walls

Most of the brickwalls in the plant have been provided with internal or external steel reinforcement. Only few walls are not having steel reinforcement. A total of five walls in the Service Building & Turbine Building require strengthening by way of providing external steel beams. These reinforcement have been provided in a modified design.

### 4.3.4.8. Cable Tray Supports

Most of the cable trays have been provided with rod hanger supports from the wall or from the ceiling with horizontal supports after every 4-5 dead weight supports. At few places, the cable tray supports are having hot spot supports i.e. short length support from the beam bottom.

Such short length supports from the beam bottoms have been removed and relocated to the ceiling near to beams.

### 4.4 Seismic re-evaluation of delicate instruments viz. relays contactors etc. by testing

The delicate instruments which perform a role of sensing a change in the parameter variation (temperature, pressure, current, voltage) viz. pressure gauge, thermowell and then transmit the signals viz.
relays and contactors etc. in electrical and instrumentation panels or racks are required to be qualified by shake
table testing to demonstrate their operability during an earthquake induced vibratory motion. Such instruments
in TAPS-1&2 that have been supplied either by GE or other companies in USA, have been tested by General
Electric. Many of the devices listed above have been tested by GE on shake table, as a part of the seismic re-
evaluation of NPP’s in USA. Few of the safety related devices, which were not tested & included in GE report,
have been seismically tested on shaketable for 3g acceleration level.

4.5. Seismic re-evaluation of Civil Structures

The civil structures viz. Reactor Building, Service Building, Turbine Building, Intake Structure & Stack, which house the SS&E of SS and SSS, have been qualified for earthquake resistance. The qualification has been completed as per ACI-349, 2001. A computer code NISA-CIVIL [5] has been used for this analysis.

4.5.1. Approach used for re-evaluation of Civil Structures

The safety structure of TAPS-1&2 had been Seismically qualified by GE in 1965 for 0.2g and other
than safety structures had been qualified for 0.1g by seismic co-efficient method. The civil structures viz.
Reactor Building, Service Building, Turbine Building, Intake Structure & Stack, which house the SS and SSS,
have been re-evaluated freshly for earthquake resistance. The re-evaluation has been completed as per ACI-349,
2001. A computer code NISA-CIVIL has been used for this analysis. These civil structures have been modeled
by finite element method. The finite element model of Reactor buildings & Service building is shown in Figure-
3.

The time history analysis of these structures has been carried out by using model super position
 techniques to arrive at the time histories and the response spectra at the various floors of the structures. These
response spectra have been used for seismic re-evaluation of the equipment and piping supported on various
floors of the building.

Same finite element models have been used for seismic re-evaluation of the buildings. Damping value
and ductility factor as listed in [1] have been used in the analysis. The seismic re-evaluation of the safety related
civil structures at TAPS-1&2 has been conducted by following the procedure as brought out above and have met
the codal requirements of ACI 349, 2001.

Fig 3: Finite Element Model of Reactor and Service Building

5. CONCLUSION
The seismic re-evaluation of TAPS-1&2 has been done by way of detailed analysis of civil structures, reactor pressure vessel, piping systems; walkdown of Structures, System & Equipment and shake table testing of active devices.

Finding of the analysis of piping systems carried out by the rigorous response spectrum analysis method, using floor response spectra and seismic anchor movement indicate that all the piping systems meet the requirements of ASME Section III, subsection NB & NC codes. This further indicates that the piping systems which were designed by General Electric by ANSI B31.1 & B31.3, using equivalent static analysis method by using 0.5% damping free field ground motion, meet the latest codal requirements.

The civil structures at TAPS-1&2 were designed way back in 1965 using the then civil design codes have met the latest ACI 349 code. The analysis and design techniques used in the present analysis are much sophisticated. The dynamic analysis of the finite element model using shell element is bound to give a very precise insight in to the forces and moment in a civil structure. Even small openings in the walls & floors have been modeled in the present re-evaluation. Irrespective of such an in-depth calculations performed on the civil structures designed & built way back in 1965 (by using the then civil structural design code and using the seismic co-efficient method) met the latest design codal requirement with the damping and ductility reduction factors given in IAEA Safety Standard [1].

The seismic adequacy of other structures & equipment is carried by way of walkdown. It’s a good tool to evaluate the equipment for seismic adequacy and to up-grade those, which are deficient. Some of the recommendations of upgradation have been implemented and remaining will be implemented during the long shutdown to be taken up in 2005 for safety and seismic upgradeation.

6.0 REFERENCES


