PBNC 2012-FA-0034

POST-FUKUSHIMA EVALUATION OF NUCLEAR POWER PLANTS IN TAIWAN

C. H. Wu, W. C. Teng, S. Chang, Y. B. Chen

Atomic Energy Council, New Taipei City, Taiwan (R.O.C.)

chhwu@aec.gov.tw, wcteng@aec.gov.tw, schang@aec.gov.tw, ybchen@aec.gov.tw

Abstract

In the wake of Japan's Fukushima Daiichi Nuclear Power Plants event, the Atomic Energy Council (AEC) has asked Taiwan's Nuclear Power Plant operator (TPC) to re-examine and re-evaluate the vulnerabilities of its nuclear units, and furthermore, take possible countermeasures against extreme natural disasters, including earthquake, tsunami and rock-and-mud slide. The evaluation process should base on both within and beyond Design Basis Accidents, by reference to the actions recommended by the world nuclear authorities and groups, namely, IAEA(2011), USNRC(2011), NEI(2011), ENSREG(2011) and WANO(2011). The purpose of the re-examination and re-evaluation in Taiwan is to assure that serious damages would not happen in the case that Taiwan faces similar natural disaster challenges as Japan, after completion of related strengthening and modification of the nuclear power plants. The re-evaluation program comprises of two parts: nuclear safety assurance and radiation protection and emergency response preparedness. Each has two stages: the near-term (up to June 2011) and mid-term (up to Dec. 2011). This report covers the 1st stage near-term assessment results for both parts. After reviewing the TPC's near-term action submittals required by AEC, two issues related to the current licensing basis of the nuclear power plants were found. The issues were later considered resolved, and AEC will continue the followup action. To keep up with the pace of the international countermeasures after Fukushima, AEC required TPC to adopt the following actions of near-term stage: to implement the EU's Stress Test specification, to re-evaluate the process for emphatic measures and related operator training, and to evaluate and revise the plant-specific emergency planning zone. AEC will to examine rigorously the 10-year periodic safety review of nuclear power plants and amend the laws with related to emergency preparedness in the second stage.

1. Introduction

In the wake of Japan's Fukushima Daiichi Nuclear Power Plant event (Japan, 2011), the Atomic Energy Council (AEC) has asked Taiwan's Nuclear Power Plant operator (TPC) to re-evaluate its capability to copy with extreme natural disasters, including earthquake, tsunami and mudslide, and take possible countermeasures. AEC has worked, and expected to continue to work, in co-operation and co-ordination with national stakeholders. The re-examination program comprises of two parts: nuclear safety assurance and radiation protection and emergency response preparedness. This report covers the near-term and mid-term assessment results for both parts. This report provides a brief background to radioactive hazards, and how to protect against them, as well as an overview of the approach to nuclear safety and security for the accidents.

While the investigation of the accident scenarios in Japan is still left to be clarified, there is sufficient information to develop initial lessons learned for the AEC. Based on our preliminary conclusions and first-stage requirements, AEC refers the recommended actions to be taken without delay by USNRC and the best international engineering practices considered in the nuclear industries by taking the nuclear regulatory cases into account to the second stage report. There are some emerging lessons, and these are proposed as requirements for further work. The direct causes of the nuclear accident, an earthquake with magnitude 9.0 resulting an over 14 meter high tsunami, are far beyond the design basis of most extreme natural events experienced. Design provisions at the Fukushima Daiichi site appear to only have been made to protect against a 5.7 meter high surge in sea level, and there was a huge tsunamis hitting this coast in the history of Japan. The nuclear power plants of TPC, both operating and being under construction, should follow the same criteria to examine the design basis. In addition, AEC's regulation to design basis analysis requires TPC to demonstrate that adequate protection is in place for an extremely rare natural event , developed based on extrapolation from the historical record. AEC then require TPC to show that there are no "cliff-edge" effects based on the specification of EU stress test.

2. Key Areas of the ROCAEC response to Fukushima Accident

Many areas of improvement have been identified in the issues of nuclear safety assurance. The key areas include the enhancement for protection of seismic, tsunami hazard, critical infrastructure, hydrogen detection and explosion, spent fuel pool cooling, prolonged station blackout (SBO), severe accidents, and safety culture, as stated in the following.

2.1 Impact of Natural Hazards

The Fukushima reactor's shutdown systems operated effectively in response to the event. It indicates the robustness of seismic design adopted for these Japanese plants. AEC has learned from the earthquake experience on Japan's nuclear power plants and requested TPC to perform the necessary studies for a couple of years. This includes the supplemental geology investigation of sea area, land territory, geological stability and seismic hazard analysis nearby the nuclear power plants. Based on the relevant information of seismic margin assessment of operating nuclear power plants, the subsequent reinforcement work is to strengthen seismic design to cope with natural disasters.

External flooding has also been considered in the report as an impact on siting and site/plant layout. The simulations of threat for nuclear power plants on tsunami effect have been provided by National Science Council (ROCNSC). TPC should analyze the tsunami hazard of nuclear power plants based on the US related laws and regulations, which is standardized by the state-of-the-art technology, and to strengthen their flooding design data.

2.2 Infrastructure Resilience

The severe disruption of the electrical grid, communications and transportation systems on Fukushima event was one of the important observations. It was a significant contributory factor to worsen the accident while the conditions lasted for several days. The reactor safety is reliant on the resilience of the local infrastructure in circumstances of extreme events affecting both the nuclear site itself and the surrounding area. TPC should enhance on-site accident management capabilities and introduce the off-site resources. The dependency of both the operating and constructed nuclear plants on the resilience of off-site infrastructure should be re-examined, by lessons learned from the Japan event. This might highlight the need for the enhancement of plant's sustainabilities for extended periods in terms of electrical power, coolants and necessary supplies.

2.3 Hydrogen detection and explosion

A considerable quantity of hydrogen could be generated by chemical reactions under accident conditions like that happened between zirconium fuel cladding and steam on loss of cooling in Fukushima Daiichi plant. In the case of the Chinshan plant, there has been installed the hardened routes for venting containment heat from the reactor vessel, updated in line with the TMI response actions. Additionally, it appears that an explosion occurred in the suppression pool of Fukushima Unit 2, possibly breaching the primary containment. This may indicate that more attention should have been given in the design and safety assessment to the robustness of the Mark I containment. Given the experience at the Fukushima plant, AEC requests TPC to prudentially review if the systems for venting containments with potentially significant concentrations of combustible gases are sufficiently robust.

2.4 Spent Fuel Pool cooling

The spent fuel strategy of TPC has necessitated increased spent fuel storage capacity at reactor sites, as well as developing the interim storage installations for spent fuels (ISFSI) at Chinshan site. The spent fuel pool is robust structure filled with water to cool the fuels and provide shielding from gamma radiation within the spent fuels. The pool is designed with cooling systems to maintain water temperature around 30°C to 40°C, and water levels several meters above the top of the fuel assemblies. After several years, the residual decay heat within the fuels were decayed to a level where the spent fuels could be transferred into dry casks for further storage. (NEI, 2006)

The spent fuel assemblies in the pools should be reconfigured in a "checkerboard" pattern (Center hot spent fuel assembly surrounded by four cold assemblies) so that newer, higher decay-heat fuel elements are surrounded by older, lower decay-heat elements (NRC, 2006). AEC orders TPC to provide sufficient safety-related instrumentation to monitor key spent fuel pool parameters (i.e., water level, temperature, and area radiation levels) from the main control room. AEC also requests TPC to provide safety-related ac electrical powers for the spent fuel pool makeup system.

2.5 Prolonged Station Blackout

Grid supplies were lost when the earthquake struck the area around Fukushima, but problems arose at the Fukushima Daiichi site because of prolonged unavailability of electrical power. The long-term independent on-site emergency electrical supplies then provide assurance of safety on the site, coupled with the timely restoration of a reliable off-site grid supply. The robustness, reliability and potential for extended unavailability in severe hazard conditions of the plant emergency power systems should be re-evaluated in light of the Fukushima accident.

The on-site emergency electrical supplies at the TPC site involves diesel generators and back-up batteries. By reviewing plant layouts, the protection against flooding and the interplay between on-site and off-site electrical supplies, consideration should also be given to the provision of additional, diverse means of providing robust long-term electrical suppliers independent of the grid for emergency cooling, emergency control and instrumentation systems. Such dedicated supplies may be located on or near the site with suitable robust connections. AEC requests TPC to evaluate the establishment of a coping time of 24 hours for a loss of all ac power, establish the requirement necessary to implement an "extended loss of all ac power" coping time of 72 hours for core and spent fuel pool cooling and for reactor and containment integrity.

2.6 Severe Accident Management Guidelines and Training

Reviewing of the suitability of Severe Accident Management Guidelines (SAMG) for supporting operator actions, informed by information on the success or otherwise of the postulated operator actions to cope with Fukushima type event. In particular such a review should consider the critical safety functions prioritization, and wider plant requirements, and the level of detail and prescription currently offered. Approach to the requirement for industries research to improve the understanding of severe accident phenomenology.

Furthermore, TPC should review any consequential impact on operator (and other personnel) training requirements. The limitation of current simulator models to support the formal training of severe accident management, and will consider the reasonable practicability and safety benefit of extending routine training in severe accident response.

2.7 Safety Culture

Many of the above considerations are intrinsically linked to nuclear plant safety culture. The events at Fukushima have highlighted a number of issues that should be reviewed for each TPC plant and, if necessary, provided as reference to the revisions of the practices of safety culture. An acceptable safety culture (IAEA, 2006) will be required to provide an appropriate basis for any changes to plant and arrangements for severe accidents. There is a particular need to consider longer term analysis of fault sequences taking account of the development of the accident sequence over time and the potential loss of services, such as cooling and electricity, as well as the potential for repair and recovery to a stable state.

3. Conclusions

The issues of radiation protection and emergency response preparedness cover emergency responses and rulemaking, to enhance the resources are necessary to support emergency plans and emergency planning implementation.

After reviewing the TPC's near-term action submittals required by AEC, two issues related to the current licensing basis of the nuclear power plants were found. The elevation measurement does not comply with FSAR in Chinshan plant. ECW pump room does not comply with the requirements of tsunami protection design in Kuosheng. The issues were later considered resolved, and AEC will continue the followup action. The assessment of post-Fukushima evaluation shows neither immediate nuclear safety concern nor threat to the public health and safety. However, improvement of natural hazards and prolonged SBO is the follow-up actions to demonstrate the capability to cope with the beyond design basis disasters.

AEC requested TPC to deliberately implement and complete the nuclear regulatory safety-issue follow-ups cases identified in the second-stage report for safety improvement. To keep up with the pace of the international countermeasures after Fukushima, the AEC is actively involved in the following activities: to have the national reports in the specification of EU's Stress Test reviewed by international counterparts, to examine rigorously the 10-year periodic safety review of nuclear power plants, and to amend the laws with regard to emergency preparedness in the near future.

References

USNRC, "Tohoku-Taiheiyou-Oki Earthquake Effects on Japanese Nuclear Power Plants," IN 2011-05, March 18, 2011.

NEI, "Industry Taking Action to Ensure Continued Safety at U.S. Nuclear Energy Plants," Fact Sheet, March 16, 2011.

WENRA, "First proposal about European-stress tests-on nuclear power plants," WENRA, March 23, 2011.

ENSREG, "EU stress test specifications," ENSREG, May 25, 2011.

WANO, "Fukushima Daiichi Nuclear Station Fuel Damage Caused by Earthquake and Tsunami," SOER 2011-02, March 17, 2011.

Government of Japan, "Report of Japanese Government to the IAEA Ministerial Conference on Nuclear Safety - The Accident at TEPCO's Fukushima Nuclear Power Stations," Nuclear Emergency Response Headquarters, June 2011.

National Research Council, "Safety and Security of Commercial Spent Nuclear Fuel Storage," Public Report, National Academy of Sciences, 2006.

NEI, "B.5.b Phase 2&3 Submittal Guideline," NEI 06-12 (Revision 2), December 2006.

IAEA, "Fundamental Safety Principles," Safety Fundamentals No. SF-1, Vienna, 2006.