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STRESS TEST OF THE NUCLEAR POWER PLANTS PERFORMED IN TAIWAN

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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 be based on both within and beyond Design Basis Accidents, by reference to the actions recommended by the world nuclear authorities and groups, namely, IAEA, USNRC, NEI, ENSREG and WANO.

Taiwan is a very densely populated region of the world. Furthermore, like Japan, due to its geophysical position, Taiwan is prone to large scale earthquakes, and although historically rare, Taiwan also faces the potential risk of tsunamis. AEC also asked TPC to perform the stress test following the specification given by WENRA (later ENSREG) and conducted in all the EU's nuclear reactors. After completion of the stress test for all the nuclear power plants, AEC was trying to have the reports peer reviewed by international organizations, as EU did. The OECD/NEA accepted AEC's request and formed a review team specific to the review of Taiwan's National Report for the Stress Test. There were 18 follow-up items after the NEA's review. Based on these items, AEC developed five orders to require TPC further enhancing their capabilities to cope with extreme natural hazards. The ENSREG also formed a nine-expert review team for Taiwan's Stress Test in response to AEC's request almost at the same time as the OECD/NEA. The ENSREG review team began their works in June 2013 by desktop review, and ended in early October 2013 by country visit to Taiwan.

While the assessment of post-Fukushima evaluation reveals neither immediate nuclear safety concerns nor threats to the public health and safety, AEC requested that TPC focus on strengthening its re-evaluation on design basis against earthquakes, tsunamis and heavy rainfalls, and enhancing its capability to mitigate a prolonged station blackout (SBO) for further improvement. However, these improvements are justified on the basis of the fact that the risk to be hit by extreme natural hazards, such as earthquakes, flooding including tsunamis, extreme weather conditions and volcanism, is much higher in Taiwan than in many other geographical environments of the world.

Introduction

Taiwan has been generating power from nuclear plants since 1977. There are currently three plants in operation and one under construction. Table 1 below listed the basic information of nuclear power plants at Taiwan. The following figure 1 shows the locations of the four existing NPPs in Taiwan.

On March 11, 2011, the Great East Japan earthquake and the ensuing tsunami led to severe accidents with core meltdown in three nuclear units at the Fukushima Daiichi Nuclear Power Plant (NPP) site in Japan. On April 12, 2011, these events were classified by the Japanese authorities as INES 7 ("major accident").As a direct consequence, AEC thoroughly reviewed the lessons learned from Fukushima accident and proposed the "Programs for Safety Re-assessment" which was approved by Executive Yuan on April 19, 2011[1] and issued administrative orders to TPC, the operator of Taiwan's nuclear power plants, in which immediate measures and additional re-assessments were required.

Table 1. Basic Information of Nuclear Power Plants at Taiwan

NPP	Type of Reactor	Site location and proximity of major population areas
Chinshan	GE BWR-4 twin units with Mark-I containment	28 km away from Capital city Taipei
Kuoshang	GE BWR-6 twin units with Mark-III Containment	22 km away from Taipei
Maanshan	Westinghouse three loop PWR twin units with large dry containment	110 kilometers south of Kaohsiung city
Lungmen	GE ABWR twin units	40 kilometers east of Taipei city

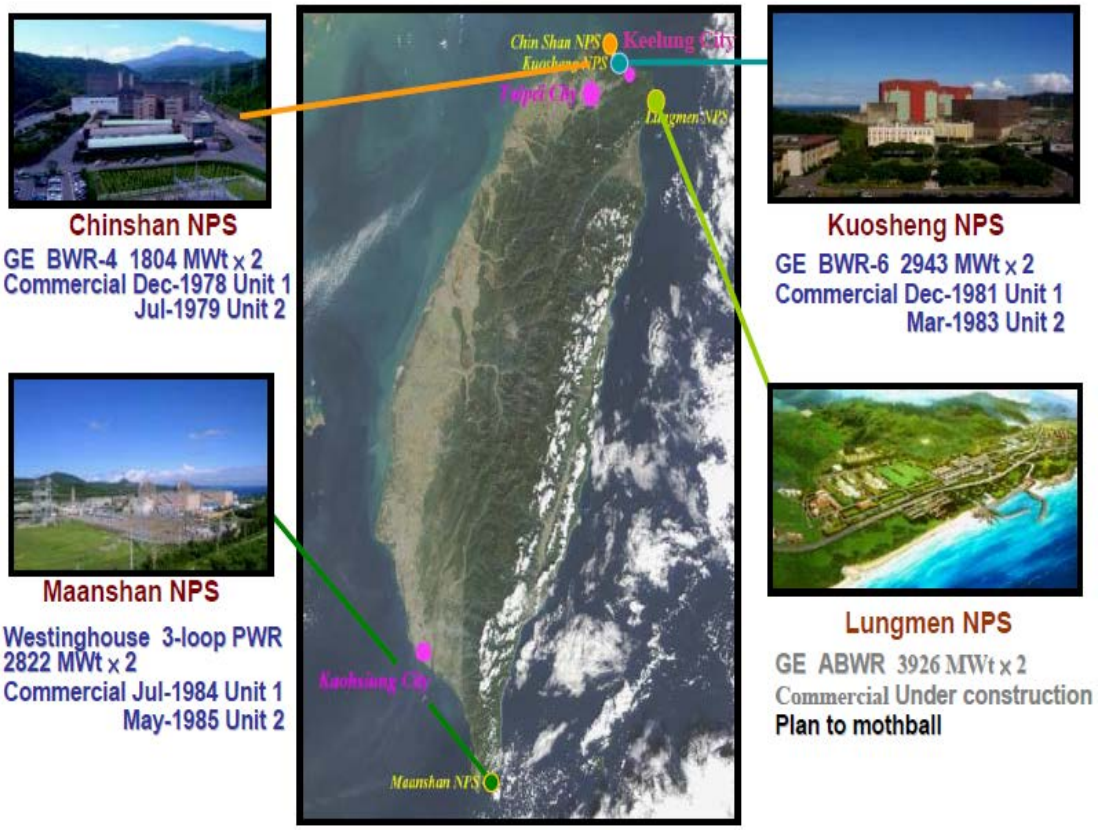

Figure 1. The site locations of Nuclear Power Plants at Taiwan

Following the wake of Fukushima accident, AEC has requested TPC to re-evaluate its capability to cope with extreme natural disasters, including earthquakes, tsunamis, extreme rainfalls and mudslides resulted from the related hazards, and take possible countermeasures. AEC has completed its assessment and verification of TPC's reports, and is committed to continuing its efforts in inter-ministerial coordination and communication with domestic organizations and stakeholders. The re-assessment program comprises of two parts: (1)nuclear safety assurance, and (2)radiation protection, emergency response and preparedness, which were implemented on two stages: near-term (by June 2011) and mid-term (by December 2011) assessments. The reports (in Chinese) on the first-stage and second-stage assessments, approved by the Executive Yuan in October 2011 and August 2012 respectively, are available on AEC's website. The final report covers the near-term and mid-term assessment results for both stages. This report provides a comprehensive background on external hazards, and the ways to protect against them, as well as an overview of the enhancement measures to nuclear safety and security for the accidents in light of the Fukushima Daiichi accident. Lessons learned from the Fukushima accident as well as relevant information available internationally were used as reference during preparation of this report.

1. Comprehensive Safety Assessment of the AEC response to Fukushima Accident

The direct cause of the nuclear accident at Fukushima, an earthquake with magnitude 9.0 resulting in an over 14 meters high tsunami, is far beyond the design basis tsunami analysed by utility and approved by regulator. Although there have been huge tsunamis attacking the east coast of northern area in the main island of Japan, design basis tsunami at the Fukushima Daiichi site appears to only have been made to protect against a 5.7 meters high surge above sea level based on numerical simulation only. The nuclear power plants of TPC, both operating and new build, should follow the lessons learned to re-visit the design basis. In addition, AEC's regulation on design basis analysis requires TPC to demonstrate that adequate protection is in place for an extremely rare natural event, developed based on simulation from the historical record. AEC then requires TPC to show that there is significant "cliff-edge" or enough safety margins based on the specification of EU stress tests [2, 3]. While the investigation of the detailed accident scenarios in Japan is still left to be clarified, there is sufficient information to develop initial lessons learned for AEC. Based on the preliminary conclusions and first-stage requirements, AEC refers to the actions recommended by USNRC [4] to be taken without delay and the best international practices considered in the nuclear community, and takes the nuclear regulatory orders into account on the second-stage report. Though there are still some emerging lessons, these would be considered as requirements for further work.

After reviewing the TPC's near-term action submittals required by AEC, two issues related to the current licensing basis (CLB) of the nuclear power plants were identified: the elevation measurement did not comply with FSAR in Chinshan plant, and the design for tsunami protection was not adequate at the ECW pump room in Kuosheng. These issues were later confirmed resolved upon site inspection in June 2011. While the assessment of post-Fukushima evaluation reveals neither immediate nuclear safety concerns nor threats to the public health and safety, AEC requested that TPC focus on strengthening its re-evaluation on design basis against earthquakes, tsunamis and heavy rainfalls, and enhancing its capability to mitigate a prolonged station blackout (SBO) for further improvement. Many areas of improvement have been identified in the issues of nuclear safety assurance. The key areas include the enhancement of capability to mitigate a prolonged station blackout, protection against tsunami hazards, spent fuel pool cooling, hydrogen detection and

explosion prevention, severe accident management, protection against seismic hazards, critical infrastructure, and safety culture.

AEC required TPC to immediately implement and complete the nuclear regulatory orders issued in the second-stage report for safety improvement. TPC may submit alternative subject to AEC approval to provide the equivalent function. To keep up with the pace of international countermeasures after Fukushima, AEC is proactively involved in such activities as to have the national reports prepared in accordance with EU Stress Test specifications reviewed by international counterparts, and to have examined rigorously the 10-year periodic safety review of nuclear power plants.

Table 2 below shows the investigations and measures set in motion in the Taiwan's nuclear power plants, and the timeline for their implementation. On the basis of the reviews conducted to date, the TPC and AEC have derived a number of improvement measures that are detailed in the following contents of this paper.

Table 2. Timeline for the investigations and measures for the Taiwan's NPPs

Date	Milestones of safety re-assessment and EU stress test
2011/03/11	Fukushima Daiichi accident
2011/04/19	"Programs for Safety Re-assessment" approved by Executive Yuan
2011/05/30	Preliminary Assessment Report for Nuclear Safety, it has included the "Stress tests" specifications proposed by the WENRA Task Force on April 21, 2011 (in Chinese)
2011/10/07	"The near-term Overall Safety Assessment Report for NPPs in Taiwan in response to the lessons learned from Fukushima Daiichi accident" approved by Executive Yuan (in Chinese) The draft report in July, 2011 has included the "EU Stress tests specifications" issued by ENSREG on May 25, 2011
2011/11~ 2012/1	AEC has conducted five regulatory meetings on stress test progress with TPC
2012/02	Draft version of Comprehensive Safety Reassessment report for NPPs in Taiwan in response to the lessons learned from Fukushima Daiichi accident (in Chinese)
2012/03	Stress test Utility reports for three operating NPPs submitted by TPC (in Chinese)
2012/04	Stress test Utility report for new build NPP submitted by TPC (in Chinese)
2012/08	"Comprehensive Safety Reassessment report for NPPs in Taiwan in response to the lessons learned from Fukushima Daiichi accident" approved by Executive Yuan (in Chinese)
2012/09	Draft National report for three operating NPPs (in English) Draft National report for new build NPP (in English)
2012/11/05	AEC issued the regulatory orders (a total of 90 regulatory orders for three operating NPPs and one new build NPP) based on the safety re-assessment and EU stress test
2013/01	Final version of National report for three operating NPPs (in English)
2013/02	To provide the final National report for three operating NPPs to the independent peer review team organized by OECD/NEA
2013/03/04 ~	OECD/NEA independent peer review Joint press conference with OECD/NEA peer review team

2013/03/15	
2013/04/23	Final report of OECD/NEA independent peer review
2013/05/31	Revised National report for three operating NPPs and new build NPP and four Utilities reports sent to the ENSREG review team (in English)
2013/06/06	AEC issued the regulatory orders (a total of 18 regulatory orders for three operating NPPs and one new build NPP) based on the recommendations and technical observations of OECD/NEA independent peer review
2013/07/09	The preparatory meeting of "EC/ENSREG peer review for Taiwan's National Report" held at Brussels, Belgium
2013/09/23 ~ 2013/10/03	EC/ENSREG team performed peer review and site visit
2013/11/07	EC and AEC issued the peer review report and EC summary report at their official website, simultaneously
2013/11/08	AEC issued EC summary report (in Chinese) at website
2013/12/12	AEC issued EC peer review report (in Chinese) at website
2013/03/06	AEC issued the regulatory orders (a total of 27 regulatory orders for three operating NPPs and one new build NPP) based on the recommendations of the EC/ENSREG peer review team

The above quoted orders are basically formed on the basis of internationally available information. AEC has carried out a safety re-assessment of Taiwan's NPPs after the Fukushima accident and has published the results in some of reports. These reports provide detailed descriptions of the findings and observations of the response of Taiwan's NPPs in response to the Lessons Learned and specific checkpoints that can be derived from these findings and orders. These checkpoints will be closely monitored in the coming years by AEC oversight activities. The national report based on the EU Stress Test specifications provides evaluation of the cliff edge and response to the Fukushima accident for Taiwan's NPPs.

1.1 Technical Requirements of Comprehensive Safety Re-assessment

After Fukushima accident, AEC proposed the "Programs for Safety Re-assessment" approved by Executive Yuan on April 19, 2011 and issued administrative orders to operator of the Taiwan's nuclear power plants, in which immediate measures and additional re-assessments were required. The re-assessment program [1] comprises two parts: (1) nuclear safety, and (2) radiation protection and emergency response and preparedness. The outcome provides a comprehensive background on external hazards, and the ways to protect against them, as well as an overview of the enhancement measures to nuclear safety and security for the accidents in light of the Fukushima Daiichi accident. Lessons learned from the Fukushima accident as well as relevant information available internationally were used as references in the safety re-assessment [5]. There are 11 technical areas in the nuclear safety field, including: (1) Re-examine the Capability for Loss of All AC Power (SBO), (2)Re-evaluate Flooding and Tsunami Protection, (3)Ensure Integrity and Cooling of Spent Fuel Pool, (4)Assess Heat Removal and Ultimate Heat Sink, (5)EOP Re-examination and Re-training, (6)Setup the Ultimate Response Guidelines (URG), (7)Support between Different Units, (8)Considerations for Compound Accidents, (9)Mitigation beyond DBA, (10)Preparedness and

Backup Equipment, and (11)Manpower, Organization, Safety Culture. All of the sub-items of each technical areas examined by the operator of nuclear power plants are submitted to AEC.

Following the AEC requirements, three operating and one under-constructing nuclear power plants of TPC submitted several progress reports based on the "Programs for Safety Re-assessment" from 2011 to 2012. These reports contain information about the work progress, the methodology applied, the tools utilized and the interim results. AEC reviewed these reports and concluded that the information is in compliance with the AEC regulations. The methods used to re-assess the plants were presented by the operators in an easily comprehensible form. With respect to earthquakes and flooding, the staffs of TPC were able to refer to the latest studies, such as the plant-specific seismic probabilistic safety analyses, or the proof of protection against flooding submitted in 2011, 2012. From the viewpoint of AEC, the procedures outlined by TPC in their progress reports differed in their level of detail, but were basically in accordance with AEC's expectations. AEC inspectors performed several special task force inspections to confirm the adequacy of progress reports submitted by TPC.

After reviewing the TPC's near-term action submittals required by the AEC, two issues related to the current licensing basis of the nuclear power plants were identified: (1) the re-measurement of site elevation showed not compliant with FSAR in the Chinshan plant, and (2) the design for tsunami protection was not adequate at the Emergency Circulating Water pump room in the Kuosheng plant. These issues were later confirmed resolved upon site inspection in June 2012. While the assessment of post-Fukushima evaluation reveals neither immediate nuclear safety concerns nor threats to the public health and safety, the AEC requested the TPC to continue strengthening its ability against earthquakes, tsunamis and heavy rainfalls, and enhancing its capability to mitigate a prolonged station blackout (SBO), i.e., loss of all AC power, for further improvement. AEC issued the regulatory orders requiring TPC to enhance the safety of nuclear power plants on November 5, 2012.

1.2 Regulatory Orders of Comprehensive Safety Re-assessment

Based on the results of the stress test and insights from the actions being taken by other countries, the AEC established clear requirements to implement enhancements. These requirements were embodied in regulatory orders issued by AEC to TPC on 5 November 2012. TPC may propose alternatives subject to AEC approval. The orders issued are listed below.

1. Requiring seismic hazard re-evaluations implementing the recommendation from the United States Nuclear Regulatory Commission (USNRC) Near Term Task Force (NTTF) Report Tier 1 recommendation 2.1 to conduct seismic and flood hazard re-evaluations [6].

2. Requiring flood hazard re-evaluations implementing the USNRC NTTF Report Tier 1 recommendation 2.1 to conduct seismic and flood hazard re-evaluations.

3. Requiring TPC to simulate the mechanism of seismic and tsunami hazards and the resulting risks based on comments from an AEC review meeting.

4. Requiring the enhancement of the water tightness of buildings (or build seawall, or tidal barrier) to a level of 6 meters above current licensing bases based on the actions being taken at Japanese

NPPs and as referred to in the USNRC NTTF Report, to address the uncertainty from the original design basis tsunami height by adding 6 meters of protection.

5. Requiring seismic, flood and other external events walkdowns consistent with the USNRC NTTF Report Tier 1 recommendation 2.3 to conduct seismic and flood walkdowns

6. Requiring TPC to take actions to address station blackout (SBO) consistent with the USNRC NTTF Report Tier 1 recommendation 4.1 on SBO regulatory actions.

7. Requiring at least 2 emergency diesel generators (EDGs) to be in an operable status all the time even when the reactor is shut down so that if one unit is shut down with one EDG under inspection and the swing EDG is assigned to it according to the new requirement, the capability of the swing EDG to back up the other unit is restricted.

8. Requiring TPC to enhance emergency DC power supply to secure a storage capacity of at least 8 hours with the storage capacity of the batteries of one system without isolating the load and at least 24 hours after the unnecessary loads are isolated.

9. Requiring TPC to extend the SBO coping time to at least 24 hours based on specific issues for Taiwan's NPP in that the original requirements of USNRC Regulatory Guide (RG) 1.155 did not include the effects resulting from earthquake and tsunami.

10. Requiring TPC to install a seismic qualified extra gas-cooled EDG at each NPP to address specific issues with electrical power supplies defence-in-depth for Taiwan.

11. Requiring TPC to install an alternate ultimate heat sink (UHS) consistent with recommendations from the ENSREG action plan [7].

12. Requiring TPC to implement the actions of the USNRC's Post-9/11 action (B.5.b) to stage response equipment on or near site to respond to extreme external events (see USNRC 10 CFR 50.54(hh)(2)).

13. Requiring TPC to address the USNRC NTTF Report Tier 1 recommendation 4.2 on equipment covered under USNRC regulation 10 CFR 50.54(hh)(2).

14. Requiring TPC to install reliable hardened vents for Mark I and Mark II containments and request the installation of filtration for all different containment designs consistent with the recommendation of USNRC NTTF Report Tier 1 recommendation 5.1 on reliable hardened vents for BWR Mark I and Mark II containments.

15. Requiring TPC to install spent fuel pool (SFP) instrumentation consistent with the recommendation of the USNRC NTTF Report Tier 1 recommendation 7.1 on SFP instrumentation.

16. Requiring TPC to strengthen and integrate the emergency operating procedures (EOPs), severe accident management guidelines (SAMGs), and extensive damage mitigation guidelines (EDMGs) with the ultimate response guidelines (URGs) developed by TPC following the

accident at Fukushima Daiichi NPP consistent with the USNRC NTTF Report Tier 1 recommendation 8 on strengthening and integration of EOPs, SAMGs, and EDMGs.

17. Requiring TPC to perform a volcanic probabilistic risk assessment (PRA) for its NPPs and to study the impacts from ash dispersion based on comments during a high-level review meeting.

18. Requiring TPC to enhance the water-tightness of the fire doors of essential electrical equipment rooms based on specific concerns with the location of the equipment at Taiwan's NPPs and recommendations from the Japanese regulatory body for NPPs in Japan.

19. Requiring TPC to enhance the seismic resistant for the fire brigade buildings to cope with beyond design basis earthquake (BDBE) conditions to address specific issues for Taiwan's NPPs and on good practices from EU peer reviews [8].

20. Requiring TPC to improve the reliability of offsite power supplies to address specific issues for Taiwan's NPPs and recommendations from the Japanese regulatory body for NPPs in Japan [9].

21. Requiring TPC to improve the seismic resistance of raw water reservoirs at the NPPs and to consider the installation of impermeable liners to address specific issues for Taiwan's NPPs and consistent with the measures being taken by TEPCO in Japan to install impermeable liners [10].

22. Requiring TPC to install passive autocatalytic recombiners (PAR) to prevent hydrogen explosions consistent with recommendations in the ENSREG action plan.

23. An Executive Order of the Yuan, requiring TPC to conduct an enhancement evaluation of safety related structures, systems and components (SSCs) for the Chinshan Nuclear Power Plant followed by the upgrading of the licensing basis safe shutdown earthquake (SSE) from 0.3g to 0.4g for specific SSCs relied upon to respond to an accident.

24. Requiring TPC to address the issue with the PWR reactor coolant pump (RCP) seal loss-of-coolant-accident leakage issue for Maanshan Nuclear Power Plant consistent with the ENSREG action plan.

Furthermore, TPC should finish the integrated PRA analytical model based on ASME PRA standard [11].

In addition to the orders issued by the AEC's Department of Nuclear Regulation, there are four orders issued by the Department of Nuclear Technology.

1. Requiring TPC to update "radiation protection measures and planning for the residences within emergency planning zone (EPZ) of Nuclear power plant" in response to the fact that EPZ has been expanded from 5 km to 8 km based on the lessons learned from Fukushima accident for all nuclear plants in Taiwan.

2. Requiring TPC to address staffing and communications issues for emergency preparedness consistent with the USNRC NTTF Report Tier 1 recommendation 9.3 on emergency preparedness regulatory actions.

3. Requiring TPC to enhance the structure of the existing non-seismically qualified technical support centre (TSC) used for emergency response to address specific seismic concerns with the NPPs in Taiwan.

4. Requesting TPC to consider building a seismically isolated Emergency Response Center (ERC) building based on the practice being implemented in Japan in light of the accident at Fukushima Daiichi NPP and consistent with guidance provide by the International Atomic Energy Agency [12].

There are three orders issued by the Fuel Cycle and Materials Administration.

1. Requiring TPC to purchase 40 mobile detection equipments with automatic data transmission capability for four NPPs to enhance domestic capability of radiation fallout monitoring in a timely manner.

2. Requiring TPC to install 13 additional radiation monitoring stations within the EPZ of NPPs to set up a radiation monitoring preparedness platform and strengthen radiation monitoring capability.

3. Requiring TPC to purchase four radiation detection vehicles to enhance mobile radiation monitoring capability.

2. Stress Test followed by EU Specifications

2.1 Peer Review for National Report followed by the stress test of EU specifications

The AEC then required the TPC to identify the “cliff-edge” effects based on EU stress tests specifications. AEC's order dated June 28, 2011 requested TPC to perform the stress test following the EU stress test specifications based on the safety enhancement requirement of comparable plants at EU. The scope of the stress test of Taiwan’s NPP to be carried out is in accordance with the ENSREG stress test specifications. The final reports submitted by TPC on January 3, 2012 were further detailed on the basis of the review insights gained as a result of the orders issued by AEC. In connection with the EU stress test the following aspects must be examined: the robustness of nuclear power plants in case of events beyond the design basis due to earthquakes, external flooding and extreme weather conditions, as well as loss of the power supply and of the heat sink. For this purpose, the first step is to set out the hazard assumptions and design bases for the nuclear power plants and to evaluate their adequacy. As a second step, the protective measures initiated and the safety margins in relation to the design, together with any cliff-edge effects, must be identified and evaluated. Finally, any relevant improvement measures must be derived from this information.

AEC asked both the European Union (EU) and Nuclear Energy Agency (NEA) of the Organization for Economic Cooperation and Development (OECD) sending experts that could conduct an independent peer review of Taiwan’s National Stress Test Report that was performed in light of the accident at the Fukushima Daiichi NPP. NEA’s independent peer review team reviewed the stress tests National Report for the three operating nuclear power plants. The independent peer review team from NEA had the opportunity to hear presentation by and discussed with AEC’s and TPC’s

staff, as well as had a site visit to Kuosheng NPP, between March 4 and 15, 2013. The preliminary findings were discussed with representatives from AEC and TPC at a meeting on March 15, 2013, and the preliminary findings were presented to the public in a press conference on the same day [13]. The final report of NEA peer review [14] was provided to AEC on April 23, 2013. The final report indicates that the methodology applied in Taiwan's stress test complies with the ENSREG's requirement. Furthermore, most of conducted or planning post-Fukushima improvements in Taiwan's nuclear power plants are regarded as "strength" by the independent peer review team. Also, in addition to the original regulatory orders established prior to the review, some of follow-up issues are subject to re-evaluation in view of the recommendations and technical observations identified in the final report, including the technical aspects of seismic, tsunami, flooding, extreme weather, loss of safety functions, and severe accident management. This would ensure Taiwan's nuclear power plants survive the hazards from beyond design basis accidents caused by natural disasters. AEC has reviewed the NEA final peer review report and issued the additional regulatory orders to TPC on June 6, 2013.

EC/ENSREG's peer review team reviewed the National stress tests Report for the three operating and one constructing nuclear power plants. The peer review team from ENSREG had the opportunity to hear presentation by and discussed with AEC's and TPC's staff, as well as had the site visit to Lungmen and Maanshan NPPs, between September 23 and October 3, 2013. The preliminary findings were discussed with representatives from AEC at a closeout meeting [15] on October 3, 2013, and the final report of ENSREG peer review [16] and EC summary report [17] were provided to AEC on November 7, 2013. The EU peer review concludes that the safety standards applied in Taiwanese nuclear power plants are generally high and comply with international state-of-the-art practices. Neither the Taiwanese nuclear operator nor the regulator found any safety shortcomings which would require the immediate shutdown of any power plants. However, the EU peer review strongly recommends further improvements in view of Taiwan's vulnerability to natural hazards such as earthquakes, flooding, tsunamis and volcanos. AEC reviewed the EC/ENSREG final peer review report and issued the new regulatory orders to TPC on March 6, 2014.

2.2 Regulatory Orders of Recommendations from Peer Review of EU stress test

The orders issued on June 6, 2013 by AEC following the recommendations of independent peer review from OECD/NEA are as follows:

1. Requiring TPC to conduct fault displacement analysis for new evidences of Shanchiao and Hengchun Faults near (within a radius of 8 km) the NPPs.

2. Requiring TPC to provide the interface between existing post-earthquake and post-tsunami operating procedures of NPPs.

3. Requiring TPC to systematically assess the combinations of events in the areas of flooding and extreme natural events at NPPs.

4. Requiring TPC to examine the probable maximum precipitation with regional topographical maps of NPPs.

5. Requiring TPC headquarters to deploy a local seismic network (one in the north and one in the south) to capture small earthquakes in order to understand whether or not the pattern of the epicentres indicate correlation with postulated tectonic features.

The orders issued on March 6, 2014 by AEC following the recommendations of peer review team from EC/ENSREG are as follows:

1. Requiring TPC to perform the thorough geological and geomorphological assessment, mud flows and mass movements on a site-specific basis and to provide the early warning systems for mud slides and mass movements.

2. Requiring TPC to conduct post-seismic inspection of SSC with a low level of seismic classification.

3. Requiring TPC to consider the development of strategies to minimize the quantities of contaminated water produced during accident and evaluating options to create closed cooling circuits.

4. Requiring TPC to improve the availability of RPV depressurization for BWRs.

5. Requiring TPC to improve the habitability in the main control room and local shutdown panel areas under accident conditions.

6. Requiring TPC to consider a systematic assessment of combinations of events, including multi-unit and multi-site accidents, since some of the NPPs are located in relatively close vicinity.

7. Requiring TPC to enhance the availability of heavy road-clearing equipment.

3. Conclusion

There are currently three plants in operation and one under construction at Taiwan. All have undergone comprehensive safety assessment, the stress tests and consequently the EU peer review. 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 did not comply with FSAR in Chinshan plant. ECW pump room did 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 concerns nor threats to the public health and safety. However, improvement of natural hazards and prolonged SBO are the main follow-up actions to demonstrate the capability to cope with the beyond design basis disasters.

AEC requested TPC to implement and complete the nuclear regulatory safety-issue follow-ups orders 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 recently. The peer review – performed by both of the OECD/NEA and EC/ENSREG – calls for actions to make the power plants more robust against the effects of large earthquakes and flooding, e.g. by building higher tsunami protection walls. Also, more up-to-date methods and data should be used to evaluate seismic and flooding risks.

Building on the results of the European stress tests and on insights from post-Fukushima actions being taken in other regions of the world, particularly in the USA, Europe and Japan, the AEC has developed a comprehensive approach to safety review and identification of actions for further safety enhancements in order to better prepare all NPPs in Taiwan against extreme external events and severe accidents. These improvements are justified on the basis of the fact that the risk to be imposed by extreme natural hazards, such as earthquakes, flooding and tsunamis, extreme weather conditions and volcanism, is much higher in Taiwan than in many other geographical environments of the world.

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