MEETING THE OBJECTIVES OF THE VIENNA DECLARATION ON NUCLEAR SAFETY: LICENSING OF NEW NUCLEAR POWER PLANTS IN PAKISTAN

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Abstract

In the aftermath of Fukushima Daiichi Nuclear Power Plants accident, nuclear think tanks sat together to draw lessons learnt and to devise new requirements to be incorporated in the standards to minimize the possibility of re-occurrence of such accidents and to reduce the consequences of such events in future. International fora encouraged policy makers and think tanks to evaluate the existing domains of regulatory regime as well as the prevailing designs of Nuclear Power Plants (NPPs) for ensuring protection of the public and environment; enhancing accident mitigation; strengthening emergency preparedness and improving regulatory performance. In light of Fukushima event, member states not only conducted different analysis (also named as stress tests) to demonstrate the adequacy of existing plants but also re-visited the regulatory framework and the governing processes to identify any area for further enhancement. In unanimity, ‘Vienna Declaration on Nuclear Safety’ has been endorsed by all the contracting parties of ‘CNS’ which highlighted the key principles to be considered by the nuclear world. The paper will focus on the areas considered during the licensing of two new design NPPs (Karachi Nuclear Power Plant Unit-2 (K-2) and Unit-3 (K-3)) as a consequence of the ‘Vienna Declaration’, the new aspects that have been considered in the regulatory processes to conform to the ‘Vienna Declaration’ and the process followed during the licensing of the new nuclear reactors.

1. VIENNA DECLARATION ON NUCLEAR SAFETY

The Vienna Declaration on Nuclear Safety (VDNS) [1] was issued as a result of the diplomatic conference on Convention on Nuclear Safety (CNS) held in February 2015, which indicated to the international community the concerns and efforts of all Contracting Parties to improve nuclear safety. The Vienna Declaration on Nuclear Safety requires all the Contracting Parties to act for implementation of the principles of VDNS to prevent accidents with radiological consequences and to mitigate consequences should these occur. The main obligations of the VDNS can be summarized as:

(a) According to principle-1 of VDNS; new NPPs are to be designed, sited, and constructed, consistent with the objective of preventing accidents in the commissioning and operation and, mitigating possible releases of radionuclides causing long-term off-site consequences. Should an accident occur, the large and early radioactive releases, which require long-term protective measures and actions, are required to be practically eliminated.

(b) The principle-2 of VDNS requires the Contracting Parties to carry out comprehensive and systematic safety assessments periodically and regularly for existing nuclear installations throughout their lifetime in order to identify safety improvements.

(c) The principle-3 of VDNS requires the national regulations to take into account the relevant IAEA Safety Standards and other international practices and experience.

Pakistan, along with other Contracting Parties, agreed to uphold and implement the Vienna Declaration. Pakistan took a series of actions to implement the objectives of the Vienna Declaration on Nuclear Safety [2].
2. SAFETY IMPROVEMENT AT NPPS OF PAKISTAN THROUGH DIRECTIVE AFTER FUKUSHIMA ACCIDENT

As a matter of principle, PNRA issued directive to its licensee and applicant, which intuitively provided the legal basis to carry out regulatory oversight of existing and future NPPs beyond the scope/requirements delineated in the existing regulatory framework. PNRA required the applicant that lessons learnt from Fukushima accident should be an integral part of design for new NPPs rather than incorporating them as backfitting measures. This directive was the need of the day as revision of regulations/regulatory framework is a lengthy process which takes time.

3. LICENSING PROCESS

PNRA has a well-defined regulatory framework which ensures comprehensive safety assessment and verification before the commencement of operation of nuclear installations. PNRA Regulations PAK/909 [3] prescribe a mechanism for licensing of nuclear installations according to which authorizations are granted for following stages which are in accordance with IAEA SSG-12:

(a) Site Registration
(b) Construction License
(c) Permission for Commissioning
(d) Permission to Introduce Nuclear Material into the Facility
(e) Operating License
(f) Revalidation of Operating License
(g) Licensing Beyond Design Life
(h) Authorization for Decommissioning/Closure
(i) Removal from Regulatory Control

PNRA Regulations PAK/910 [4] prescribes detailed site assessment requirements for site registration. PNRA Regulations PAK/911 [5] require that at the design stage of a nuclear installation, a comprehensive safety analysis shall be carried out to identify all sources of exposure and to evaluate radiation doses which could be received by workers and the public, as well as potential effects on the environment. The safety analysis shall take following into consideration:

1) All planned normal operation modes of the plant
2) Plant performance in anticipated operational occurrences
3) Design Basis Accidents
4) Event sequences that may lead to a severe accident

Thorough assessment of the above mentioned safety analysis, robustness of the engineering design to withstand postulated initiating events and accidents are established, effectiveness of safety systems and safety related items or systems is demonstrated, and requirements for emergency response are established. Regulations PAK/911 [5] require that measures should be taken to ensure that radiological consequences are mitigated. Such measures include: engineered safety features; onsite accident management procedures established by the operating organization; and on-site and off-site emergency planning and preparedness measures to mitigate radiation exposure if an accident occurs. A safety analysis of the plant needs to be conducted in which methods of both deterministic and probabilistic analyses are applied. These analyses establish and confirm the design basis for items important to safety. In addition, the safety analysis also included the demonstration of the adequacy of additional systems which were provided to cope with events beyond the design bases including severe accidents. Applicant is required to demonstrate that the plant as designed is capable of meeting prescribed limits for radioactive releases and acceptable limits for potential radiation doses for each category of plant states. The safety assessment is based on the results derived from the safety analysis, operating experience, results of supporting research and proven engineering practices. The applicant needs to ensure that an independent verification of the safety assessment is performed before the design is submitted for regulatory review and approval.
4. **REGULATORY REQUIREMENTS RELATED TO SITE REGISTRATION**

Requirements for site registration/siting of a nuclear power plant are provided in Regulations PAK/910 [4] which is mainly based on IAEA Safety Standards No. NS-R-3 titled Site Evaluation for Nuclear Installations and USNRC 10 CFR Part 100. Before site registration, the applicant has to obtain approval from the Environmental Protection Agency. Subsequently, a Site Evaluation Report (SER) is submitted to PNRA for site registration in order to ensure that the plant complies with the national laws and regulations regarding environment protection, land and water use, marine life, etc. In the evaluation of suitability of a site for a nuclear installation, various aspects are considered such as external events (natural origin or human induced), characteristics of the site and its environment that could influence the transfer to persons and the environment of radioactive material to be released, population density, population distribution and other characteristics of the external zone, as they may affect the possibility of implementing emergency measures and the need to evaluate the risks to individuals and the population.

Regulations PAK/910[4] are currently under consideration for revision to incorporate requirements for periodic re-evaluation and re-assessment of all hazards (natural or man-made) in line with the current revision of IAEA safety requirements on siting and the principles of the Vienna Declaration on Nuclear Safety.

In addition, Regulations PAK/909 [3] also require provision of clearance/approvals from local, provincial and other federal agencies.

5. **NEW ASPECTS COVERED IN THE EXISTING SITE REGISTRATION PROCESS**

For site registration, licensee submitted the Site Evaluation Report (SER) to PNRA which included details/information mainly on geography, demography, meteorology, geology, seismology and geotechnical engineering of the site. In-line with Vienna Declaration and based on lessons learnt from Fukushima Daiichi accident, PNRA included new aspects in its existing site registration process. Accordingly, PNRA took on-board other government organizations, held/arranged discussions, acquired technical data, utilized their knowledge/expertise and updated assessment in the site registration process. The government organizations which were consulted during the technical review of the site evaluation to facilitate decision making are listed below:

(a) National Institute of Oceanography (NIO)
(b) NED University (Civil Engineering Department)
(c) Pakistan Meteorological Department (PMD)
(d) Geological Survey of Pakistan (GSP)
(e) Pakistan Coast Guards (PCG)

6. **IMPLEMENTATION OF VIENNA DECLARATION DURING SITE REGISTRATION OF K-2/K-3**

K-2/K-3 is located on the coastline of the Arabian Sea, near Karachi city in the Sind Province of Pakistan. The site of K-2/K-3 is about 1.5km in the North-West of existing Karachi Nuclear Power Plant Unit-1 (K-1). In-line with Vienna Declaration and based on lessons learned from Fukushima Daiichi accident, amidst other, following aspects were specially focused by PNRA during the review of site evaluation report:

(a) Licensee was required to perform Probabilistic Seismic Hazard Analysis (PSHA) for the site.
(b) K-2/K-3 site was investigated for any earthquake potential up to 300km and potential fault sources were evaluated for peak ground acceleration.
(c) PNRA also directed the licensee to re-evaluate the seismic potential of Murray Ridge situated about 75km from the site with the perspective of tsunami potential. The tsunami analysis of Murray Ridge and historic instrumental seismicity along with other geophysical and drilling data indicated that no tsunami event occurred along Murray ridge in recent and distant past. Whereas, other potential sources related to Karachi site i.e. Makran subduction zone and triple junction are identified and also evaluated with special emphasis.
Based on PNRA requirements, licensee performed studies by using next generation attenuation (NGA-2008) relationships to determine PGA values for K-2/K-3 site. The Safe Shutdown Earthquake (SSE) for site was reassessed as 0.2g.

Study has been performed for site to analyse the Seismic Hazard along with tsunami potential as per new IAEA guidelines. According to this study, in the worst case scenario, flooding height as a result of expected tsunami would be 2.8m. Moreover, site has been enlisted with Tsunami Early Warning System (TEWS) of Pakistan Meteorological Department (PMD) for dissemination of tsunami warnings.

7. NEW ASPECTS COVERED IN THE EXISTING PROCESS FOR ISSUANCE OF CONSTRUCTION LICENCE

In accordance with Regulations PAK/909, after site registration, the licensee applied for construction licence of K-2/K-3 along with applicable submissions which includes Preliminary Safety Analysis Report (PSAR), Quality Assurance Program (QAP) and Probabilistic Safety Analysis (PSA) Report. Verification of safety of nuclear installations was carried out at this stage through review & assessment, analysis & audit calculations and site surveys. Safety analysis, carried out by the licensee to support the design was reviewed and audit calculations were conducted by PNRA on sampling basis using analytical computer codes. The underlying assumptions, modelling techniques, accident sequence quantification, results and uncertainties were verified against the acceptance criteria.

PNRA included the following new aspects in the existing licensing process in-line with the lessons learned from Fukushima Daiichi accident and Vienna Declaration, in evaluation of application for issuance of construction licence to K-2/K-3.

(a) Although, the review and assessment process implicitly covered the feedback from operating experience, a new phase has been introduced in the review and assessment process following Fukushima accident which explicitly covers the operating experience feedback (OEF). The duration of phase is about 04 months.

(b) PNRA required submission of scale model testing reports which mainly included: tests of passive core cooling system in Station Blackout condition and passive residual heat removal system, secondary piping rupture upstream or downstream the isolating valve, passive containment cooling system, heat conducting capacity margin test and test on effect of flow pass change of in-vessel retention on heat exchange characteristics of pressure vessel.

(c) Based on regulatory review, PNRA required the licensee to submit detailed design report of secondary or outer containment and shield building which are new design features against impact of large commercial aircraft.

(d) As per existing regulatory framework, the design shall be independently verified by persons or groups separate from those carrying out the design before the submission to PNRA. Accordingly, PNRA required the licensee to submit the report describing the results of this independent verification.

(e) PNRA participated as an observer in IAEA Generic Safety Review of ACP-1000 (K-2 & K-3) and used the feedback of this review in licensing process.

(f) A number of additional supporting analyses were also required for regulatory review such as; the evaluation of steam generator components against cold emergency feed water, fatigue monitoring program, the stability and settlement analysis for foundations of seismic category-1 structures etc.

8. IMPROVEMENT IN NUCLEAR SAFETY REGULATIONS

In light of the overriding concept of priority for safety, PNRA has proposed that design objective of NPPs be modified in the revision of Regulations PAK/911 to include the principle of practical elimination of event sequences which may result in significant radiation release. This necessitates that the design should ensure that off-site intervention measures to mitigate radiological consequences be limited or even eliminated in technical terms (VDNS Principle-1). National regulations already require the Periodic Safety Review of the operating nuclear power plants at least every 10 years. This includes re-evaluation of the site related aspects along with other factors (VDNS Principle-2). Keeping in view the lessons learnt from the Fukushima Daiichi
accident and in line with Vienna Declaration, the following changes have been proposed in PNRA Regulations PAK/911 in accordance with the international practices and experience (VDNS Principle-3):
   (a) Consideration of reliable filtered venting system independent of any AC power with limited operator action for operation;
   (b) Consideration of low probability independent events to occur simultaneously;
   (c) Consideration to control hydrogen within the spent fuel storage building in the event of loss of spent fuel cooling and to maintain integrity and functionality of fuel building;
   (d) Availability or provision of combined means to provide emergency power having reliability and form consistent with the safety requirements of the systems to be supplied, and performing their safety functions for longer durations on the assumption of a single failure;
   (e) Consideration of passive design features in the plant systems specially the emergency core cooling systems, Hydrogen recombining systems and spent fuel pool cooling systems.

(Note: These regulations are currently being revised.)

9. CONCLUSION

The existing process of licensing of NPPs along with new aspects that has been considered in recent applications covered the objectives set out in the Vienna Declaration and Fukushima experience feedback. The objectives set out in the Vienna Declaration are now being implemented in all the new licensing applications and are also considered in the revision of regulations on siting and design of nuclear installations.

REFERENCES

[3] PNRA Regulation for Licensing of Nuclear Installation(s) in Pakistan (PAK/909), 2012