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Risk Management Regulatory Framework for Embarking Nuclear Power Countries

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1. Introduction

The management of uncertainty (unquantified at that time) was invariably an issue and the term "defense in depth" has been used since the 1960s in the context of ensuring nuclear reactor safety. The concept was evolved and applied to compensate for the perceived lack of knowledge of nuclear reactor operations and the consequences of potential accidents [1]. A set of licensing-basis events was enacted to assure conservatism in design and protection from a wide spectrum of postulated events, up to and including Design Basis Accidents (DBAs). Although this may be true but there are drawbacks with DBAs concept which include qualitative approaches, operating experience and modern understanding of "risk triplet" are not appropriately addressed [2]. The Reactor Safety Study of 1975 (WASH-1400) and Three Mile Island Accident in 1979 raised momentous contemporary safety questions notably the use of new analytical tools such as risk assessment to supplement deterministic analysis, the need to study and regulate severe accidents, and human factors considerations. Determinism design remained the underpinning of safety regulations but the insights of probabilistic risk assessment (PRA) made feasible a conversion toward a risk-informed regulatory framework [3]. Afterward, performance-based regulation markedly maintenance rule (MR) had been proposed and implemented as a part of regulatory oversight for evaluating the continuous effectiveness of licenses maintenance programs since the 1990s [4].

In February 2011, U.S. Nuclear Regulatory Commission (U.S.NRC) established a Risk Management Task Force (RMTF) to develop a more comprehensive and holistic risk-informed, performance-based regulatory approach for nuclear facilities [1]. The Fukushima nuclear power plant (NPP) accident transpired shortly after the RMTF was founded and the Fukushima Near-Term Task Force (NTTF) of U.S.NRC recommended that future regulatory frameworks should be based on the defense-in-depth philosophy, supported and modified as necessary by state of the art PRA techniques [5]. Ultimately, the RMTF suggested a general regulatory framework impacted by the Fukushima nuclear disaster and the successive studies including the NTTF recommendations in 2012.

This paper focuses on the risk management regulatory framework (RMRF) for embarking nuclear power countries. It also investigates the current status, challenges, and recommendations to be executed. At the beginning, IAEA proposed an integrated risk management framework as a tool to explore a broad context of risk (safety, operations, financial/commercial, strategic) to enhance the performance of NPPs in 2001. It consists of four steps namely identify risks, identify techniques or strategies to manage risks, implement risk management strategies and monitor the effectiveness of solutions [6]. In reality, each newcomer country has disparate nuclear infrastructure status and it could be unfeasible to implement IAEA general framework. In contrast, U.S. has extensive experiences of risk-informed approach and U.S.NRC is now implementing the RMRF. Thereupon, we have preferred U.S.NRC risk management approach for embarking countries.

2. Risk Management Regulatory Framework

The RMTF has considered the history and process for licensing and oversight of power reactors in the context of the framework and has developed a set of findings and recommendations. The RMTF identified 10 findings and 6 recommendations for power reactors in the area of DBA licensing approach, beyond DBAs, external hazards, defense in depth, and security. They have also mentioned 6 recommendations for operating, new and generation IV power reactors severally. The U.S. NRC's RMRF is expounded underneath [1]:

Mission: Ensure adequate protection of public health and safety, promote common defense and security and protect the environment.

Objective: Manage the risk from the use of by-product, source, special nuclear material through performance-based regulatory control and oversight.

Risk Management Goal: Provide risk-informed and performance-based defense-in-depth protections to ensure appropriate barriers, controls, and personnel to prevent, contain, and mitigate exposure to radioactive material according to the hazard present, the relevant scenarios, and the associated uncertainties. Ensure that the risks resulting from the failure of some or all of the established barriers and controls, including human errors, are maintained acceptably low.

Decision-making process: Use a disciplined process to achieve risk management goal through Identify issue, Identify options, Analyze, Deliberate, Implement decision, and Monitor.

Following the Fukushima accident, there is renewed concern regarding the compulsion to contemplate the plant's capability to withstand accidents that are more severe than DBAs. In 2012, a new IAEA Specific Safety Requirements entitled SSR-2/1, "Safety of Nuclear Power Plants: Design" was published. Among the most noteworthy changes in contradiction to the preceding IAEA Safety Requirements NS-R-1 published in the year 2000 [7], are the extension of plant states to incorporate the design extension conditions (DECs) in the plant design as detailed in Fig.1. Eventually, IAEA TECDOC-1791 [8] was issued in 2016 which provide insights and approaches in support of the practical application of the new crucial requirements introduced in SSR-2/1, Rev.1 [9].

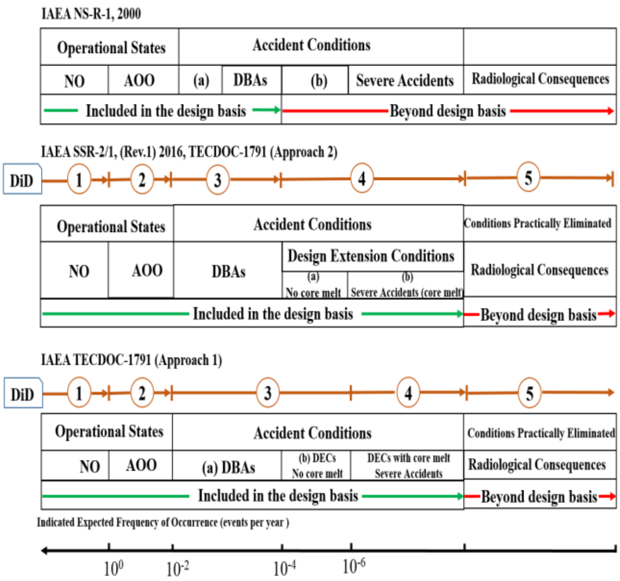

Fig. 1. Safety of Nuclear Power Plants Design before and after Fukushima Accident (IAEA)

In practice, the operating reactors elemental design was established many years ago and their licensing-basis sporadically have been amended to include additional events such as station blackout (SBO), anticipated transient without scram (ATWS) and aircraft impact. A "patchwork" of regulatory requirements has been constituted as a result of addressing problems to regulate nuclear industry on a case-by-case basis over many years. Forthwith, the task force proposed the creation of a design-enhancement category for beyond DBAs which is also consistent with IAEA.

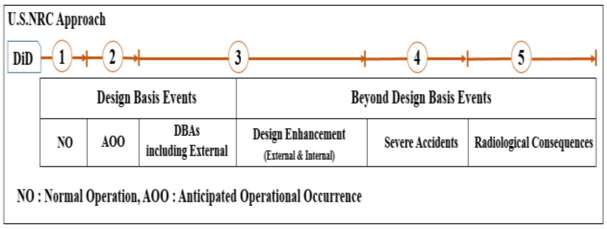

Fig. 2. U.S.NRC Event Categories and Comparison with IAEA's Defense in Depth

In 2013, NRC adopted a new term "design-basis extension" to define and describe the events and requirements for NPPs that have typically been characterized as "beyond-design-basis" events and accidents [10] as displayed in Fig. 2. On the contrary, NRC made a decision in 2016 to maintain the existing regulatory framework, not plan to establish a formal "design-basis extension" category, for the nuclear power reactor safety program area [11]. This is because the requirements of DECs were evaluated in line with the current risk management regulatory framework. For example, some regulatory requirements such as ATWS Rule (1984), SBO Rule (1988) etc. are developed in line with the deterministic approach which is prescriptive. These requirements are mostly intelligible and more detailed, and thus are easier to implement and regulate [4]. Conversely, the other DECs (complex sequences) and severe accidents, for instance, steam generator tube rupture (SGTR) induced by the main steam line break (MSLB) are analyzed using the PRA approach [12]. This type of regulation gives each licensee the flexibility to determine the most efficient and effective way to meet the requirements [4].

3. Current Status & Challenges for Emerging Nuclear Power Countries

3.1. Current Status

According to World Nuclear Association (WNA), about 30 countries are considering, planning or starting nuclear power programs, and a further 20 or more countries have expressed an interest as of July 2018. The front-runners are the United Arab Emirates (UAE), Belarus and Bangladesh each of which is constructing their first nuclear power plants (NPPs). All new entrant countries have already separated their regulatory bodies from the organization concerned with the promotion or utilization of nuclear energy in accordance with article 8.2 of the IAEA Convention on Nuclear Safety [13]. The technological transfer will be accomplished in the upcoming years but 'know-how' development will entail time and the process is sophisticated.

However, to review the progress of nuclear infrastructure development in newcomer countries, the Integrated Nuclear Infrastructure Review (INIR) mission and the INIR Follow-up mission are conducted by the IAEA. The INIR mission in 2011 reviewed the 19 infrastructure issues set out under the IAEA's milestones approach in Bangladesh. Consequently, most of the issues identified by the INIR follow-up mission in 2016 have already been addressed by Bangladesh [14]. The Integrated Regulatory Review Service (IRRS) mission is expected to be conducted in Bangladesh to strengthen and enhance the effectiveness of regulatory infrastructures probably in the early stage of 2019. On the contrary, the IRRS mission in UAE has already completed in 2011 and 2015 IRRS follow-up team concluded that UAE has strengthened its regulatory oversight [15]. Furthermore, the International Physical

Protection Advisory Service (IPPAS) team of IAEA has completed the nuclear security mission to review the UAE's legislative and regulatory framework for nuclear security in 2016. At the present time, IAEA has completed INIR mission in UAE.

Though there are continuous national as well as international efforts to strengthen the emerging countries nuclear infrastructure but the gaps that we have discerned are stated beneath:

- In some newcomer countries, the regulatory body and operating organization are still working under the identical ministry which could be a barrier for effective separation and independence in regulatory decision making.
- IAEA has already recommended each embarking country to implement an integrated management system (IMS) the GSR Part 2. It is a single framework for arrangements and processes to address organizational goals and requirements and integrates its elements such as safety, health, environmental, security, quality, human-and-organizational-factor, societal and economic elements [16]. Majority embarking countries have not yet successfully implemented IMS within their organizations.
- Some newcomer countries have already made their human resource development (HRD) plans for NPP operator/owner but it is nevertheless under development stage for regulatory bodies. In contrast, new entrant regulators are now too much relying on IAEA, vendors or other impartial countries experts for their regulatory infrastructure development due to the deficit of enough self-competence as well as local experts.
- The newcomer countries are now importing the latest reactor designs from developed countries. It is assumed that their first NPP will be the best, safer and more reliable. On the other hand, people are becoming more aware of the nuclear industry after the Fukushima accident. Thus, the top level of the regulatory body has a deterministic mindset rather than the risk-informed approach in regulatory decision making as they do not have operational experiences as well as sufficient expertise.
- The most notable change in the RMRF is the inclusion of the design enhancement category within the beyond DBAs regime. The accession of a design-enhancement category and related requirements for identifying events and developing measures may change the landscape currently defined by design basis events and several selected conditions [1]. It will be arduous to revise the overall assessment of events and hazards due to the addition of a design enhancement category as newcomer countries do not have any NPP operating experiences.

3.2. Challenges

- The nuclear infrastructure of embarking as well as mature countries except for the U.S. is not utterly underpinned to exchange operational experience data. Their nuclear infrastructure customarily comprises limited stakeholders. Conversely, U.S. has inclusive databases that incorporate component failure data found during maintenance, outages, and operation. This operational experience is backing NRC to implement a more performance-based way of ensuring risk-informed and performance-based defense in depth but it could be an enormous challenge for newcomer countries.
- After the Fukushima accident in 2011, the concept of "practically eliminated" of some specific initiating events leading to early or large releases has been dealt in several international publications markedly IAEA-TECDOC-1791, IAEA SSR-2/1 (Rev. 1) [8, 9]. At the same time, the international nuclear community also reveals the snag in building the prevalent understanding around this concept [17]. Henceforth, the newcomer countries will experience the complication to take into account this "practically eliminated" concept and further elaborations are needed.
- If the newcomer countries would like to implement risk-informed, performance-based approach, public trust is of crucial importance for the understanding of risk perception about NPPs.

4. Recommendations

The actions that need to be accomplished for the risk management regulatory framework are stated underneath:

- A legislative reform may be performed so that the regulatory body and operator could work under the supervision of diverse authorities with effective independence and separation.
- The integrated management system should be executed for the involved organizations working within the nuclear power program.
- An integrated national HRD plan should be developed and implemented.
- A long-term commitment of the top level management for changing the deterministic mindset to risk-informed decision-making framework would be entailed.
- An engineering judgment should be carried out during adopting or adapting regulations to assure

that the vendor's regulatory approach is enforceable in the new entrant country.

- New or revised risk-assessment codes and standards should be developed as the newcomer countries ongoing regulatory framework does not sufficiently support the proposed RMRF.
- Stakeholder management program including public understanding activity for nuclear energy and safety should be developed so that they will get involved in the processes from planning to implementation as responsible entities.

5. Conclusion

In essence, at the present time, the embarking countries could consider the risk-informed approach distinctly PRA insights in their decision-making process but the implementation of this approach has some challenges. This is because newcomer countries do not have any operational experiences including PRA data and they may need vendor countries PRA information. This confidential information could be restricted to exchange in accordance with vendor countries law. Hence, at first, the emerging countries can address a number of policy and technical issues related to the use of PRA in the risk-informed regulatory framework. It is important to reiterate that newcomer countries need to formulate and implement HRD plans at the early stage since the development of nuclear knowledge management entails considerable time. Eventually, the implementation of the proposed framework can be pursued in a planned and deliberate manner through selected guidance and rule changes. With this in mind, it is also inevitable to review the ongoing activities that ensure the new entrant regulators continue to protect the people and environment from NPPs risk.

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