

# Risk And Safety Analysis in Nuclear Power Plant

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## Abstract

India is the nation with the highest energy use in the world. Over the past few years, its domestic use of oil and power has also been rapidly rising. The rapid population growth and the expansion of the national economy are to blame for this rise. In the next ten years, if nothing changes, their usage of fossil fuels will quadruple. To meet its huge demand, India has little choice but to make investments in alternate energy sources like nuclear and renewable energy. The Indian government intends to build nuclear reactors. A safe and dependable base-load energy source is nuclear energy. Furthermore, if all safety procedures are taken, it can be very safe. There are, however, sizable risks as well. These precautions and risks will be thoroughly addressed in this thesis.

**Key Notes:** Nuclear reactors, Precautions and risks, Loss of Radiation, multi unit risk.

## I. INTRODUCTION

There are three lines of defense in a nuclear power plant to stop radioactive elements from escaping into the atmosphere. The zirconium alloy fuel rods that hold the fuel pellets are the initial barrier. As soon as these rods take in free neutrons, a fission reaction happens. This causes a significant amount of heat to be produced. Radiation control rods that reduce the fission speed are used to regulate the fission reaction. On the other side, the reactor cooling system regulates the temperature of the reactor's core. The second barrier is thought to be the cooling system and control rods. The reactor is housed in a substantial concrete building, which serves as the third and final barrier. To better understand the effects of a nuclear disaster, a thorough examination is required of the potential loss of radiation control and cooling system failure.

### Loss of Radiation Control:

The loss of radiation control causes an increase of power excursion, which in turn leads to the first barrier failure. So, control rods are used to reduce the fission rate whenever it exceeds the limit or to shut down the reaction entirely. These rods are made of special metals, such as boron, silver, indium and cadmium, which have a capability of absorbing neutrons resulting from the fission.

### Failure of Core Cooling:

The shutdown of fission reaction does not mean the stop of power generation. In fact, there is abundant residual heat, which decays over time. The heat is generated from the fission reaction that. Therefore, it is essential to maintain the reactor cooling system uninterruptedly running. If the cooling system stops for any reason, the fuel rods get overheated.

## II. LITERATURE REVIEW

Safety management is commonly understood as an effective means to the achievement of good operating conditions, identification of safety hazards and risks, prevention and mitigation of accident consequences [1]. The reconciliation of deterministic and probabilistic risk insights brings better focus on the issues of safety management in an adequate manner [2]. The temperature of core fuel elements and structural materials will rise continuously with the release of fuel decay heat. At high temperature, zirconium alloy cladding will react with water or water vapor and generate large amount of hydrogen, which will be released into containment through the break of primary circuit pressure boundary [3]. Atomic Energy Agency (IAEA) has revised safety standards, and proposed that we must consider measures to maintain the integrity of containment at severe accidents [4]. Researchers and practitioners are putting their tireless efforts to ensure and measure the dependability of such systems [5,6]. These systems are composed of heterogeneous hardware, software and firmware components. Failure of one component may fail to perform the system function and hence effects of components' failure on the overall system need to be analyzed. [7] developed necessary, sufficient conditions for mean square exponential stability for the discrete time system with correlated stochastic uncertainties. The stability is expressed in terms of the spectral radius of input output linear matrix operator. However, the proposed method is applicable for discrete time stochastic systems. The "safety triangle" or Heinrich ratio is analyzed in many domains, e.g., in the UK railway domain where the common causation relation between accidents and near miss events is analyzed [8], in the stable Heinrich ratio analysis for drug domain [9], for occupational safety and health incidents [10], and for near-hit reporting to reduce construction injuries, [11]. The "safety triangle" Heinrich ratio principle claims that there is a fixed ratio between the numbers of events with different safety significances.

This is the case regardless of very advanced operating experience feedback programs at international, national and utility levels, [12-16]. Insights from this analysis could be used for development of leading performance indicators, to better use operating experience in probabilistic safety assessment (PSA) models and to improve.

Nuclear energy companies have independently researched and developed third-generation pressurized water reactors, National Nuclear Corporation have developed two types of third-generation reactors, CPR1000 [20] and ACP1000, respectively. Both are three-loop designs, but the core design is different. The risk insights and influences resulting from probabilistic safety assessment

are increasingly considered on the safety decisions applied by both utilities and regulatory bodies along with the rapid advancement of PSA [17]. Among the PSA enhancements, the development of Living PSA and risk monitor are mostly focused on ensuring the safe operation of nuclear power plants [18]. Atomic energy Research Institute is developed in on-line consolidator and elevator of all the mode risk for nuclear systems, a risk assessment tool that integrated internal/external event, full power low power and the shut down mode and the level 1, 2 and 3 PSA. The propose integrated risk assessment Framework is expected to address PSA related issue and help reduce the inconsistency exist between Internal and external PSA models, full power and low power shut down PSA model and development of Site risk assessment mythology. nuclear utility companies for your hydro and nuclear power is also working as the evaluate the multiunit risk based on its single unit PSA Models, currently it is performed all mode PSAs for individual unit and is development level 2 and 3 PSA models in addition the regulatory authority nuclear safety and security Commission has initiate review of multi unit risk and command necessary studies Canada has launched the three major project reflected the lesson of the Fukushima accident the review of the PSA, a reassessment of the design are safety margin for external event and the development of a mythology. Multiunit safety unit goal or risk Matrix the represent the safety goal should be the significant of PSA framework to access the multi unit risk through the seabrook PSA [19-25].

### III. NUCLEAR SAFETY SYSTEMS AND PERSPECTIVE

Overview of nuclear safety perspectives, modern instrumentation and control (I&C) systems, and vital nuclear assets. risks and their remedies will be addressed in terms of the safety perspective and the advancement of the digital I&C system in the new reactor technologies.

Defense in Depth (DID) is a fundamental design and operational concept in NPPs. The basic questions DID can address are:

1. What if it goes wrong?
2. Can we protect ourselves from an unknown "unknown"?"

DID integrate all safety activities, technologies, and human behavior in multiple layers. Hence, the DID components complement each other and prevent an accident or mitigate its consequences.

The primary objective of DID in NPPs is to control and manage power generation, cooling the reactor, and contain the radioactive materials inside the reactor building. Figure 1 illustrates the concept of defense in depth protection layers.

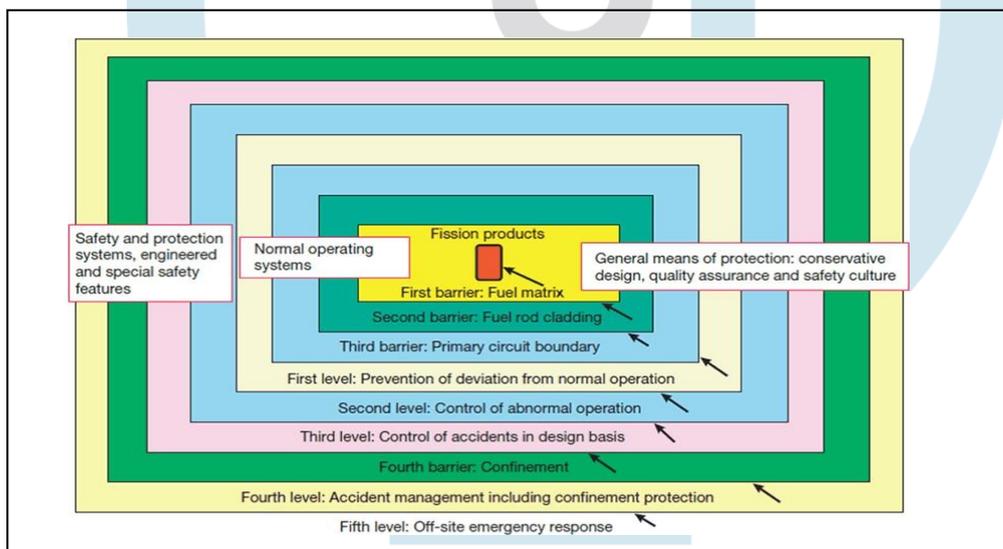


Fig. 1 *Défense in Depth Barriers and Levels of Protection, Source: IAEA*

It is noted in Figure 1 that there are multiple barriers and control levels to prevent a nuclear accident or at least mitigate its consequences. The radioactive fuel is secured by three different barriers: a fuel matrix, cladding, and the primary circuit boundary. In addition, there are three segregated control levels to manage the normal operation process, abnormal operation, and emergencies within the design basis. Let's assume none of the previous systems work: the fourth barrier, confinement, exists to prevent radioactive release to the environment. Next, the fourth control level takes place to manage the accident on-site. The fifth level is the off-site emergency response, which is activated if the site officials could not handle the accident. Failure modes and effects analysis (FMEA) is a powerful technique used in DID philosophy. FMEA is conducted on a component, system, or at a global functional level to determine the effects of failures on a particular item, or on overall plant safety. Hence, it identifies other systems and functions necessary for promoting plant safety.

#### (1) Probabilistic Risk Assessment (PRA):

The PRA is an engineering approach for establishing the risk profiles of NPPs. It identifies unrecognized deficiencies in a plant design or operation. The PRA is analogous to FMEAs but it is more quantitative. It is often used to relate the expected failure probabilities of the plant to specific regulatory goals. The PRA can simply answer the following questions:

- What can go wrong?
- How likely are these scenarios?

- What are their consequences?

The PRA involves the identification and analysis of: initiating events, safety functions, and accidents' sequences. Figure 2 illustrates a PRA model, which consists of three levels.

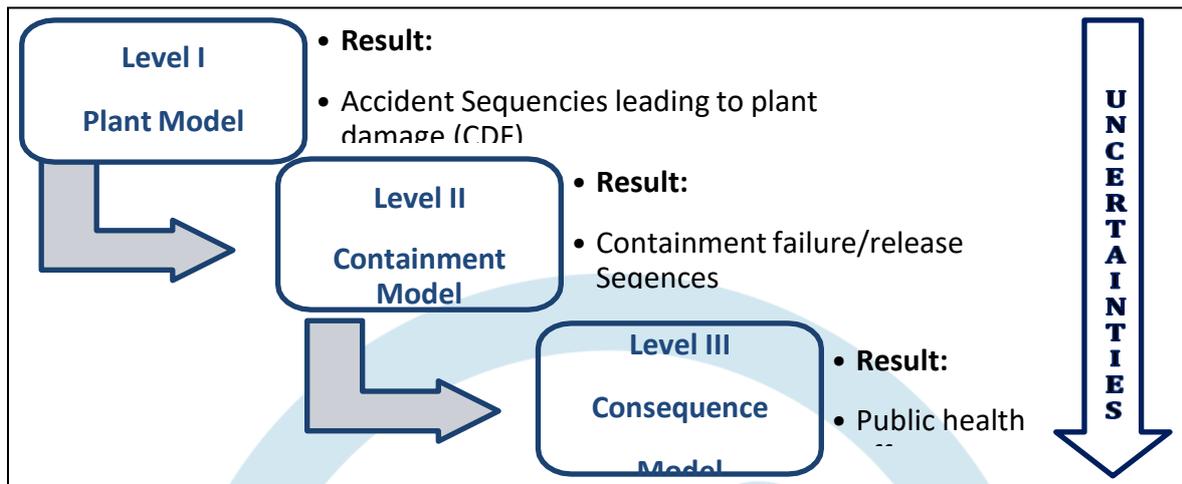


Fig. 2 PRA Model Overview, Adopted from USNRC

The above PRA model is constructed to model the as-built and as-operated plant. The PRA model uses multiple sources of information, including:

- Plant design data,
- Thermal hydraulic analyses of plant response,
- System drawings and performance criteria,
- Operating experience data,
- Abnormal and emergency operating procedures, and
- Maintenance practices and procedures.

#### IV. RISK ASSESSMENT:

The analysis of risks and their consequences is crucial to improving the safety level in an organization. Organizations with strong safety culture, first, conduct risk assessments for their critical activities on a regular basis. Next, they identify control measures to eliminate or mitigate the assessed risks. Finally, they integrate control measures with their pre-work activities.

1. Systematic in-depth approach to identify a problem and resolve it:

Safety culture in an organization mandates adoption of a proactive and long-term planning strategy. It also requires the use of a systemic approach in identifying issues and conflicts as well as finding the proper solutions to close the gaps. The strategy of business development shall be driven by the importance of safety not only by the economy.

2. Involvement of contractors in safety programs:

Contractors are a key resource in many organizations and their efforts and suggestions to improve the safety level should always be encouraged. The contractors should receive the same attention and training in safety culture as the directly hired employees.

3. Measurement of safety performance:

Safety performance cannot be determined without the proper use of the major performance indicators (KPIs). There are two types of KPIs, lagging and leading. The lagging KPIs are widely used in many organizations, but they are not effective since corrective actions are taken in a reactive mode. Also, the taskforce may focus on achieving the highest KPIs by unethical means, especially when the safety reward system is designed based on lagging indicators achievements. Regulatory inspectors should monitor the NPP's KPIs and take immediate action when there are attempts to violate safety by manipulating the indicators. The leading indicators, on the other hand, are more complex and detailed. They proactively measure the plant safety performance by identifying the competency and system gaps, and thereby help the plant officials take remedial actions in advance.

4. Self-assessment for safety improvement:

Safety always has an area of improvement. Conducting safety culture self-assessment on a regular basis is a good safety culture practice to achieve safety excellence. The purpose of self-assessment is to promote the plant safety performance. The methodology of conducting self-assessment is by involving various individuals from all key areas in a critical through examination to identify competencies and artifact gaps, and propose remedies to close the identified gaps. The self-assessment has to be comprehensive and inclusive to the three safety culture levels, artifacts, espoused values, and basic assumption. This exercise analyzes the general organizational culture and investigates its influences. It is better to be led by a facilitator who is familiar with the concept of safety culture. It is preferable that the facilitator is not a member of the organization.

#### V. SAFETY CULTURE DEVELOPMENT

The revolution development of an organizational safety culture passes through three stages at which:

- Safety is based on rules and regulations,
- Safety is considered an organizational goal, and

Safety can always be improved. Each stage has its characteristics, which involves broad awareness of human factors influence on safety.

## **VI. INFLUENCE OF THE REGULATORY BODY ON SAFETY CULTURE**

Regulatory bodies play a vital role in monitoring, assessing, and promoting safety culture in a nuclear facility. Their role is to issue regulations, safety procedures, and safety policies to be complied with by the operating facilities. The responsibilities of regulatory inspectors areas follows:

- Monitoring the overall organization safety performance,
- Participating in inspecting and testing the integrity of the safety critical systems,
- Participating in conducting critical self-assessments, and
- Monitoring the operators' behaviors and actions, and take immediate actions whenever they feel the plant safety is jeopardized. [26].

## **VII. INITIATION NUCLEAR POWER PROGRAM CHALLENGES**

India would experience substantial challenges regarding the infrastructures of the nuclear program. Those challenges can be summarized as follows:

- Establishment of an independent nuclear regulatory commission to develop a regulatory framework based on safety culture principles,
- Insufficient nuclear experience represented in research capabilities, technical support organizations, and scarcity of local university nuclear programs,
- Difficulty of hiring international expertise due to the high global competition to acquire them,
- Requirement of training of a large number of national professionals in multi- disciplines related to the nuclear power field.

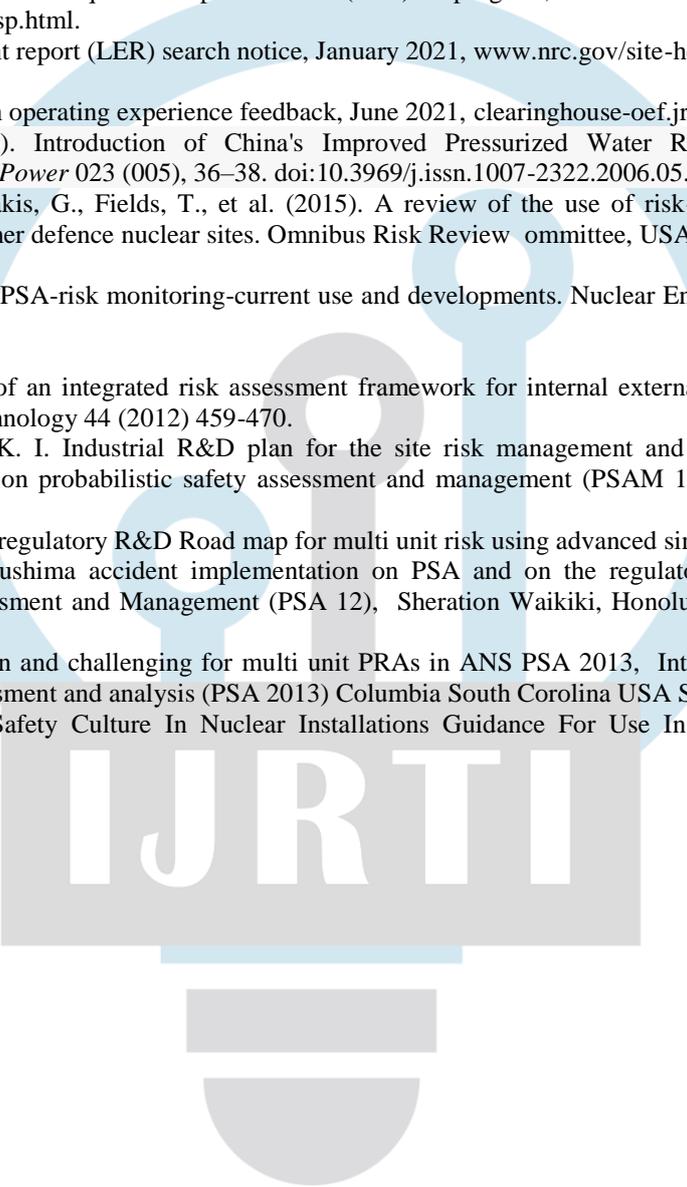
## **VIII. CONCLUSION**

This thesis provided an overview of the essential nuclear safety areas, including lessons learned from severe nuclear accidents, reactor technologies, safety perspectives, safety systems, and safety culture. these work is urged to focus on these essential areas during the development of its nuclear power program. The thesis also delivered an evidence on how nuclear safety is complicated and dense. Despite the advancement of the nuclear technologies, potential risks are always available. The western countries have learned the hard way from the severe accidents. However, they still have been deliberating with the global nuclear society means to improve their NPPs' safety. Nuclear knowledge sharing has been promoted among nuclear international organizations. Nuclear safety becomes a global concern due to the high demand on the utilization of nuclear energy to help reduce the realized global warming threats. Nuclear energy remains the only safe, clean, and reliable based-load source if all safety precautions are followed. The IAEA provides a greater nuclear safety information that this report has been referred to. Massachusetts Institute of Technology, MIT, offers an informative and fruitful short program concerning nuclear plant safety. The program is an excellent opportunity to learn about the recent nuclear safety topics, discussed by high level experts and authorities in the nuclear field. I highly recommend the India concerned entities to participate in that course and other equivalent knowledge sharing venues. Finally, I would like to give a credit to all multidisciplinary scientists and professionals who are innovative and work hard to make the aggressive nuclear nature a peaceful and useful source of energy.

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