

## A Review on the Regulatory Strategy of Human Factors Engineering Consideration in Pakistan Nuclear Facilities

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### 1. Introduction

The Three Mile Island (TMI) accident brought the general consensus among the nuclear community on the integration of human factors engineering (HFE) principles in all phases of nuclear power. This notion has further strengthened after the recent Fukushima nuclear accident. Much effort has been put over to incorporate the lesson learned and continuous technical evolution on HFE to device different standards. The total of 174 ergonomics standards are alone identified by *Dul et al. (2004)* [1] published by International Organization for Standardization (ISO) and the European Committee for Standardization (CEN) and number of standards and HFE guidelines (S&Gs) are also published by organizations like Institute for Electrical and Electronics Engineering (IEEE), International Electrotechnical Commission (IEC), International Atomic Energy Agency (IAEA), United States Nuclear Regulatory Commission (USNRC), etc. The ambition of effective review on HFE integration in nuclear facility might be accomplished through the development of methodology for systematic implementation of S&Gs. Such kind of methodology would also be beneficial for strengthening the regulatory framework and practices for countries new in the nuclear arena and with small scale nuclear program.

The objective of paper is to review the legislative and regulatory framework applied in Pakistan in the light of international HFE S&Gs and consequently to identify the key improvements areas and also to develop the methodology, which enable to mend the applied working procedure and checklists for safety case review in comparison with countries having the advanced nuclear program.

### 2. Legislative and Regulatory Infrastructure

The legislative and regulatory infrastructure for nuclear and radiation facilities has been placed in Pakistan way back in 1970; when started negotiating with Canada for its first PHWR reactor. Since then the concrete steps has been taken to ensure nuclear safety during all phases of nuclear power starting from siting, design, construction, commissioning, operation and decommissioning of the plant. Accordingly, the regulatory requirements have been set by the Pakistan Nuclear Regulatory Authority (PNRA). The upper most document in the hierarchy is ordinance followed by the

national regulations and PNRA guidelines and international codes and standards [2].

#### 2.1. Nuclear Power Program

The nuclear program in Pakistan is being pursued for the last four decades to cope the ongoing increase of energy demand. Right now there are three nuclear reactors in the fleet under operation. The Table-1 shows the overall status of nuclear power in Pakistan. Pakistan has an aggressively plan for nuclear energy, as per the energy vision the Govt. of Pakistan is looking for 8800 MWe from nuclear power by the end of 2030; which suggest strengthening the existing regulatory infrastructure to regulate the highly vulnerable facilities and to overcome the future challenges related with the human and organizational factors [2].

Table 1: Profile of nuclear power plants in Pakistan

Unit	Type	MWe	Vendor	CO
KANUPP-1	PHWR	137	Canada	1972
CHASNUPP-1	PWR	325	China	2000
CHASNUPP-2	PWR	325	China	2011
CHASNUPP-3	PWR	325	China	2016
CHASNUPP-4	PWR	325	China	2016
KANUPP-2	PWR	1000	China	TBD
KANUPP-3	PWR	1000	China	TBD

CO: commercial operation, TBD: to be determined

#### 2.2. HFE Regulations

The domestic regulations cover most of the areas of the nuclear and radiation safety. However, there are certain areas in which further enhancement and an improvement is required. The one such area is the application and integration of HFE principles. The national regulations PAK/911 "Regulation on Safety of Nuclear Power Design" require due consideration of human factors at the design stage; i.e., the design is required to be operator friendly aiming at minimizing human errors and their effects. However, all such regulations are higher level requirements and there is no such guidance available to meet the regulatory expectations on human factor integration. The review model proposed by USNRC is currently being used due to lack of domestic S&Gs on HFE aspects [2].

### 3. Consideration for HFE Integration

There are four core functions of any regulatory body i.e., licensing and authorization, review and assessment, inspection and enforcement and making regulations and guidelines. All these tasks are interconnected with each

other to ensure the ultimate safety goal. The review of the aspects of HFE is considered at every phase of the regulatory activity. These reviews support the nuclear safety and verify that accepted HFE principles are applied during design and also ensure through periodically verification [3].

### 3.1 Mapping of Standards

The standards like IEEE-1023, IEEE-603, 10CFR50, IAEA SSR-2/1 etc., provides the high level requirements and plenty of resources material is available to meet the expectations of these requirements. The problem arises during the applications of these guidelines. All these guidelines are varied by the degree of abstractness and redundancy.

A comprehensive checklist clarifies the criteria that at least should be considered while reviewing and; supports the evaluator; improves the assessment's objectivity, credibility; reproducibility and benefit during inspection activities. Checklist are useful for both formative and summative evaluations (Daniel L. S. 2000) [4]. Myung Hwan Yun et al., (2000) presented the approach on systemically development of check list for operator aiding system [5]. Yung-Tsan Jou et al., (2009) provided and implemented a HFE checklist for human system interfaces (HSIs) upgrades in nuclear power plants (NPPs) [6]. Similar approaches might be applied to enhance the licensing process by developing the check lists on different review areas.

### 3.2 Program Review Model elements

The NUREG series documents are largest source of documents databases available to utilize in conjunction with other standards. NUREG-0711 document provides the 12 areas of review relevant to HFE. These HFE program review elements (PRM) can be classified as planning phase, analysis phase, design phase, verification and validation phase, and design implementation and performance monitoring phase. These five segments may be utilized to integrate the HFE guidance documents in licensing and review process. The Table-2 provide the referenced documents for devising regulatory guidelines, working procedures for regulatory activities and check lists [3].

### 3.3 HFE review element implementation criteria

The methodology on HFE elements can be established by reviewing the criteria, scope and implementation scheme on each element during the whole life cycle of the plant. The 12 review elements also contribute information among each other. e.g., The Operating Experience Review (OER) contributes information in functional requirements analysis & function allocation in the form of providing basis for initial requirements, basis for initial allocation and identification of need for modification [3]. Similarly others elements also contributes information among each other. The implementation scheme is also helpful in identifying the cross referenced documents for

efficient review. One such methodology for HFE OER review is proposed by Danying Gu. et al., (2010) providing the USNRC and Chinese criteria on OER [7].

Table 2: HFE references for guidelines and procedures

Sr. No	HFE Review Phase	Referenced material
1.	Planning	IEC 60964, IEEE-1023, NUREG-0800, 0711
2.	Analysis	ANSI/ANS 58.8, 3.1, 3.5 IEC 60964, IEEE- 845, 1023, 1082 NUREG-0800, 0711
3.	Design	ANSI/ANS 3.1, 3.5 IEC 60964, IEEE-1023, NUREG- 0696, 0800, 0711, 0700, 0899, 1220, 1358
4.	V&V	ANSI/AIAA G-035 IEC 61771, IEEE-845, 1023, NUREG-0800, 0711, 0700
5.	Implementation & performance monitoring	IEC 62096, NEA 96-01, NUREG-1649, 0800, 0711

## 4. Conclusion

In this paper, the legal and regulatory infrastructure available in Pakistan for HFE requirements is assessed, and the methodology for strengthening of legal infrastructure is presented. The regulatory strategy on evaluation of HFE consideration should provide reviewers with guidance on review process. Therefore, the suggested methodology is based on preparation of guidance documents such as checklist, working procedures, S&Gs etc.; incorporation of PRM elements in regulatory system; and finally the development of PRM implementation criteria. Altogether, the scheme provide the enhancement in regulatory infrastructure and also the effective and efficient review process.

## REFERENCES

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