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Human and Organizational Factor Considerations at Nuclear Power Plants in Pakistan

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Abstract
Recent events at Fukushima Dai-ichi Nuclear Power Station (NPS), the Chernobyl disaster and the Three Miles Island (TMI) accident revealed the importance of human and organizational factors for the safe and reliable operation of nuclear power plants (NPPs). At Fukushima Dai-ichi NPS, organizational levels of defense-in-depth were severely challenged. Inadequate human performance was later found to be the principal cause of the multiple events happened at Fukushima. Occurrence of nuclear accidents despite of continued technical improvements at the operational NPPs indicates that human judgment is imperfect and human error is the major cause of most of the accidents. The entire range of interactions of individuals with technology and organization plays a key role in enhancing safety based on interdependency of organization and personnel. Therefore, it is necessary to identify human errors directly affecting safety and the way to eliminate or mitigate them, in order to achieve a high tolerance of human errors in the nuclear installations. In this context, post-Fukushima assessments of NPPs in Pakistan were conducted to evaluate technical improvements made, as well as human and organizational factors considered, for avoiding recurrence of such accidents. This study provides an insight to several improvements made to enhance human performance such as: more comfortable work environment; more operators friendly Human-Machine Interface (HMI) in the Main Control Rooms (MCR); appropriate training imparted to workers; use of Full Scope Training Simulator (FSTS), training / re-training of MCR operators, enhanced ability of MCR operators to develop action plans and procedures in real-time during normal as well as accidental conditions; enhanced decision making competence of the plant management; refining design of Emergency Control Centers (ECC) considering human performance, etc.

Keywords
Human Factors, Organizational Factors, Human Machine Interface, NPPs, Nuclear Safety

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1. Introduction

Recent events at Fukushima Dai-ichi and past accidents at TMI and Chernobyl revealed the importance of Human and Organizational Factors for the innocuous and reliable operation of NPPs in addition to technical excellence. At Fukushima Dai-ichi, the organizational levels of defense-in-depth were severely challenged along with the physical barriers. Human performance played a crucial role in course of these events just as they did at TMI and Chernobyl.

According to Japanese Government report [1], inadequate human performance was the principal cause of the accident at Fukushima Dai-ichi, that is, inadequate site location/ elevation, plant design for the tsunami (sea wall height), improper technical review and safety management of historical tsunami data, accident analysis, regulation, and inadequate attention to international advice, well before the earthquake occurred.

Human Factors (HFs) that may influence safety include administrative controls, e.g. operating rule compliance arrangements, procedures and training, personnel competence, HMI, job/ work design, work environment, individual and team performance, behavioral safety. Organizational Factors concern the characteristics of the organization i.e., the structure of the organization, the management systems and processes, organizational learning, communication, performance indicators, development & management of organizational change, staffing levels and workload and the management of HFs.

Pakistan Nuclear Regulatory Authority (PNRA) and Pakistan Atomic Energy Commission (PAEC) recognize the importance of human performance in ensuring the safety of a nuclear installation during all phases, i.e.

siting, design, construction, commissioning, operation and decommissioning. Accordingly, PNRA has set regulatory requirements for establishing management systems and procedures for HFs to ensure safe operation. Subsequently, PAEC has established management systems and procedures for analyzing events involving HFs and to improve human performance for ensuring safe operation [2].

After Fukushima Dai-ichi accident, a survey of NPPs in Pakistan was conducted to assess improvements in human and organizational factors along with technical improvements to avoid the occurrence of accidents and to prevent adverse consequences due to human performance error. The details are given in the subsequent sections.

2. Methodology

The NPPs at various stages of life have submitted Periodic Safety Analysis (PSA) reports to PNRA to analyze the events due to HFs. For the recently licensed operating NPPs and the NPPs in design phase, Human Factor Engineering (HFE) has been applied from the conceptual design phase to final detailed design. The design of MCR has been improved with respect to HFs by using Operating Experience Feedback (OEF) from other operating NPPs. Work on Task Analysis in psychological aspects of personnel has been completed. The NPPs already in operation have also been evaluated against the HFs in first Periodic Safety Review in line with the international safety standards [3-5].

3. The interaction between Individuals, Technology and the Organization (ITO)

The entire range of interactions of individuals at all levels with technology and with the organizations is an important factor to augment safety. Safety barriers are designed or eroded by the actions of individuals. Individuals are the necessary resources to carry out the activities of the organizations. Individuals may have inherent aptitudes (competence, motivation, cognitive abilities, etc.) and extrinsic resources (instrumentation, procedures or computer aids, working environment). Human error can be minimized, if framework of the task corresponds to the individual's capabilities. In this context improvements have been implemented in Pakistan's nuclear installations, details of which follow in the succeeding subsections.

a. Human Machine Interface

The increasing use of advanced HMI on NPPs brings many benefits in reducing and mitigating human error and optimizing the workload of operators. However, there are potential disadvantages if the system is implemented without due consideration for HFs. It is pertinent to identify imperative human factor issues associated with developments in advanced HMIs.

National Regulations PAK/911 [6] emphasizes on HFs at the design stage. The design is required to be "operator friendly" aiming at minimizing human errors and their effects. In this regard, PAEC has made several improvements to enhance human performance [2]. Work environment has been made more comfortable. Man-machine interface has been made more operators friendly by installing computer displays in MCR. A Work Control Office has been established to relieve the control room operator from log writing and to reduce undue stress. Now the design of MCR is based on a comprehensive and systematic task analysis and follows good human factor practices to facilitate the operators. It is compatible with human psychological and physical characteristics and enables the required tasks to be performed reliably and efficiently. Undesired Alarm Reduction Program has been initiated to reduce alarms that cause undue pressure on MCR operators. Integrated Corrective Action Plan (ICAP) [2] is being implemented to collect, categorize, investigate and implement corrective actions plan related to plant events. If human performance related issues are found, it is subject of further investigation to identify the corrective actions to prevent the recurrence.

In Pakistan three NPPs are operational, the last became operational in 2011. All NPPs have performed PSA including analysis of human factor events and their importance for different stages of the plant life.

In the newly operating plant HFE has been applied from the conceptual design phase to final detailed design. All elements of HFs were considered in the control room design in accordance with international practice. On the basis of HFE requirements Bypass inoperable safety system indication system has been included in the MCR. PSA was conducted at design stage and Human Reliability Analysis (HRA) was performed for HFE. On the basis of MCR functional analysis, operator tasks and operation areas have been classified as; a) normal operation, b) anticipated operational occurrences and c) accident conditions. The design includes HMI devices suited to various operator tasks, especially necessary monitoring and control means for the operator to perform emergency operations efficiently. HFE is also considered for the design of emergency control room.

Large Display Panel (LDP) is located at center of the MCR at a height such that both operators and the shift supervisor can view it from their respective consoles. LDP provides dynamic overview display of plant variables and alarm information so that understanding of plant's current status can be readily ascertained.

Considering all elements of HFs in the design of MCR, improvements will be made in HFE design and training program of FSTS on the basis of latest codes and standards and operating experience of NPPs.

All operating NPPs have evaluated HFs in first PSR in line with international safety standards [2]. They assessed the adequacy of staffing, training, procedures and man-machine interface to identify the weak areas and to take actions to enhance safety against HFs at the plant.

In this context, review of staffing, training and qualification, competency, fitness for duty and OEF system for human errors was carried out keeping in view the requirements of regulations [7]. For this purpose, checklists were prepared and accordingly plant documents and actual status were evaluated to ascertain implementation of these requirements. Surveys and interviews of plant personnel were carried out on matters of training and qualification. The adequacy of corrective actions as suggested in Periodic Inspection Reports (PIRs), Operation Inspection Reports (OIRs) issued by PNRA and Audits and Deficiency Reports issued by Quality Assurance Division (QAD) were also assessed. Event reports pertaining to human errors were identified and analyzed to assess effectiveness of OEF program to minimize human errors. In HMI scope of work, design of MCR and other work stations was reviewed, compliance with the latest codes and standards were verified, walk-downs for MCR and other work stations including FSTS were carried out, modifications regarding HMI design were evaluated and design of C-1/C-2 MCR was compared and evaluated. In addition, modifications and events reported during last 10 years in this regard were studied and feedback from plant operators was analyzed. Furthermore, the work load of MCR crew was also explored and investigated by conducting interviews. Review of HRA and PSA reports to find linkages with HMI was also conducted. No such issues were identified which challenged the safety of the plant [2].

Based on the review results, the following corrective actions were recommended:

- Development of comprehensive certification program
- Self Assessment in the area of training and qualification
- Inclusion of competency level training and qualification procedure
- Formation of Corrective Action Plan (CAP) Review Board
- Strengthening of manpower in deficient work groups
- Development of need based training program of Emergency Response personnel
- Development of need based /performance based training adopting Systematic Approach to Training (SAT) methodology
- Flow diagram of actuation control switches on panel in MCR
- FSTS updating in line with modifications in MCR may be initiated, where necessary
- Maintaining digital record instead of paper record for significant parameters
- Formation of a dedicated Work Control group to take care of MCR work authorization process
- Marking of controllers in accordance with the process result i.e. write open/close on the respective sides of the controller.

b. Human Behavior during Emergency Tasks

In extreme events, human performance is reduced by greater levels than previously assumed. In high-stress incidents individuals demonstrate a range of deficits from cognitive paralysis to executive problems, and attention deficits impacting on working memory which slows down the information processing. These deficits and effects impact on the ability of individuals, and ultimately the teams, to undertake emergency tasks. Group behaviors and influences, and the impact of effective leadership may provide some positive influences that help individuals to perform effectively in extreme circumstances.

The extraordinarily perplexing physical conditions at Fukushima led personnel in an unprecedented situation with no pre-established guidance and they had to develop action plans and procedures in real-time [8]. For critical thinking in such situations, it is important to have formally trained personnel in these areas. Therefore decision making capabilities should be further strengthened. The use of decision making support tools, such as Operational and Conservative Decision Making (ODM and CDM) may be encouraged [9].

The operators of Pakistan’s NPPs are capable of using procedures in emergency situations, where they may be expected to quickly adapt the transition between procedures dealing with different situations. They have the ability to use different procedures in parallel during severe emergency conditions to obtain all possible necessary guidance. HFE for the design of emergency control room has been considered [10-15]. Work on Task Analysis in psychological aspects of plant personnel has been completed [2].

c. Effective Team Performance in Control Rooms

HFs in the effective implementation of new technology affect effective team performance in MCR. Effective performance of the team in MCR requires operators to share information and to co-ordinate their tasks to deliver specific goals. Use of technology and systems affect the nature of information available to operators and their role within the activities being undertaken. This requires a common understanding of the status of the system and mutual understanding of each other's, intentions and actions.

In PAEC it is ensured that sufficient information associated with individual plant systems and equipment are available to operators to initiate necessary safety actions in time. In this context, FSTS is used for the training of plant personnel. The simulator allows entire operating crews, along with plant management personnel, to respond to simulations of rapidly changing plant conditions and unexpected failures of equipment and instruments. It tests procedures, communications and decision-making in a realtime environment.

Maintaining leadership is required for excellence in human performance. Involvement of managers in the training of human error prevention techniques as advisers and evaluators greatly facilitates effective implementation of these techniques in PAEC.

d. Procedures and Training

Procedures and training ensure operator's awareness with all operating rules and procedures that adequately support the safety. However, adherence to procedures continues to be cited as a contributor to events, and breach of rules or technical specifications. During uncertain events, appropriate action depends on reasonable flexibility in the use of procedures and professional knowledge. There should be balance between procedures and training. Skilled and experienced individuals have vital role in promoting safety. Pakistani control room operators are highly skilled and provided with simulator training to develop and test their skills required to respond to various scenarios. Training program was re-evaluated [16] in light of the Fukushima Dai-ichi accident with particular emphasis on the limitations of simulator.

At the national level, a number of institutes have been established for education, research and training of personnel. PNRA and PAEC organize symposia, workshops, training courses, etc. in collaboration with International Atomic Energy Agency (IAEA) in the areas related to nuclear safety. The scientists and engineers of PNRA and PAEC received trainings in this area in various countries with the help of IAEA.

Training is provided to deal with the following:

- The induction of new personnel
- Improving the performance of individuals (refresher courses and trainings on FSTS)
- The introduction of new equipment, technology or procedures
- Follow-up actions (corrective actions) after the investigation of an incident.

Improved procedures and training is important to deal with conditions of great stress, inadequate data, personal danger, time pressures, complex event evolution, and conflicting safety management attitudes and expectations. Emergency Operating Procedures (EOPs) have been revised in the light of Fukushima Dai-ichi accident and training imparted accordingly to operating shift crews. Severe Accident Management Guidelines (SAMGs) are being revised as a result of modifications at the plant in response to Fukushima Dai-ichi accident [2, 16].

Through HRA human error probabilities are calculated for the errors that may be due to procedural lapses or operator errors. These inputs are used to improve procedures and operator training on simulator to minimize human errors. As per requirement of Final Safety Analysis Report (FSAR), human performance monitoring program is being established. Improvements suggested during the verification and validation process of HFE design were feedback to improve the training program. Several improvements have been brought on the basis of requirements of HFE design standards and OEF, in human system interface design of MCR, local control rooms, MCR alarm system and training programs of plant specific FSTS.

4. The role of systemic perspective in severe accident management strategies

Accident prevention is the first safety priority of designers and the operating organization. In case of an accident, the organization should be able to protect the public and environment and to mitigate the consequences. Preparation for unthinkable events initiates when the organization starts thinking about it. There is a need for a systemic ITO perspective to strengthen nuclear safety to enhance resilience to unexpected events. "Fundamental surprise" and "crisis management shift" protocol should be introduced into simulator training. Personnel should be trained to identify threats and response strategies in situation [9].

PAEC and PNRA have made preparations to cope with the accident situations. Particularly, PAEC has prepared accident management procedures and on-site/off-site emergency plans. Off-site emergency procedures have been prepared with the involvement of off-site competent authorities. Both on-site and off-site emergency plans are exercised periodically to ensure the preparedness of responsible organizations and stakeholders.

Continuous tracking of small failures in the everyday work and evaluation of safety culture and management system are performed to enhance safety and to be prepared to manage unexpected events. Knowledge of major nuclear accidents, inquisitive attitude and use of internal and external operating experience play important role in severe accident management strategies.

Systematic safety reviews are carried out to confirm that the safety analysis for the installation remains valid, or, if necessary, implement safety improvements. The reviews consider the cumulative effects of modifications, procedural changes, components ageing, operating experience and scientific & technological developments [17].

5. Managing the unexpected through Organizational Defence in Depth (DID) approach

Primary means for managing the consequences of accidents is DID concept [17]. When properly implemented, DID ensures that no single technical, human or organizational failure could lead to harmful effects, and that the combinations of failures that could give rise to significant harmful effects are of very low probability. Organizational DID is provided by an effective organizational structure, organizational learning, coordination among responsible organizations etc. The Organizational DID comprises four levels;

- Workers and workgroups
- Management/supervision
- Independent internal assessment
- External assessment.

In PAEC, the management develops accident management procedures [10-15], for regaining control over a nuclear reactor core, nuclear chain reaction or other source of radiation. Oversight meetings are held to maintain an awareness of, and to respond appropriately to, nuclear safety issues. Information relevant to safety is communicated to individuals in the organization. Plant staff and the management system represent an important line of defence.

Processes have been improved to reduce the time waiting for approvals or eliminating unnecessary interactions between departments. PNRA also takes account of the fact that, in an emergency, routine regulatory administration such as the issue of prior authorizations may need to be simplified in favor of a timely emergency response.

a. Organizational Learning (OL)

OL is very important for safe operation of NPPs. A questioning and learning attitude is important to enhance safety. Decisions, attitudes, lack of understanding or questioning, etc. play major role in organizational failures.

PAEC and PNRA invest in broadening the knowledgebase and skills for the future. They use different mechanisms e.g. workshops, peer review and assist missions. PAEC has established processes and methods to generate learning from operational experience, organizational and cultural root causes and learning points.

Reporting of an operating/regulatory experience can result in significant corrective actions in relation to equipment, human performance and the management system for safety, as well as changes to regulatory requirements and modifications to regulatory practices. PNRA receives information from other States and authorized parties and makes available to others as lessons learned from operating experience and regulatory experience and also shares measures that have been taken in response to information received.

b. Organizational Drift

Observations show that small events, encountered in unexpected ways result in incidents/ accidents. Organization and management is responsible both for detecting and removing hidden deficiencies in the system which result in gradual deterioration of local or organizational safety culture and safety management i.e., Organizational drift. Organizational drift has played a major role in some recent nuclear accidents [1] and a large proportion could have been avoided if the organization had taken corrective actions before the incident.

Management of PAEC aims to prevent organizational drift. Independent and self-assessments are performed to detect and remove hidden deficiencies in the system.

c. Coordination among organizations

Strong and effective communication is necessary among all responsible organizations for safety. Inappropriate communication & coordination are among the major contributing factors of accidents and unsafe acts. Failure of various/different responsible organizations to adequately manage critical situation was observed at Fukushima [8]. Strong communication protocols must be established and maintained. PAEC and PNRA are both independent and have a constructive relationship. PAEC has effective coordination with off-site authorities involved in emergency preparedness. For effective performance, PNRA directly communicates with governmental authorities when necessary. It makes information on incidents in facilities, and other information, as appropriate, available to authorized parties, governmental bodies, national and international organizations, and the public.

In this context, the National Radiation Emergency Coordination Centre (NRECC) [16] has been established at PNRA Headquarters for coordination & response to nuclear incidents or radiological emergencies and remains functional round the clock. NRECC is also the National Warning Point (NWP) of Pakistan for the Conventions on "Early Notification of a Nuclear Accident" and "Assistance in the Case of a Nuclear Accident or Radiological Emergency". It is responsible for notifying National Competent Authority (Abroad and Domestic) and IAEA about a nuclear event or radiological emergency. In order to verify the accuracy and continuous availability of designated emergency contacts of the licensee and regional offices, PNRA conducts Communication Test Exercises (COMTEX) thrice a year on regular basis. Any change in the emergency contact details is updated at the NRECC [16].

6. Regulatory challenges in the interaction of individuals, technology and organizations in the management of safety

The primary objective of regulatory body is to ensure that the human and organizational contribution to nuclear safety is understood and reflected at every stage from the plant design to commissioning, operations and ultimately decommissioning of facilities.

Advances in technology and the dynamic environment around humans have impact on the human role. The processes, structures and interactions within an organization, human behavior under adverse environmental conditions, developments in technology, organizational learning and ensuring the uptake of best practices across the nuclear industry etc. have introduced new regulatory challenges and opportunities, both in effective integration with old technology and in understanding the safety implications of developing technologies and their often differing concepts of operation. In order to meet such challenges, PNRA is in the process to revise its regulations in accordance with the international safety standards, OEF, technological advances, research and development work and institutional knowledge.

PNRA has a proper organizational culture that prioritizes public safety. The personnel at PNRA are being trained on safety management and safety culture. PNRA uses training and re-training programs for its staff to maintain and improve their knowledge. In order to address gaps or emergent safety issues as they develop, PNRA attaches its engineers with plant operation group for a period of four years. These engineers receive extensive on job training during plant operation to obtain operation license. After that, they work with plant operation group in MCR for at least one year before rejoining PNRA. So they get familiar with any advancement in MCR design and also capable to understand individual and group behavior in MCR. PNRA ensures that safety is not compromised when replacing old technologies.

PNRA also helps the licensee in the augmentation of its safety culture. PNRA verifies that HFs are considered throughout the life of a NPP. Firstly, at the design stage it is ensured that HFs are considered in the probabilistic safety assessment, design of main control room, safety parameter display system and remote shutdown panels. Secondly, during operation stage, regulatory inspections include various elements like inspection of work conditions such as lighting, labeling, environmental and habitability issues, housekeeping, fitness for duty, etc. PNRA Inspectors witness simulator exercises during training/re-training. They also carry out inspections of operation shift crews to verify compliance with procedures and to assess if the operator actions are in accordance with the procedures and design intent. Human performance evaluation is also an essential element of safety culture.

Inspections and reviews of unusual occurrence reports help to determine the contribution of HFs in initiation and subsequent progression of the event. PNRA evaluates all human factor elements of HFE planning and analysis (HFE program management, operating experience review, function requirement analysis and function allocation, task analysis, staffing and qualification and human reliability analysis), design (human system interface design, procedure development, training program development, verification and validation (human factor verification and validation), implementation and operation (design implementation and human performance monitoring)) as per requirements of national regulations and best international practices. Improvements are recommended in procedures and training material to minimize operator errors during normal operation, anticipated operational occurrences and design basis accidents.

7. Results / Conclusions

Post-Fukushima assessments of NPPs in Pakistan were made to evaluate the implemented technical improvements, as well as human and organizational factors considered for avoiding recurrence of such accidents. It was observed that several improvements have been made to enhance human performance including more comfortable work environment;

installation of efficient computer displays and set point changing facilities in the Main Control Rooms (MCR) resulting in man-machine interface that is more operator-friendly; appropriate training provided to workers; use of FSTS, training / re-training of MCR operators, enhanced ability of MCR operators to develop action plans and procedures in real-time during normal as well as emergency conditions; enhanced decision making capabilities of the plant management; design of the ECCs considering human performance etc.

It was learned from the Fukushima Dai-ichi accident that efficient and effective communication is necessary among all responsible organizations to manage during the emergency situations. PAEC has efficient and effective coordination with PNRA and off-site authorities involved in the emergency preparedness. PNRA has also developed the efficient coordination with all concerned governmental bodies, national and international organizations, and the public. Considering Radiological Emergency Preparedness as the last barrier, Emergency Plans and implementing procedures of all the operating NPPs have been revised.

Organizational learning is very important for the safe operation of a NPP. For this purpose, PAEC and PNRA make use of workshops, peer group exchange forums, operational experience feedback, peer review and interaction with a number of Missions from IAEA, World Association of Nuclear Operators (WANO) and other international organizations.

8. Perspectives/ Future Suggestions

Safety is a journey not the destination hence there is always a room for improvements. Apart from all the actions and procedural improvement (at organizational level) made taking account of the lessons learned from the Fukushima Dai-ichi accident, there is still need for improvement in decision making capabilities and Panic/Crisis Management. For Panic Management, radiation workers must be trained to cope with not only the situation of panic at workplace but also with that of panic in the general public. There is a need to train our media teams to inform the public without causing undue hue and cry situation. Usually the management of the nuclear facilities is not well conversant with the media tools. For critical thinking during emergency situations, we must train them to foster their needs in decision making and to face media as spokespersons during emergency situations at the nuclear facilities. Therefore, we should look for the use of decision making support tools, such as Operational Decision Making (ODM) and Conservative Decision Making (CDM). Our future work will focus on responsible reporting in media and media conversant personnel to deal with all the situations after incidents/accidents to avoid undue panic and encouraging the effective use of decision making support tools.

References

1. Report of Japanese Government to the IAEA Ministerial Conference on Nuclear Safety, The Accident at TEPCO’s Fukushima Nuclear Power Stations, Japan, June 2011
2. Pakistan’s Sixth National Report to Convention on Nuclear Safety, 2014
3. NUREG 0700, “Human-System Interface Design Review Guidelines” Rev. 2, USNRC, Washington, 2002
4. NUREG 0711, “Human Factors Engineering Program Review Model” Rev. 3, USNRC, Washington, 2011
5. NUREG 0800, “Standard Review Plan – Human Factors Engineering” USNRC, Washington, 2007
6. PAK-911, Regulations on the Nuclear Power Plant Design, January 2002, Rev. 1, PNRA, Islamabad
7. PAK-913, Regulations on Safety of Nuclear Power Plant Design, Rev. 1, 2004, PNRA, Islamabad
8. The Fukushima Nuclear Accident Independent Investigation Commission Report, Japan, 2012
9. Nuclear Power-Control, Reliability and HFs, Edited by Pavel V. Tsvetkov, InTech, 2011
10. PSAR of Chashma Nuclear Power Plant Unit-2, May 2005
11. PSAR of Chashma Nuclear Power Plant Units-3/4, October 2010
12. PSAR of Karachi Nuclear Power Plant Unit-2, January 2014
13. FSAR of Chashma Nuclear Power Plant Unit-2, March 2009
14. FSAR of Chashma Nuclear Power Plant Units-3/4
15. Periodic Safety Review of Chshma Nuclear Power Plant Unit-1, 2010
16. Pakistan’s Special National Report to Convention on Nuclear Safety, 2012
17. SF-1, Fundamental Safety Principles, IAEA, Vienna, 2006