Optimized Application of Regulatory Human Factors Engineering Guidelines

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ABSTRACT

In AREVA NP's recent projects of new plants or control room modernizations, the engineering of human factors was guided by NUREG 0711 and IEC 60964 and applied throughout the project phases. Each of the projects had a group of stakeholders, whose early mutual agreement on HFE matters was a prerequisite for successful HFE work.

The group of main stakeholders comprises the utility's plant managers and members of the plant operating team, AREVA NP's project managers and members of the various technical competence centers, and representatives of the local safety authority. The objectives of each of these stakeholders and our advanced yet practice-proven HFE approach to successfully meet these objectives are described in this paper. It describes both our unique attention to the project's reference plant and its human-centered aspects thus inherited as well as our focus on those issues of the current plant which significantly depart from referenced practices. Deviations' significance and nature determine and grade the resulting HFE effort and its interdisciplinary conductance.

Key Words: Plant Modernization, Human Factors Engineering (HFE), Project Management, AREVA

1 INTRODUCTION

The modernization of I&C systems is a prerequisite for plant life extension. While improved instrumentation and signal validation ensure that plant information is precise and reliable, the flexibility of computerized information processing, presentation and visualization enables designers to present information in ways optimally suited to error-free tasks performance and personnel needs. The resulting avoidance of transients, forced outages and unnecessary shutdowns increases the cost-efficiency of plant operation and thus power generation.

In recent years the AREVA NP HFE team was involved in the design of two new EPR control rooms, two BWR nuclear control rooms, the complete modernization of two control rooms, and the design of several safety and non-safety Human System Interfaces (HSI) all over the world, turning AREVA NP into one of the most experienced companies in the nuclear HSI design worldwide.
The HFE team thereby joined each project's group of stakeholders to mutually ensure that the plant HSIs and other HFE aspects of the plant are engineered in compliance with best-practice HFE principles to optimally meet task performance requirements. How the expected benefits of the modernization can be achieved while meeting stakeholders' objectives holistically and avoiding potential problems is described in Section 2.

The resulting experiences and the derived recommendations reported in this paper reflect the main principles of AREVA NP's generic program of *Applied HFE*. While regulatory guidance is oriented

toward the design of a new plant - designed starting essentially from scratch – our generic program specifically addresses the design of new plants and the modification and upgrading of existing plants by applying the concept of a reference plant. This concept is described in Section 4.
The nature and significance of each of the intended plant modifications determines which HFE activities shall become an inherent part of the engineering of particular modifications. As described in Section 5, the HFE effort is thereby graded. The assessment of proposed modifications adjusts the level and effort of HFE analysis, design guidance, and evaluation. Less significant modifications need limited HFE, while a "high risk" modification may need considerably more HFE.

2 A PROJECT'S GROUP OF MAIN STAKEHOLDERS

In the following section we describe the objectives of each of a project's stakeholders and pair objectives with the AREVA NP set of HFE activities that meets them.

Operating personnel's objectives of adherence of the designed HSI to the plant-specific conventions can be met by our focus on HSI usability. While making users - thus far accustomed to conventional HSI - aware of the advantageous features of computerized HSI displayed on multiple desktop screens and wall-mounted large screens, HFE efforts shall focus on the advice given to HSI designers.
The recommended style of alarms, indicators, controls and on-screen task support shall reflect conventions and effectively support personnel interactions with plant systems (for their monitoring and control), personnel response to plant events (for the prevention or mitigation of postulated accidents' consequences), and related administrative practices. See Section 3.

Project management's main objectives of time and cost efficient application of HFE can be met by our focus on the project's reference plant. The "human-centered" aspects of plant design are then inherited from predecessor designs on which the current one is based. HFE focus can then be set on the few design issues which are new or modified and significantly depart from current practices and/or are identified by impacted plant personnel as potentially problematic.
The execution of applicable HFE program elements – to verify e.g. the adequacy of an adjusted level of automation (now prescribing manual intervention upon automation fault), analyze a new or modified task, revise a validation scenario (as one of its underlying assumption is no longer valid), etc. – is governed by effective procedures and needs to be properly planned, given these elements' interdisciplinary nature.

Technical competence centers generally focus on technology and technical solutions. They provide less attention to the "human element" linked to each of their plant systems – implicitly relied on for the system's manual control and the monitoring of automated control. This is recovered by our elucidation of Applied HFE. The interdisciplinary engineering of the whole plant addresses plant operation – and required HSIs – holistically, is no longer limited to the main control room, is unbiased by purely technical matters, and enjoys operators' consent.

Authorities' objectives of personnel safe and reliable plant-wide performance of their tasks throughout normal and emergency operations, accident management, maintenance, and tests can be met by our focus on the risk in personnel tasks, risk importance, the likelihood of human error, and the mechanisms of error. Based on the assessment of risk, the characterization of potential errors, and the prevention of design-induced error, the particular HFE program elements to focus on are chosen and the graded nature of their application is determined.

3 OPERATOR-CENTERED DESIGN

It is widely known that direct involvement of operations personnel is critical to the success of newly designed HSIs. This is even more the case – and cannot be stressed often enough – for modifications of a plant's HSIs. Operators' initial doubts, fears, and uncertainties concerning computerized HSIs' reliability, key-hole views on separate screens (notoriously impacting awareness), and effects on operational practices deserve full attention and can only be dispelled by close interaction of experienced HF engineers with operations personnel.

Admittedly only crews of operations personnel fully understand integrated plant operations and its supervision. Having operated the plant over time, operators and their supervisors have developed methods of operation, preferred work practices, and their own mental models of the plant and its operation, all of which are based on the experience gained from operation, including unusual events, high workload situations (e.g. during startup and shutdown), tasks that are relatively difficult or error-prone, distractions that impact operators' ability to do their assigned tasks, etc.

This has led to a concept of operations that is plant-specific, not fully documented, but well understood and ingrained in the operating teams. Extensive input from the operators is further required to determine the specifics of the existing concept of operations and its due adaptation to reflect modified tasks and HSIs.

The nature of tasks and the HSIs required to support their performance is determined by the interaction of plant operators (monitoring and controlling the plant) and plant maintainers (restoring plant components when malfunctions occur) with plant systems and components and the reaction to events. These are determined in turn by the plant's level of automation and computerization of HSIs. The advantages taken of the computerization of HSIs and the opportunities to further improve them – while maintaining current HSIs strengths – result in features such as sit-down workstations, desktop task-based displays, wall-mounted large-screen overview displays, computerized procedures and decision-making aids, etc.

The overall concept of plant operations duly evolves to reflect the effects on personnel, both individually and as a team, e.g.

- roles and responsibilities
- the functions allocated to automated systems
- the tasks of manual control and monitoring, their assignment to individual team members under normal, abnormal, and emergency conditions, the way these tasks are performed, coordinated, and supervised
- the procedures governing task performance, and
- the required knowledge, skills, and training.

Compliant with the approach described above, groups of selected operators were involved in all design and HFE activities, serving as a vital source of knowledge. In parallel, prototypes of the evolving HSIs were developed and explored in numerous workshops and video presentations in order to involve the whole crew and support its members and other plant personnel during the change process their plant was subject to.

4 THE ADAPTATION OF THE HFE BASELINE

The obligatory efficient application of HFE is met by our focus on the project's reference plant, on which the current plant is based. The "operator-centered" aspects of plant design are then inherited from the predecessor designs of the plant's systems, components, and equipment – including

- the operating procedures governing their intended monitoring and control
- the indicators, controls, and alarms rendered necessary and sufficient to support these tasks performance, and
- the training sessions known to effectively convey required skills.

The scope of HFE analysis, design guidance, and evaluation of inherited operating procedures, HSIs, and training sessions can subsequently be reduced. HFE focus and the limited set of still applicable HFE program elements – e.g. the task analysis of new or modified tasks only – are thus determined in the project's adaptation phase. As illustrated in the Figure 1 below, the past experience of operating the reference plant is subjected to an HFE-guided yet interdisciplinary conducted review (HF V&V) in order to identify and holistically assess required improvements, extensions, or minor adjustments.

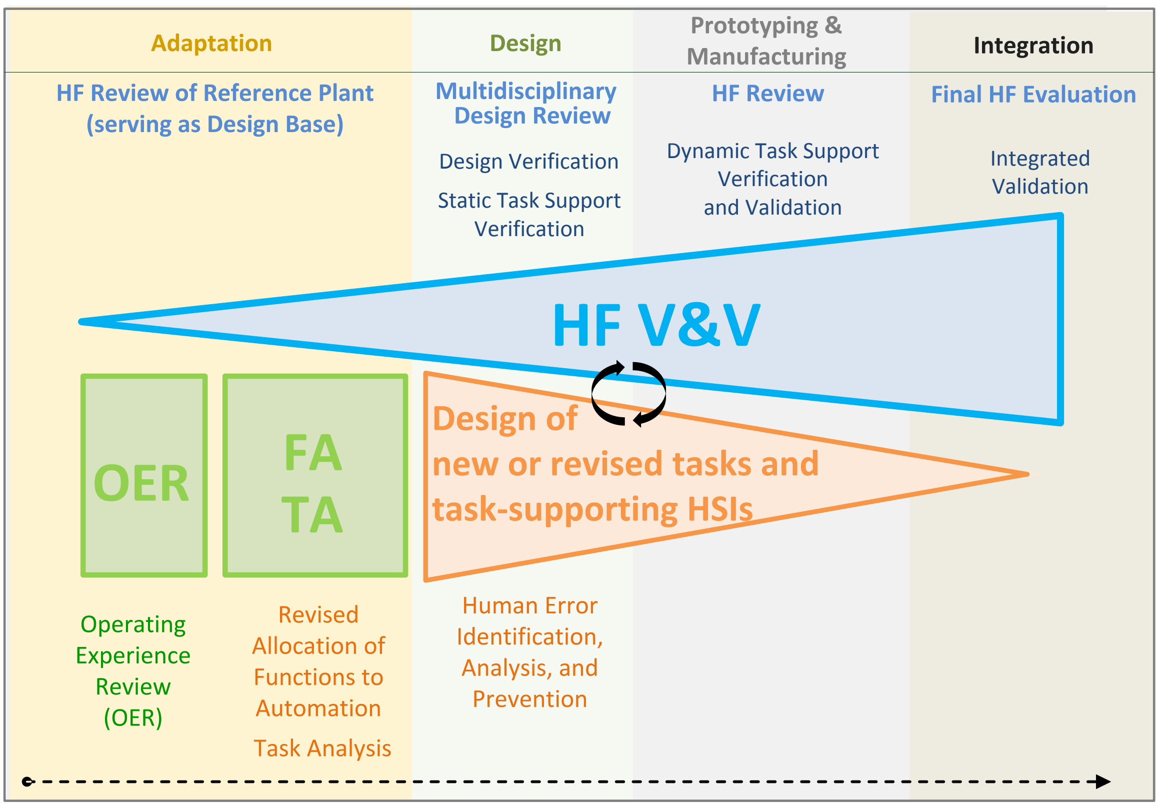

Figure 1. The AREVA NP Human Factors Engineering Lifecycle

Figure 1 further illustrates the very early application of V&V in the engineering lifecycle (as opposed to the common waterfall scheme) in order to

- verify the applicability of inherited assumptions - identified during OER - for the current plant
- assess the adequacy of the applied degree of automation, or

- validate the effectiveness of conceived and initially prototyped HSIs.

Figure 1 also illustrates the parallel conductance of design and V&V. It maximizes the involvement of operators and the effectiveness of design iterations. Planned iterations of HF V&V and early design implementation reduce the effort for design and reduce the cost of modifications at late stage, thus ensuring the project's cost and time effectiveness.

5 RISK-BASED GRADING OF HFE EFFORTS

The overall complexity of analyzing and evaluating the human aspects of plant operation in general and personnel tasks in particular can only be tamed by the planning of these HFE activities. The level of HFE effort can thereby be graded, focusing it on the particular project's needs. These are determined by the kinds of tasks of greatest significance, determined in turn by the nature of the project's plant modernization or design adaptations vs. its reference plant.

The scope of the safety authority's regulatory review of the intended plant design, reflected in the new and modified I&C and HSIs, will be determined by the varying significance of impacted plant personnel tasks.
The HFE activities of analysis, design guidance, and evaluation that should be performed for a relatively simple change are considerably different from those required for a complex change or one that affects highly risk significant systems or tasks.

Engineering judgment is used to determine the recommended level of HFE activities for the analysis, design guidance, and evaluation of a given modification (of the I&C and HSIs). Our method screens all modified or new tasks in order to determine the task characteristics based on e.g.

- task complexity
- available time for action
- concurrently pursued objectives
- operator workload

and the impact of human error on

- nuclear safety
- power production
- major equipment health (equipment damage could cause prolonged plant shutdown, impacting plant productivity)
- personnel safety and health (threatened by exposure to high levels of radiation, high temperature, etc.)

I.e. if human errors can result in death, serious injury, or significant radiation exposure (above plant allowed limits to workers), their risk significance is considered high. If such errors can result in no more than mild injury or radiation exposures within plant allowed limits, then risk significance is considered medium. For all other less severe potential personnel consequences, risk significance is considered low.
Three corresponding levels of activity for each of the HFE activities are defined in turn.

Only those human actions that are of high risk importance need receive the full Level 1 for all HFE activities. Other human actions may receive either the Level 2 (moderate risk) or the Level 3 (low risk) of HFE activities, where the performance of

- detailed HFE analyses of e.g. past operating experience, reliance on automation, the peculiarities of tasks and subtasks, etc. and
- the obligatory subsequent scenario-based and multi-team validation of due support for tasks performance

is not required, except where appropriate. Walkthroughs or talkthroughs of selected tasks can be performed instead of an exhaustive task analysis. Nor is the elaboration of detailed analysis descriptions required, thus lessening the documentation burden.

6 CONCLUSIONS

The well thought-out use of resources allocated to HFE described in this paper allows to extend the “operator-centered” scope of an HFE program to include electrical, mechanical, and I&C maintenance personnel as well as radiological and chemistry technicians.

Extending the HFE scope beyond the team of the main control room, monitoring and control tasks at local control stations and at the remote shutdown facility are also verified and validated, as well as the coordinated collaboration of the main control room team with members of the technical support center and emergency operations facility.

7 REFERENCES

1. IEC 60964 International Standard titled “Nuclear Power Plants - Control Rooms – Design” of the International Electrotechnical Commission
2. NUREG 0711 Human Factors Engineering Program Review Model of the United States Nuclear Regulatory Commission