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Experiences in Systematic Approach to

Procedures Validation in Simulator

Nicolás Moyano de las Heras,
Tecnatom S.A.
Av. de los Montes de Oca, 1
28703, San Sebastián de los Reyes (Madrid), Spain
nmoyano@tecnatom.es,

Alejandro Arroyo Zapata, Francisco Borja Hervás Martín
Tecnatom S.A.
Av. de los Montes de Oca, 1
28703, San Sebastián de los Reyes (Madrid), Spain
aaroyo@tecnatom.es, bhervas@tecnatom.es

ABSTRACT

Tecnatom has provided NEK an independent Human Factor Engineering (HFE) review and validation of their Emergency Operating Procedures (EOPs). The goal of the evaluation was to ensure the proper incorporation of the new plant DEC systems and equipment operation philosophy into the existing EOPs. The job was culminated with the execution of an Integrated System Validation (ISV), where several emergency scenarios were tested at Krško Full Scope Simulator (KFSS), using the new set or procedures. This validation showed up that the set of procedures meets performance requirements and supports the plant's safe operation.

This paper explains the steps, methodology and lessons obtained from the EOPs review and validation.

1 INTRODUCTION

Nuklearna Elektrarna Krško (NEK) requested Tecnatom S.A. to provide an independent evaluation of the new revision of the Emergency Operating Procedures (EOPs). This new revision was prepared due to the Safety Upgrade Program (SUP) modifications, whereby new additional Design Extended Conditions (DEC) equipment is available in the Krško Nuclear Power Plant (NPP).

The evaluation scope was focused in the new or modified instructions from the procedures due to the availability of the new equipment, from a Human Factors Engineering (HFE) perspective.

The evaluation process mainly consisted in a three-step program [See figure 1]:

1. Review of the new version of emergency procedures to comply with general Human Factors Engineering guidelines from the industry,
2. Human Factors Engineering analysis (Functional and Tasks Analysis) of the new equipment's related actions and modified actions in the procedures,

3. The Integrated System Validation (ISV) using a selection of scenarios to validate all the elements from the modification that can potentially impact over the procedures, design basis and previous conditions.

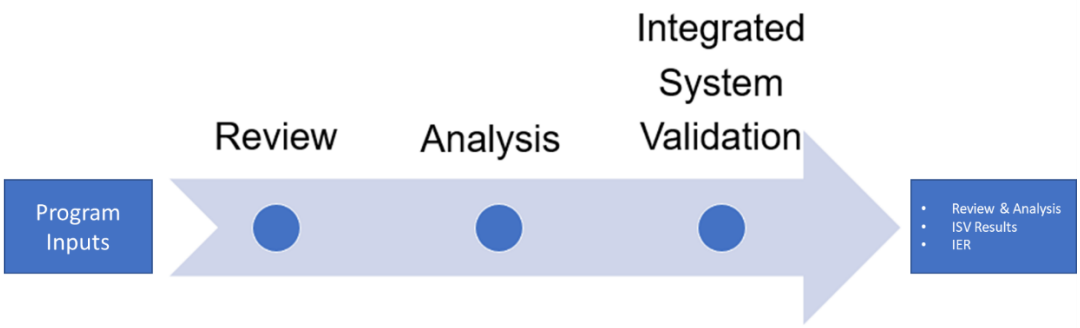

Figure 1: Validation program steps

2 REVIEW

The initial step consisted in a plain review against Tecnatom checklists. These checklists were divided into three types: General Management, Development Basis, and Human Factor Engineering Consistency and Compliance and they gathered guidelines from international standards such as [1], [2], [3], [4] and [5].

The checkpoints targeted several aspects of the procedures like: compliance with current plant procedure's writer's and user's guides, avoidance of ambiguity in the instructions, level of information presented, consistency, unambiguous identification of components, readability, unambiguous usage of references, etc. [Figure 2]

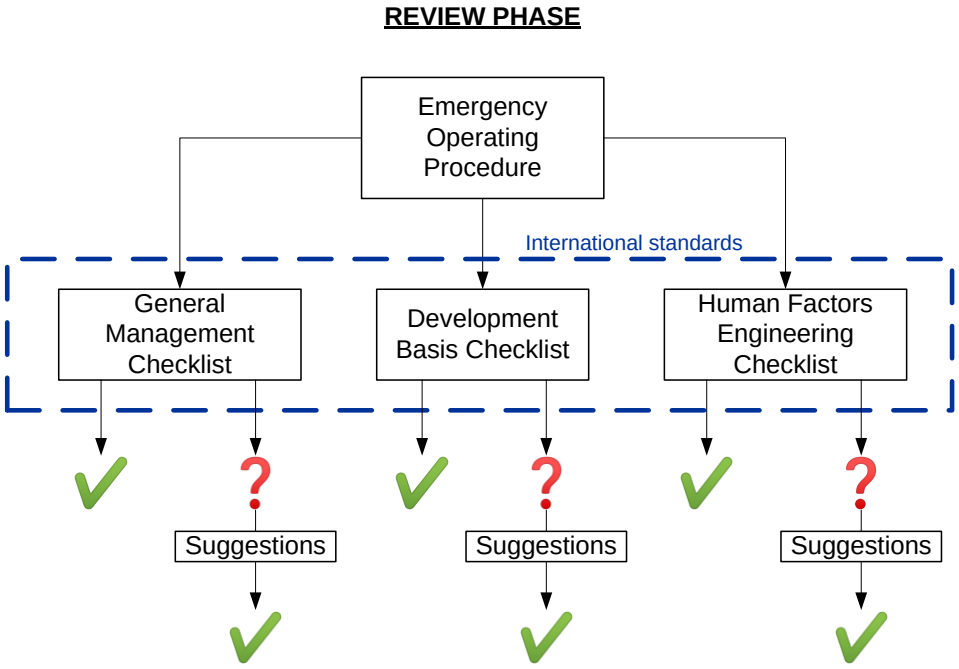

Figure 2: Overview of the Review Phase of the Program.

3 ANALYSIS

A high-level Human Factors Engineering analysis based on elements 3 and 4 from NUREG-0711 HFE Program was performed. The analysis mainly consisted in a Functional Requirements Analysis (FRA) and a Task Analysis (TA) using the procedures as input information. The scope of this analysis was focused in the new or modified actions due to new equipment for Design Extended Conditions in the emergency procedures.

During the Analysis phase, changes in the procedures were used to define a set of new tasks. These tasks were assessed in terms of items required, operators involved and other particular requirements, such as information, operator aids, workplace factors, communications, tools.

This step also included the analysis of the scenarios selected by NEK. These scenarios were analysed by Tecnatom team during the Analysis phase, following the expected flowpaths in the procedures and identifying all the new tasks defined in the Task Analysis, that were required in each scenario. This process allowed to build the Operation Sequence Diagrams (OSD) for each of the scenarios [See figure 3]. An OSD is a graphic presentation of the sequence of the operator tasks during a scenario. The OSDs provides a global vision of the operation process through the entire scenario. The diagram includes the estimated task timeline for each operator in main control room involved and the transitions among the different emergency procedures required to face the event. They are prepared based on conservative approximations made using the procedures as input, and based on the amount, complexity and place of execution of tasks. Times and sequences in OSDs are validated afterwards during the execution of the selected scenarios in the simulator, as part of the Integrated System Validation activity. The sequence diagrams are a powerful tool to follow the scenarios during the Integrated System Validation activity and to detect potential problems during the analysis. Deviations found in the OSDs during the Integrated System Validation may identify problems in the sequence of operations that otherwise could be unnoticed.

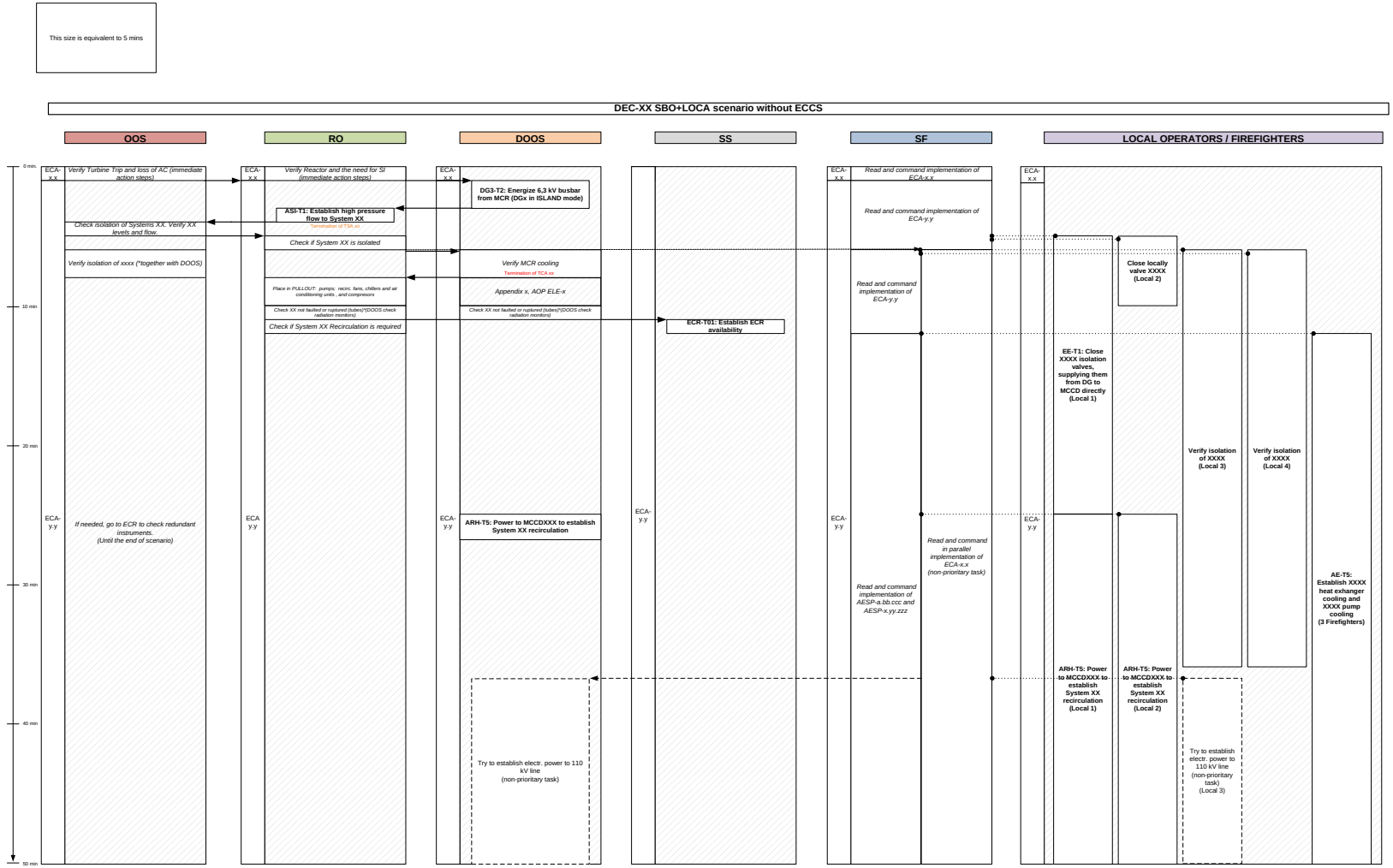

Figure 3: Example of an Operation Sequence Diagram (OSD)

The design modifications implemented as part of the Safety Upgrade Program, had also an impact on NEK's Time Critical Actions (TCA) and Time Sensitive Actions (TSA). The modifications in the emergency procedures must ensure then that these actions can be implemented in the prescribed times. Therefore, these actions where considered in the analysis of scenarios and they were included in the development of OSDs.

Finally, NEK requested Tecnatom to evaluate local actions as well, since it was expected that modifications in the emergency procedures due to new equipment had a great impact in local operators workload. Main goal of this evaluation was to verify analytically if local operators crew is sufficient to face the selected scenarios. Additionally, the evaluation looked for possible interferences between new tasks in main control room and related local actions that required to be previously completed for the execution of these tasks in main control room. Hence, local actions were also included in the development of OSDs, considering estimated times for their performance provided by NEK [See figure 4].

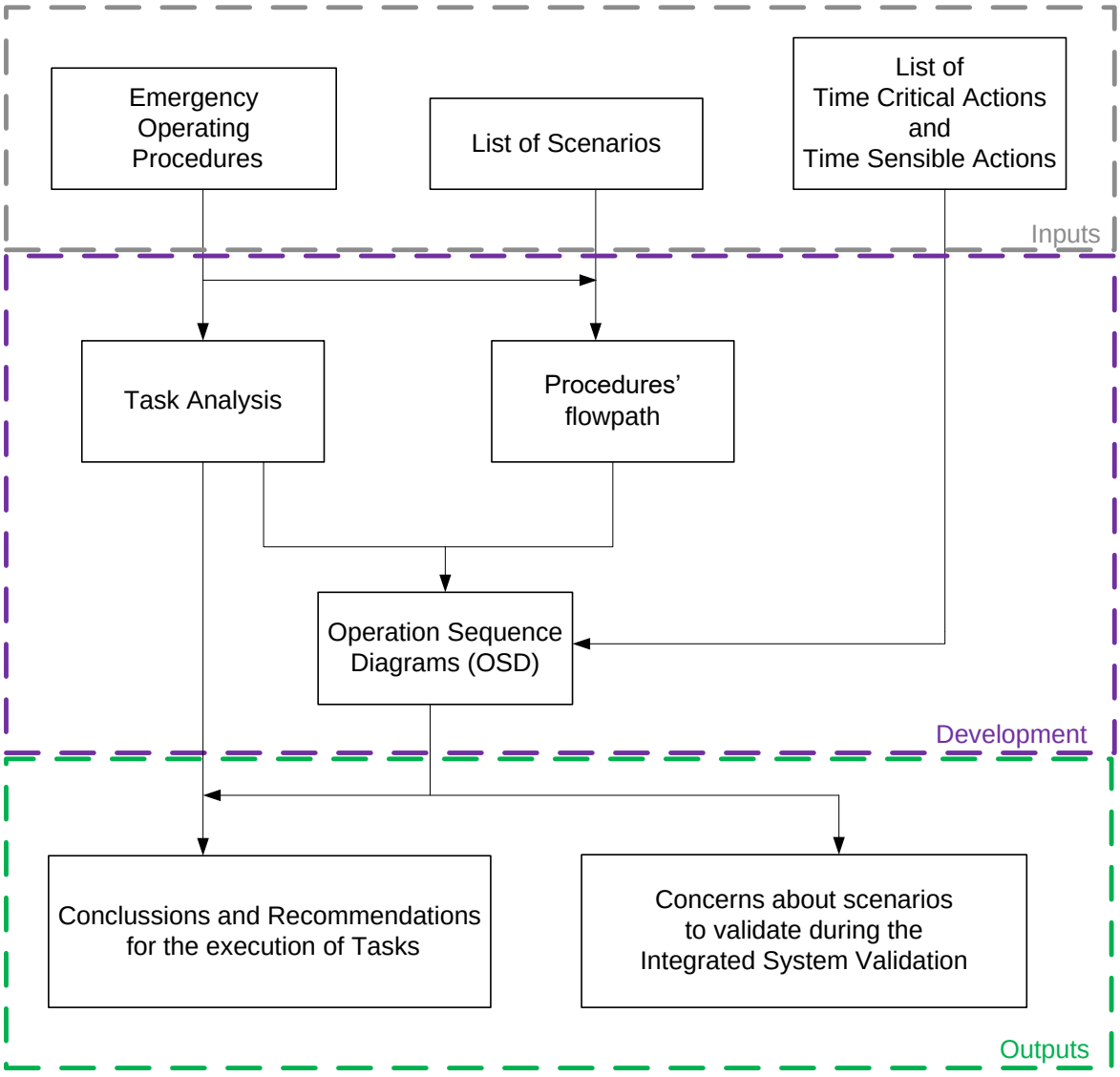

Figure 4: Overview of the Analysis Phase of the Program.

4 INTEGRATED SYSTEM VALIDATION

The Integrated System Validation (ISV) is an evaluation using performance-based tests to determine whether an integrated system design (i.e., hardware, software, procedures, and personnel elements) meets performance requirements and supports the plant's safe operation. This activity is contemplated in NUREG-0711 as part of the program for Human Factors Engineering, specifically for the Verification and Validation element of the program.

The validation of NEK emergency procedures consisted in a simulation of the selected scenarios performed by two different shifts of licensed operators in the plant simulator and evaluated by Tecnatom observers. It provided valuable observations and conclusions related to the operator behavior in the selected scenarios.

In this case, the aim of this activity was focused in the procedure correctness and specifically in the new equipment's related action or modified action. However, other recommendations to improve operator's performance were considered.

Main objectives can be summarized as follows:

1. Validate the acceptability of the Emergency Operating Procedures Revision 22, especially those changes, new instructions and cautions regarding new Design Extended Conditions equipment actions.
2. Validate that specific personnel tasks (related to new equipment actions or actions that can potentially modify Time Critical or Time Sensitive Actions) can be accomplished within the time and performance criteria, with effective situational awareness, and acceptable workload levels with the current staffing in main control room.
3. Ensure that the Human System Interfaces fulfil operator's needs to accomplish the scenario, minimize personnel error and assure error detection and recovery.

To fulfil these objectives, the specific acceptance criteria for the results of the Integrates System Validation activity were established as follows:

1. Main plant parameters were stable within their operating ranges or trending as expected. For this purpose, simulation charts of main plant parameters were recorded during the course of the scenarios performed in the simulator and were analysed afterwards.
2. The procedures allowed to reach the final scenario status in a reasonable sequence and time, according to the Operation Sequence Diagrams, and no major issues raised from the procedure changes and incorporations of new equipment.
3. Actions related to new equipment were performed correctly and allowed the operation team to a safer, easier and simpler operation comparing to the previous condition.
4. The Time Critical and Time Sensitive Actions identified for the scenarios were performed in less time than the prescribed time.

The acceptance criteria were subject to be validated by Tecnatom subject matter experts supported by a set of performance measurements observed and recorded during the tests. In this case:

• Sequence according to expected procedures flow path, using the Operation Sequence Diagrams. The flow paths followed by the shifts for each of the performed scenarios were checked. Any deviation observed this way was noted and it was analysed looking for its cause and consequences. If the flowpath was different or there were tasks that took more time to complete than it was initially estimated in the analysis phase, the OSDs were reviewed and modified according to the data observed during the execution of the scenarios. An accurate OSD is a powerful tool that may allow the detection of some sequence issues in the procedures that otherwise could be unnoticed.

• Real time to complete Time Critical and Time Sensitive Actions and other relevant actions. Times to complete these specific tasks were noted down during the ISV an compared to the established requirements for their completion times. This served to asses if they were

completed within the requirements, leaving a reasonable margin of time for conservative purposes [See figure 5].

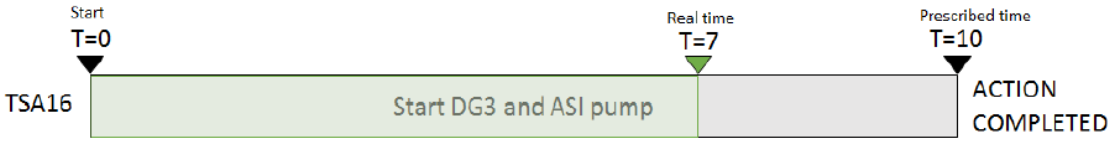

Figure 5: Example of the Completion timeline of a Time Critical Actions and Time Sensitive Actions

• Accuracy, completeness and omission of actions. The observers took note that every action expected to be completed by the procedure was performed accurately, according to the procedures' purpose. The objective of this measure is to identify any issue in the procedure structure or composition that could possibly lead to misunderstanding or omission.

Other subjective measurements were assessed during the execution of the scenarios in the simulator, making use of the observers annotations and questionnaires filled by each member of the shift after these sessions:

• Workload: Refer to the tasks that the operators have to perform simultaneously (i.e. when following more than one procedure)

• Situation Awareness: Operators conception of the plant status vs. the plant status (i.e. when facing faulted indications or confusing symptoms of an event)

• Communication and teamwork: With locals and within the crew

Figure 6: Performance of an Integrated System Validation (ISV) in Krsko Full Scope Simulator (KFSS)

5 CONCLUSIONS

Tecnatom provided NEK with an independent Human Factor Engineering review and validation of twenty Emergency Operating Procedures, which implemented the inclusion of new equipment for Design Extended Conditions in plant.

The Human Factor Engineering works were specified in a Validation Program which was divided in 3 main phases Review, Analysis and Integrated System Validation. The conclusions for each phase can be summarized as follows:

1. The Review and Analysis activities resulted in several comments that were provided to NEK. Most of them were accepted and implemented in a new version of the emergency procedures, improving them in terms of safe operation and human performance.
2. The Analysis also served to identify the most demanding tasks and critical points and foresee some potential problems that could arise during the execution of the selected scenarios designed to challenge the new procedures. This allowed to put the focus on these concerns during the ISV. These concerns were mainly related with workload at specific steps of the scenario, staffing available at certain points for performing highly demanding local actions, coordination between operators (field and main control room) and completion of Time Critical and Time Severe Actions which had the least margin of time according to the expected sequences.
3. The results of the Integrated System Validation activity were positive as the pre-established acceptance criteria for each scenario were met. The procedures' flowpath followed during the ISV were in accordance with expected flowpaths defined in the Analysis phase. Completion times of Time Critical and Time Severe Actions were measured, confirming they were all implemented within the stablished time limits. Completeness or omission of every expected step was checked, with positive results. Additional observations were made by the human factors engineers regarding subjective measures such as workload, situation awareness, communication and teamwork, leading to some suggestions provided to NEK. They mostly focused on polishing some specific steps of the procedures, reinforcing training and getting used to the new procedures.

The Validation Program filled a double objective: enhance the developed revision of emergency procedures and confirm that the modifications implemented were adequate to handle Design Extended Conditions events.

ACKNOWLEDGMENTS

To our families, to the all the people from Tecnatom Human Factors Engineering team that contributed to successfully complete this job, and, finally, to the people of Krško for their kindness and hospitality during all these years.

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