Operating Experience Review Implementation Plan

Technical Report

Non-Proprietary

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ABSTRACT

The purpose of the operating experience review (OER) is to identify and assess HFE-related issues to ensure that negative design features of predecessor or reference designs are avoided and positive features retained.

The methodology described in this technical report for OER implementation provides information on the past performance of previous designs.

The issues and lessons learned from operating experience provide a basis for improving the plant design, through the incorporation of operating experience into the human-system interface (HSI) design.

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List of Acronyms

CFR	Code of Federal Regulation
EPRI	Electric Power Research Institute
HED	human engineering discrepancies
HFE	human factors engineering
HFEPP	human factors engineering program plan
HRA	human reliability analysis
HSI	human-system interface
I&C	instrumentation and control
ITS	issue tracking system
MCR	main control room
NRC	U.S. Nuclear Regulatory Commission
OER	operating experience review
PPM	project procedure manual
PRA	probabilistic risk assessments
PWR	pressurized water reactor
RSR	remote shutdown room
SKN 3&4	Shin-Kori nuclear power plant unit 3&4
V&V	verification and validation
VDU	visual display units

1.0 Overview

The APR1400 engineering design process, described in the Project Procedure Manual (PPM, Reference 6), contains an engineering activity within the inputs element of the plan that addresses collecting and applying lessons learned from previous experience. This is part of the on-going comprehensive effort to provide customers with high quality products.

As a product of this focus on experience and its application to the APR1400 design, this Implementation Plan results in an operating experience review (OER) that is in full compliance with the review criteria that is related to human-system interface (HSI) design, as stated in 10 CFR 50.34(f)(3)(i) (Reference 1), 10 CFR 50.47(a)(22) (Reference 2), and NUREG-0711 (Revision 3, Reference 3) Element 3.

1.1 Purpose

The APR1400 engineering design process, described in the PPM and the Human Factors Engineering Program Plan (HFEPP) (Reference 7) includes the development of functional requirements that describe the functionality that the final APR1400 HSI design must meet.

This Technical Report details an implementation plan that establishes methods, criteria, and guidance for identifying, analyzing, and documenting lessons learned from published reviews of past events, probabilistic risk assessments (PRA) / human reliability analysis (HRA), and other available information.

The lessons learned and insights gained are used to guide and direct the HFE effort that is applied to the design, construction, and installation of the APR1400 HSIs, so as to reduce human errors and their impact on the risk and reliability of plant operation.

In this way, negative features associated with previous designs are avoided in the current design, while positive features are retained. This plan describes the methodology for identifying and assessing experience information that is performed by the HSI design team, as specified in the HFEPP.

1.2 Scope

The scope of the OER for the HSI design includes the following categories:

- Predecessor plants and systems
- Recognized industry HFE issues
- Related HSI technology
- Issues identified by plant personnel
- Important human actions (IHAs)
- U.S. nuclear industry operating experience

1.3 Background

The APR1400 is based on the System 80+ design and as such, the APR1400 OER is based upon the SKN 3&4 OER, which in turn, is based on the System 80+ OER.

The SKN 3&4 OER includes the following operating experience (OE) from Korean pressurized water reactor (PWR) plants:

- The operating experience of the OPR1000 plants
- Issues identified by plant personnel (e.g., maintenance and test personnel)
- Control Room and Auxiliary (i.e., local control stations) operator interviews
- Operator training instructor interviews
- Emergency operator (e.g., shift technical advisors, technical support center staff) interviews
- Operating plant event reports
- Halden Reactor Project reports
- Reviews of related HFE technology

The APR1400 HFE design team maintains the OER database that includes, but is not limited to, data fields that contain:

- A description, including the originating source of the experience or event in question
- The name of the organization or agency that performed the root cause analysis and determined the lessons learned from the experience or event
- A description of the root cause
- The lessons learned (i.e., best corrective action relevant to the design of HSIs to address the root cause)
- The disposition of the lessons learned from the experience or event within the APR1400

HFE design process, typically, this is the formulation of a functional requirement or a APR1400 Style Guide (Reference 8) criterion that is included in the APR1400 HSI functional requirements or Style Guide, as appropriate.

1.4 Definition of Terms and Acronyms

At power

Those plant operating states characterized by the reactor being critical and producing power, with automatic actuation of critical safety systems not blocked and with essential support systems aligned in their normal power operation configuration.

Human error

Human error is defined as a mismatch between the work domain performance demand and the human failure to satisfy that demand.

Human Reliability Analysis

A structured approach used to identify potential human failure events and to systematically estimate the probability of those errors using data, models, or expert judgment.

Human-system Interface

HSI encompasses all instrumentation and control systems and the mechanisms for presentation of process data to the human operating, maintenance and test staff.

HSI system design team

The HSI system design team is a team of engineers, as defined in the HSI system and HFE Implementation Plan, responsible for the design of the HSIS.

Human interaction

A human action or set of actions that affects equipment or physical systems, or an action that influences other human actions. Human interactions can be represented as an event in a fault tree or branch point in an event tree.

Important human actions

Important HAs consist of those actions that meet either risk or deterministic criteria. Risk-important human actions (RIHA) means human actions defined by risk criteria that plant personnel use to assure the plant's safety. There are absolute and relative criteria for defining risk important actions.

For absolute ones, a risk-important action is any action whose successful performance is needed to reasonably assure that predefined risk criteria are met. For relative criteria, the risk-important actions are defined as those with the greatest risk compared to all human actions. The identifications can be made quantitatively from risk analyses, and qualitatively from various criteria, such as concerns about task performance based on considering performance-shaping factors. Deterministically-identified important human actions (DIHA) means deterministic engineering analyses typically are completed as part of the suite of analyses in the DCD in Chapters 7, Instrumentation & Controls, and 15, Transient and Accident Analyses. These deterministic analyses also often credit human actions.

Maintenance

Activities carried out to keep systems and equipment available. Specific types of maintenance include preventive, and corrective. Activities associated with preventive maintenance include testing, surveillance, inspection, and calibration. Activities associated with corrective maintenance include repair, replace, and modify.

Operating experience review: A systematic review, analysis and evaluation of operating experience that can apply to the development of the HSI design.

2.0 APPLICABLE REFERENCES

1. 10 CFR 50.34(f)(3)(i), ″Contents of applications; technical information.”
2. 10 CFR 52.47(a)(21), ″Contents of applications; technical information.”
3. NUREG-0711, Revision 3, “Human Factors Engineering Program Review Model,” November 2012
4. NUREG-0933, “Resolution of Generic Safety Issues.”
5. NUREG/CR-6400, “HFE insights for advanced reactors based upon operating experience,” Higgins, J. and Nasta, K., 1996.
6. KHNP, “Project Procedures Manual,” 2013.
7. KHNP, APR1400-E-J-NR-12002-P, “Human Factors Engineering Program Plan,” September 2013.
8. KHNP, APR1400-E-J-NR-12005-P, “APR1400 Style Guide,” September 2013.
9. KHNP, APR1400-E-J-NR-12010-P, ″APR1400 HF V&V Implementation Plan,” September 2013.

3.0 PRINCIPLES AND GOOD PRACTICES APPLICABLE TO THE OER

3.1 General

As noted earlier, the OER for the APR1400 is based upon the OER that was created for the SKN 3&4 plants, which, in turn, is based upon the OER for the System 80+ plants. The HSI design process employed for the SKN 3&4 plants required that the lessons learned that were derived from the SKN 3&4 OER be fed into the downstream design steps such that the final SKN 3&4 HSI design (e.g., alarms, controls, procedures, training, etc.,) addressed those lessons learned.

This requirement is leveraged in the APR1400 HFE design process by using the SKN 3&4 HSI design as the basis or starting point for the design of the same artifacts for the APR1400 HSI design.

As a result, the APR1400 OER built on the SKN 3&4 OER, and extended that review for the time period since the completion of the SKN 3&4 OER, the three areas that were given especially careful attention are:

- Plant process with expected operational differences due to differences in the process or in the equipment that implements the process between the SKN 3&4 plants and the APR1400 design. This is particularly true if the differences involved in important human actions (IHAs) including risk-important human actions (RIHAs) and deterministically-identified important human actions (DIHAs)
- Changes and differences in the level of automation between the SKN 3&4 plants and the APR1400 design. Again, particularly careful scrutiny is given to those reviewed experiences that had application, in the APR1400 design, to IHAs
- The transition from predominately analog instrumentation and control (I&C) and HSI implementation technology in the SKN 3&4 plants to predominately digital technology for the APR1400 I&C and HSI design.

A data flow diagram showing the flow and translation of operational experience within the APR1400 HFE design process is provided as Figure 1.

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Figure 1. Flow Diagram for Operating Experience Review

3.2 Sources of Experience

The APR1400 OER effort collects operating experience from the following sources:

- Korean commercial nuclear power plant operating experience
  - Documented
  - Plant personnel interviews
- U.S. and world-wide commercial nuclear power plant operating experience

The collected experience includes all modes of plant operation, including low power and shut-down operations.

The APR1400 OER effort included the review of commercial nuclear power plant operating experience within the U.S. as documented in reports from:

- U.S. NRC
- U.S. vendor owners groups
- U.S. commercial nuclear power plant industry support groups, such as
  - The Institute for Nuclear Power Operations (INPO)
  - The Electric Power Research Institute (EPRI), which hosts the Nuclear Safety Analysis Center (NSAC)
  - Significant operating experience and significant event reports from the World Association of Nuclear Operators (WANO)

The specific reports used in developing the APR1400 OER effort are listed in section 2.0 of this document.

3.3 Screening of Experience for Applicability

The sources of operating experience are first screened to determine if the experience transpired after the close date for the SKN 3&4 OER. Sources that are older than that are assumed to be included in that OER. Sources newer than that are then screened for applicability to the APR1400 plant design using the following set of screening questions:,:

- Is the experience applicable / related to a Pressurized Water Reactor (note that there are experiences that happen in other types of commercial nuclear reactors that have relevance to a PWR (e.g., the Tennessee Valley Authority's Brown's Ferry fire), thus, must be included in the APR1400 OER
- Is the experience related to human error, or is it related to other problems, e.g., mechanical or electrical failure of a plant process component
- Is the experience related to the level of automation in the HSI design
- Is the experience concerned with an automation or HSI technology that is being planned for use in the APR1400 design

For those experiences that pass the applicability screening, the next step is to group and classify them.

3.4 Grouping and Classifying the Applicable Experience

Subsequent to the screening for applicable operating experience, the remaining experience is grouped and classified so as to enable the efficient determination of root causes and to better understand the nature of possible similarities and differences that may exist between the root causes that aid in the determination of a lessons learned and the most efficient HSI design correction.

Class 1 issues contain information that related to activities that may impact the HFE related safety goals to maintain the safety and health of the public and plant staff. Class 1 issues are addressed in the additional design effort, and a review of the resolution is performed during human factors verification and validation activities.

Class 2 issues are those issues which do not impact safety goals directly but are addressed to provide improved consistency and to avoid the cumulative effects of significant issues. Class 2 issues are not deemed to be essential, but each is addressed.

All other issues are considered Class 3 issues and will be reevaluated if future HIS changes occur. Issue tracking and follow up is dependent on classification as follows:

Figure 2 shows the process for selecting the OER items that need continuous issue tracking. In the Figure, the class is determined by the HFE design team as follows:

- Class 1 issues require continuous tracking until resolution.
- Class 2 issue resolutions will be audited by the HFE design team.
- Class 3 issues are only required to be reviewed for quality improvement and are for HSI designer reference only.

Members of the APR1400 HFE design team perform this grouping and classifying activity with the technical discipline group leaders reviewing and approving the results.

The APR1400 OER process includes steps that identify positive design, construction and operational experiences and formulate lessons learned that capture those elements of design, construction and operation that enabled the positive OE result. The APR1400 OER process also call for the review of the applicable portions of the design, construction and operation of the APR1400 to assure that these positive lessons learned have also been incorporated in the appropriate phase of the APR1400 life cycle.

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Figure 2. Classification Process of OER Issues for Human Engineering Discrepancies

3.5 Identifying and Associating Root Causes with HFE Design Process Activities

Data structures that capture the APR1400 OER root cause analysis of abnormal operational experience is usually performed by the organization that has published the description of the abnormal experience. The HFE design team, then, interprets the reported root causes and develops 'lessons learned' for the abnormal experience. In this context, the difference between a root cause and a lesson learned is the difference between a negative explanation and positive one, e.g., a root cause explains that the source of a human error is that the HSI lacked some attribute, e.g., the operator failed to address an alarm because they misinterpreted the meaning of the alarm message. The lesson learned is to positively state how that misinterpretation can be rectified (e.g., how to better word the alarm message).

The generalized lessons learned is to provide a general schema for message wording that is robust

enough to avoid the problem for all messages. The purpose of this step in the OER is to identify the appropriate generalized lesson learned. The HFE design team documents the results of these OER steps in a data structure that includes:

- The HSI design artifact (e.g., control room layout, alarm presentation, operating procedure presentation, operator training module, etc.) that was involved in the operating experience that is being reviewed
- Key HF Issues that resulted from the analysis of the operating experience in question (i.e., the root cause that resulted in the operating experience in question)
- Method of Incorporation within APR1400 HFE design process (i.e., the generalized lesson learned from the analysis of the given operating experience). This data field is divided into multiple sub-fields in order to indicate where within the APR1400 HFE design process, the generalized lesson learned is placed so as to be most effective in improving, the HSI design (i.e., in reducing human error by eliminating a known site for its initiation). Examples of these sub-fields are:
  - HSI functional requirements
  - Style Guide,
  - Other, including procedure modification, training module modification, etc.

3.6 Incorporating HSI Design Improvements into the HFE Design Process

The entries of generalized lessons learned, along with their approved assignment to a particular activity within the HFE design process are entered into the HFE issues tracking system (ITS). The ITS tracks progress to assure that the generalized lesson learned is addressed by the appropriate HFE design process activity and incorporated into the final HSI design and included in the HSI integrated system validation during V&V.

4.0 IMPLEMENTATION

4.1 Operating Experience Data Collection

HFE design team actively updates and maintains the database of world-wide operating experience and lessons learned current to the latest model plant by KHNP has built in South Korea (e.g., SKN 3&4).

As described above, HFE design team reviews this database along with more current operating experience of the entire nuclear power plant fleet that is currently operating or has operated within the country of South Korea.

In addition to the documented operating experience from these plants, the HFE design team conducts face-to-face interviews with operations personnel assigned to these plants to learn of their experiences in conducting plant operations and evolutions with the process equipment and their associated HSIs. These interviews cover all modes of plant operation, and the operators' experience.

These interviews are structured in nature, but include a period of free form discussion, and follow a script of questions and hardcopy questionnaires that were designed by human factors specialists defined in HFEPP, who are expert in conducting personal interviews.

Example of a structured interview questions and written questionnaires that KHNP uses in their operational personnel interviews will be submitted to the above request. Each question will be developed to match the bulletized items under from Section 3.4.1 (4) from NUREG-0711 (Revision 3).

In addition, the APR1400 HFE program includes the review of operating experience from other countries that employ commercial nuclear power plants. That experience is collected from, but not limited to, the following list of sources:

- U.S. NRC unresolved and generic safety issues
- U.S. NRC NUREGs, including NUREG/CR-6400, that address lessons learned from U.S. and non-U.S. experience, such as Three Mile Island (TMI)

With respect to NUREG/CR-6400 (Reference 5), the data collection, analysis and lessons learned for operating experience is limited to that OE that occurred prior to 1996.

As such, the OER for the SKN 3&4 plant design is complete and details the additional OE between 1996 and the SKN 3&4 design completion. KHNP is continuing to refresh the OER and has included and continues to include OE to the present time.

This additional OE that is more recent than the SKN 3&4 OER and is grouped, according to the OE categories that are itemized in NUREG/CR-6400, and repeated below:

- Unresolved safety issues/generic safety issues
  (See 10 CFR 52.47(a)(21) and NUREG-0933 (Reference 4))
- TMI issues
- NRC generic letters and information notices
- Operating experience reports in the NUREG-1275 series, Volume 1 through 14
- Low power and shut down operations
- Operating plant event reports

4.2 Operating Experience Lessons Learned Analyses

Most of the collected operating experience data comes with an assessment of the root cause that was determined by the responsible organization or agency that was responsible for the plant or technology involved in the experience. In cases in which a root cause has not been determined by the originating organization, the HFE design team makes an effort to do so, provided that there is sufficiently detailed descriptive material about the experience available to them.

From this collected set of operating experiences and events, the HFE design team examines the root cause and lesson learned from the experience. The team assures that the lesson learned statement(s) is expressed as a general positive statement that addresses the root cause, i.e., is expressed in terms that do not include the specifics of the instance or event from which the lesson learned was derived, but rather in terms that insure that the application of the lesson learned is sufficiently inclusive so as to assure that all appropriate applications within the APR1400 design will be identified and addressed during the remainder of the design and implementation process.

For example, if the operating experience data indicates a root cause that is related to the color coding that was used in the user interface AUTO / MANUAL coding for the operation of a particular motor controlled valve, the lesson learned statement is worded so as to assure that all instances in the design of the APR1400 in which the application of AUTO / MANUAL color coding is applied are

included, not just those that are related to either the specific valve or the specific class (motor operated) of valves, but for all applications in which this particular type of operation occurs).

4.3 Operating Experience Lessons Learned Applied in Design

The HSI lessons learned from operating experiences are applied within the APR1400 HSI design through the appropriate step in the design process. The majority of the collected lessons learned is applied as either the development of new or modified functional requirements or through new additions to or modifications of the design directions that are found in the Style Guide.

However, OE can affect the choice of implementation hardware. Some may be most appropriate as additions to or modifications to procedures or to training modules. Table 1 provides example of the OE results and the options for including the lesson learned in the APR1400 HSI design and implementation process.

The HFE design team monitors and approves the method chosen for applying the HFE OER lessons learned and assures, through meetings and independent reviews, that all technical disciplines working on the APR1400 design are aware of any implications to their respective design activities.

4.4 Verification and Validation with Respect to OE Lessons Learned

The specific activities and steps that are tailored to the HFE design process are described in the APR1400 HF V&V Implementation Plan (Reference 9).

As the APR1400 HSI design progress through the HFE design process, during verification activities that occur with the completion of intermediate design steps, the generalized root cause descriptions, in the form of design functional requirements or design guidelines, are included , and the current state of the HSI design is assessed and documented to assure that the root cause from the operating experience or event in question is absent from the HSI design.

Similarly, during the validation testing of the APR1400 HSIs, a controlled sample of operating experience lessons learned is addressed through the sampling of operational conditions. This approach assures that the treatment of operating experience and events within the HFE design process has a high likelihood of addressing that experience and those events that are captured in the OER.

These verification and validation activities are fully documented. Any human engineering discrepancies (HEDs) that are found during V&V activities are entered into the ITS for tracking to resolution.

4.5 Role and Responsibilities of the Multi-Disciplinary HFE Design Team

Within the HFE design process, the role of the HFE design team has the responsibilities to review, comment, and approve the HFE work that is performed in executing the HFE design process.

As part of these responsibilities, the technical discipline group leaders within the HFE design team periodically host a technical review of the HSI design progress. These reviews enable each technical discipline within the team to acquire an understanding of design decisions that are being made within the other technical disciplines and to assess the impact of such on their own design work. This cross-design discipline exchange helps to eliminate latent design errors that can cause problems later in construction or operation of the APR1400 plant. In the course of such exchanges, the OER is approved by the entire team.

4.6 Documenting the Operational Experience Review

The HFE design team maintains a database of operational experience that includes, but is not limited to, data fields containing:

- A description from the originating source of the operating experience or event
- A description of the root cause and the name of the organization or agency that determined it, along with justification as to why it is, indeed, the root cause
- The lessons learned (i.e., best correction to address the root cause) determined or approved by the HFE design team
- The HFE design team approves the recommendations as to the most effective method for implementing the correction in the APR1400 HSI design (e.g., change to functional requirements, change to APR1400 Style Guide, change to operator or maintenance procedures, change to operator or maintenance training, etc.). The approved recommendations are entered in the OE database
- Each operating experience is logged in the ITS
- The date reflecting the inclusion of the lesson learned in the HFE design process (e.g.,

date functional requirements were modified to include the lesson learned or other method of OE resolution)

The HFE design team performs the OER and monitors the design process by conducting appropriate verification of each step in this implementation plan, including the appropriateness and completeness of the resulting design documentation.

The documentation resulting from the OER activity is considered to be part of the design bases for the APR1400 design, and is entered into the APR1400 engineering design documents.

5.0 RESULTS

Results from the OER will be included in the OER Results Summary Report. Table 1 provides a sample of typical results from the OER, and illustrates the format for documenting each OER issue and its lessons learned result into the APR1400 HFE design process by the HFEPP.

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Table 1. A Sample of the Major OER Issues associated with the APR1400 HSI Design