Document Preparation Profile (DPP)
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1. IDENTIFICATION

Document Category **Safety Guides**

Working ID: **DS492**

Proposed Title: **Human Factors Engineering in Nuclear Power Plants**

Proposed Action: **New document**

Review Committee(s) or Group: **NUSSC**

Technical Officer(s): **Alexander Duchac**

2. BACKGROUND

Human performance and human-machine interface are closely related essential features to the safety of nuclear installations and nuclear power plants (NPPs) in particular. Although human performance is usually associated with the operation of the plant, adequate design provisions are required to ensure an effective and safe human-machine interface.

Operating experience from nuclear power plant operation has revealed the importance of human factors. The consideration of human factors has significant impact on the design of the main and supplementary control rooms, local control panels, and technical support centres. A design of human-machine interface impacts significantly the composition of the operation teams, timelines and correctness of tasks that they need to be accomplish in various plant states including accident conditions.

Human factors need to be considered not only in the control room design and human-machine interface, but also in the conduct of equipment operation, maintenance, testing, inspection and replacement in a safe manner considering the anticipated operational conditions. Inadequate human-machine interface should not be compensated solely by enhancing operator's training, skills and procedures.

A strong emphasis is being placed on the independence of safety provisions at different levels of the defence in depth. The human intervention on plant remains an aspect that cannot easily be diversified. Hence, human factor engineering which has been carefully considered during the design constitutes a cornerstone of the defence in depth.

The IAEA Specific Safety Requirements on NPP Design, SSR-2/1 published in 2012 contains set of requirements for consideration of human factors and the human-machine interface throughout the entire design process.

A draft Safety Guide on the Design of instrumentation and control systems for nuclear power plants [DS431], which is a revision and combination of two Safety Guides, namely IAEA Safety Standards Series No. NS-G-1.1 and No. NS-G-1.3 takes into account the continuing development of computer applications and the evolution of the methods necessary for their safe, secure and practical use. In addition, account is taken of *developments in human factors engineering* in the human-machine interface considerations.

The Safety Guide on Format and Contents of the Safety Analysis Report for Nuclear Power Plants, GS-G-4.1[1] includes the need to assess human factors engineering in the framework of general design aspects but for specific aspect it refers to the particular plant system analysis, where these aspects are not always addressed in required level of details.

Nowadays, in many member states, the safety analysis reports for new nuclear power plants include a dedicated chapter on human factors engineering, which integrates the functional and operational aspects at the design stage.

3. JUSTIFICATION FOR THE PRODUCTION OF THE DOCUMENT

The advances in I&C technology have led to the enhancement of human-machine interface, e.g. the use of digital instrumentation and displays. The inclusion of the new design requirements on human factor engineering as well as a dedicated chapter of the safety analysis report on this subject has become a common practice in Member States.

Several IAEA Member States and Standard Design Organizations (SDOs), such as the International Electrotechnical Commission, are implementing particular requirements and comprehensive guidance for the design, implementation and safety demonstrations of human factors engineering in nuclear power plants.

Although SSR 2/1 and DS 431 include considerations of human factor engineering in the design of nuclear power plants, there is no dedicated IAEA Safety Guide that would provide a set of specific recommendations on how to address human factor engineering in the design and operation of nuclear power plants.

4. OBJECTIVE AND SCOPE

The main purpose of the new safety guide is to provide recommendations and guidance for meeting the requirements of SSR-2/1 on human factors engineering, in particular:

Systematic consideration of human factors, including the human–machine interface, shall be included at an early stage in the design process for a nuclear power plant and shall be continued throughout the entire design process:

- The design for a nuclear power plant shall specify the minimum number of operating personnel required to perform all the simultaneous operations necessary to bring the plant into a safe state.
- Operating personnel who have gained operating experience in similar plants shall, as far as is practicable, be actively involved in the design process conducted by the design organization, in order to ensure that consideration is given as early as possible in the process to the future operation and maintenance of equipment.
- The design shall support operating personnel in the fulfilment of their responsibilities and in the performance of their tasks, and shall limit the effects of operating errors on safety. The design process shall pay attention to plant layout and equipment layout, and to procedures, including procedures for maintenance and inspection, to facilitate interaction between the operating personnel and the plant.

[1] DS 449: A revision of GS-G-4.1 currently being prepared.

- The human–machine interface shall be designed to provide the operators with comprehensive but easily manageable information, in accordance with the necessary decision times and action times. The information necessary for the operator to make a decision to act shall be simply and unambiguously presented.
- The operator shall be provided with the necessary information:

  (a) To assess the general state of the plant in any condition;

  (b) To operate the plant within the specified limits on parameters associated with plant systems and equipment (operational limits and conditions);

  (c) To confirm that safety actions for the actuation of safety systems are automatically initiated when needed and that the relevant systems perform as intended;

  (d) To determine both the need for and the time for manual initiation of the specified safety actions.

- The design shall be such as to promote the success of operator actions with due regard for the time available for action, the conditions to be expected and the psychological demands being made on the operator.

- The need for intervention by the operator on a short time scale shall be kept to a minimum, and it shall be demonstrated that the operator has sufficient time to make a decision and sufficient time to act.

- The design shall be such as to ensure that, following an event affecting the plant, environmental conditions in the control room or the supplementary control room and in locations on the access route to the supplementary control room do not compromise the protection and safety of the operating personnel.

- The design of workplaces and the working environment of the operating personnel shall be in accordance with ergonomic concepts.

- Verification and validation, including by the use of simulators, of features relating to human factors shall be included at appropriate stages to confirm that necessary actions by the operator have been identified and can be correctly performed.

While it is understood that design and operation need to be considered in a holistic manner, the focus of this safety guide is on the provisions in the design of the plant that facilitate the safe operation and minimize the probability of human errors, including all plant states and accident conditions, conduct of maintenance, inspection or other kind of activities. The analysis and consideration of the human-machine interface and factors related to the interaction of the operating and maintenance personnel with the plant systems and controls will constitute the focus of the safety guide.

The use of human-machine interfaces, e.g. displays navigation, information retrieval, alarms, access to controls, etc. can be influenced indirectly by a number of factors beyond the design or environment conditions, such as shift training, plant organizational factors and the safety culture.

The plant organizational factors are excluded from this safety guide and will be covered in other IAEA safety standards. Intentional acts as well as aspects of human performance relating to ‘trustworthiness and background checks’ are excluded from this safety guide too.

The safety guide will address the human factor engineering related to operation and maintenance of plant systems, instrumentation and controls, equipment layout, control room and supplementary control room design. This guide will be made consistent with existing IAEA and international guidance related to these areas.

5. PLACE IN THE OVERALL STRUCTURE OF THE RELEVANT SERIES AND INTERFACES WITH EXISTING AND/OR PLANNED PUBLICATIONS

This document would further elaborate on systematic consideration of human factors and the human–machine interface in the design process, verification and validation, implementation, operation, and human performance monitoring.

This document will interface with the following IAEA Safety Standards:

- SSR 2/1: Safety of Nuclear Power Plant: Design
- SSR-2/2: Safety of Nuclear Power Plants: Commissioning and Operation
- DS 431: Design of Instrumentation and Control Systems for Nuclear Power Plants[2]
- DS 449: Format and Content of the Safety Analysis Report
- NS-G-2.8 Recruitment, Qualification and Training of Personnel for Nuclear Power Plants50-P-10 Human Reliability Analysis in Probabilistic Safety Assessment of NPPs.
- NP-T-3.10: Integration of Analog and Digital Instrumentation and Control Systems in Hybrid Control Rooms, the IAEA Nuclear Energy Series
- Proceedings from International Experts' Meeting on Human and Organizational Factors in Nuclear Safety in the Light of the Accident at the Fukushima Daiichi Nuclear Power Plant, Vienna, Austria, 21-24 May 2013, Conference ID: 45441 (I2-CN-212)

This document will interface with the following relevant international guidance:

- IEC 60960:1988, Edition 1.0 (1988-08-30): Functional design criteria for a safety parameter display system for nuclear power stations
- IEC 60964-2009, Nuclear Power Plants–Control Room– Design".
- IEC 60965:2009, Edition 2.0 (2009-07-16): Nuclear power plants - Control rooms - Supplementary control points for reactor shutdown without access to the main control room
- EC 61227:2008, Edition 2.0 (2008-04-29): Nuclear power plants - Control rooms - Operator controls
- IEC 61771:1995, Edition 1.0 (1995-12-13): Nuclear power plants - Main control-room - Verification and validation of design
- IEC 61772:2009, Edition 2.0 (2009-04-29): Nuclear power plants - Control rooms - Application of visual display units (VDUs)
- IEC 61839:2000, Edition 1.0 (2000-07-21): Nuclear power plants - Design of control rooms - Functional analysis and assignment
- IEC 62241:2004, Edition 1.0 (2004-11-02): Nuclear power plants - Main control room - Alarm functions and presentation
- NUREG 0700-2002, "Human-System Interface Design Review Guidelines".

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[2] A revision and combination of two Safety Guides, namely IAEA Safety Standards Series No. NS-G-1.1[2] and No. NS-G-1.3[2], which it supersedes

- NUREG 711, Rev. 3 Human Factors Engineering Program Review Model
- NUREG-0696-1980 Functional Criteria for Emergency Response Facilities
- IEEE 1289-1998, "Guide for the Application of Human Factors Engineering in the Design of Computer-Based Monitoring and Control Displays for Nuclear Power Generating Stations".
- IEEE1023-2004, Recommended Practice for the Application of Human Factors Engineering to Systems, Equipment, and Facilities of Nuclear Power Generating Stations and Other Nuclear Facilities".

6. OVERVIEW

The envisaged safety guide would include the following contents:

1. INTRODUCTION
2. HFE PROGRAM MANAGEMENT
3. REVIEW OF OPERATING EXPERIENCE
4. FUNCTIONAL REQUIREMENTS ANALYSIS AND FUNCTION ALLOCATION
5. TASKS ANALYSIS
6. STAFFING AND QUALIFICATION
7. HUMAN RELIABILITY ANALYSIS
8. HUMAN SYSTEM INTERFACE DESIGN
9. PROCEDURE DEVELOPMENT
10. TRAINING PROGRAMME DEVELOPMENT
11. HUMAN FACTORS VERIFICATION AND VALIDATION
12. DESIGN IMPLEMENTATION
13. HUMAN PERFORMANCE MONITORING

REFERENCES

GLOSSARY

ANNEXES

Examples of human factors assessment methods

7. PRODUCTION SCHEDULE: Provisional schedule for preparation of the document, outlining realistic expected dates for:

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STEP 1: Preparing a DPP	DONE
STEP 2: Approval of DPP by the Coordination Committee	4Q 2014
STEP 3: Approval of DPP by the relevant review Committees	4Q 2014
STEP 4: Approval of DPP by the CSS	1Q 2015
STEP 5: Preparing the draft	2015
STEP 6: Approval of draft by the Coordination Committee	1Q 2016
STEP 7: Approval by the relevant review Committees for submission to Member States for comments	1st half 2016
STEP 8: Soliciting comments by Member States	1st half 2016
STEP 9: Addressing comments by Member States	1st half 2017
STEP 10: Approval of the revised draft by the Coordination Committee Review in NS-SSCS	1st half 2017
STEP 11: Approval by the relevant review Committees for submission to the CSS	2nd half 2017
STEP 12: Endorsement by the CSS	1st half 2018
STEP 13: Establishment by the Publications Committee and/or Board of	1st half 2018

Governors (for SF and SR only))	
STEP 14: Target publication date	2nd half 2018

** Column A for Safety Fundamentals, Safety Requirements and Safety Guides*

8. RESOURCES

It is estimated that development of the new guide would involve approximately 50 weeks of effort by member states experts. This is based upon assuming 3 one-week consultant meetings involving no more than 7 experts and an average of one week of work per expert between meetings, and one-week technical meeting to provide for a review of the draft publication by a wide cohort of experts in this field.

Secretariat resources involved are estimated at 10 weeks of effort by agency staff plus support for expert travel and honoraria for experts whose effort is not otherwise funded.