



**UNITED STATES  
NUCLEAR REGULATORY COMMISSION  
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS  
WASHINGTON, DC 20555 - 0001**

May 24, 2011

Mr. R.W. Borchardt  
Executive Director for Operations  
U.S. Nuclear Regulatory Commission  
Washington, DC 20555-0001

**SUBJECT: HUMAN FACTORS CONSIDERATIONS ASSOCIATED WITH EMERGING TECHNOLOGIES IN NUCLEAR POWER PLANTS**

Dear Mr. Borchardt:

During the 583<sup>rd</sup> meeting of the Advisory Committee on Reactor Safeguards, May 12-14, 2011, we completed our review of human factors considerations associated with emerging technologies in nuclear power plants. We also discussed this subject during our 582<sup>nd</sup> meeting, April 7-9, 2011. During these reviews, we had the benefit of discussions with representatives of the NRC staff. We also had the benefit of the documents referenced.

**CONCLUSION AND RECOMMENDATION**

1. The human factors research program has developed valuable information that can be used to improve human performance and plant safety as new digital instrument and control (I&C) systems are introduced into nuclear power plants.
2. The staff should identify areas where the concepts and understanding about factors affecting human performance with new digital I&C systems can be incorporated into formal regulatory guidance documents.

**BACKGROUND**

Although digital technology is expected to improve operational performance, there are challenges to using this technology in nuclear power plants. Increases in sensing capabilities, information processing support, intelligent agents, automation, and software-mediated interfaces extends the "distance" between personnel and the physical plant. While these technologies are beneficial, sometimes they add complexity for personnel operating and maintaining the plant.

To examine some of the opportunities for improved performance as well as potential pitfalls, an information briefing was held during our April 7-9, 2011, meeting. Two specific issues were presented and discussed: 1) the effects of degraded digital I&C systems on human-system interfaces (HSIs) and operator performance, and 2) development of a concept of operations (ConOps) model for small modular reactors (SMRs). Both issues are being examined within the NRC human factors research program.

## DISCUSSION

The purpose of this letter is to encourage continued research on the important issue of human factors considerations associated with emerging technologies in nuclear power plants and incorporation of this new knowledge in regulatory guidance.

The Office of Nuclear Regulatory Research sponsored a research project to investigate the effects of degraded I&C systems on human performance and on plant operations. The objective was to develop guidance for human factors engineering (HFE) reviews addressing the operator's ability to detect and manage degraded digital I&C conditions.

Pertinent standards and guidelines, empirical studies, and plant operating experience were reviewed. The effects of selected failure modes of the digital feedwater-system on HSIs and the operators' performance were evaluated. The findings of this research project indicate that degradation of digital I&C systems is not uncommon and the overall effects on the plant's behavior can be significant, such as causing a reactor trip or equipment to operate unexpectedly. Various modes of digital I&C degradation may affect the HSIs used by operators to monitor and control the plant. For example, deterioration of the sensors can complicate the operators' interpretation of displays, and sometimes may mislead them by making it appear that a process disturbance has occurred.

A conceptual framework was developed to generalize the effects of degraded I&C conditions on human performance. The information obtained was used as the technical basis upon which to develop HFE review guidance. The guidance addresses the treatment of degraded I&C conditions as part of the design process, and the HSI features. We appreciate the value of new understanding of human performance issues associated with new digital I&C systems and support continuing research in this area.

The guidance has already been applied in HFE reviews, because those who developed the guidance also serve as reviewers of licensing applications. However, the guidance has not been incorporated into formal regulatory guidance documents.

The second project addresses the application of human factors research to issues associated with SMRs. A model was developed to describe the ConOps for SMRs. The ConOps idea is taken from IEEE Standard 1362-1998 (R2007) and examines new systems from a user's point of view. The ConOps model represents a vision of what plant operation should be and is considered integral to the systems engineering process. The approach involves both top-down and bottom-up considerations in which high level mission and goals are reflected down to define functions necessary to achieve the goals. These functions are then applied to human and system resources, where they are decomposed into tasks. Then, from the detail at the bottom the technological infrastructure is developed (i.e., tasks are analyzed to define performance requirements; and detailed HSIs, procedures, and training are designed to support these requirements).

This structured approach led to developing a ConOps model with the plant's mission at the center and the following ConOps "dimensions":

- Staffing, qualifications and training
- Management of normal operations

- Management of off-normal conditions and emergencies
- Management of maintenance and modifications
- Roles and responsibilities of all agents

A search for SMR issues was conducted by examining available information sources, conducting surveys, and visiting surrogate systems with some similar operating controls and characteristics (nuclear naval vessels, refineries, tele-intensive care units, and unmanned drones). From this effort, a preliminary list of SMR issues was developed. During a recent meeting with the staff, we learned that the ConOps model is beginning to be used in reviews of SMR designs. This approach offers value to the staff's reviews and should be incorporated into formal regulatory guidance documents.

The two projects discussed above are part of a larger program designed to identify and respond to human factors issues in new designs, rather than waiting for operating experience to teach its own lessons. We support continued work in this area and urge the staff to move the new knowledge into the formal regulatory review process as it is tested and found to be useful. We look forward to following the program as it continues.

Sincerely,

*/RA/*

Said Abdel-Khalik  
Chairman

References:

1. U.S. Nuclear Regulatory Commission, "Human Factors Considerations with Respect to Emerging Technology in Nuclear Power Plants," NUREG/CR-6947, BNL-NUREG-79828--2008, October 2008
2. O'Hara, J., Higgins, J., Brown, W., & Fink, R., "Human Factors Considerations with Respect to Emerging Technology in Nuclear Power Plants: Detailed Analysis," BNL Technical Report No. 79947-2008, Upton, NY: Brookhaven National Laboratory, 2008
3. O'Hara, J., W. Gunther, and G. Martinez-Guridi, "The Effects of Degraded Digital Instrumentation and Control Systems on Human-system Interfaces and Operator Performance: HFE Review Guidance and Technical Basis," Brookhaven National Laboratory, Technical Report BNL-91047-2010, February 2010
4. U.S. Nuclear Regulatory Commission, "Criteria for Use of Computers in Safety Systems of Nuclear Power Plants," Regulatory Guide 1.152, Revision 2, January 2006
5. U.S. Nuclear regulatory Commission, "Cyber Security Programs for Nuclear Facilities," Regulatory Guide 5.71, January 2010
6. Institute of Electrical and Electronics Engineers, "IEEE Guide for Information Technology—System Definition— Concept of Operations (ConOps) Document," IEEE Std 1362™-1998 (R2007), Approved 03/19/1998, Reaffirmed 12/05/2007

- Management of off-normal conditions and emergencies
- Management of maintenance and modifications
- Roles and responsibilities of all agents

A search for SMR issues was conducted by examining available information sources, conducting surveys, and visiting surrogate systems with some similar operating controls and characteristics (nuclear naval vessels, refineries, tele-intensive care units, and unmanned drones). From this effort, a preliminary list of SMR issues was developed. During a recent meeting with the staff, we learned that the ConOps model is beginning to be used in reviews of SMR designs. This approach offers value to the staff's reviews and should be incorporated into formal regulatory guidance documents.

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Letter to R.W. Borchardt, EDO, NRC, from Said Abdel-Khalik, Chairman, ACRS, dated May 24, 2011

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