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ABSTRACT

Commercial nuclear power plants (NPPs) in the United States need to modernize their main control rooms (MCR). Many NPPs have done partial upgrades with some success and with some challenges. The Department of Energy's (DOE) Light Water Reactor Sustainability (LWRS) Program, and in particular the Advanced Instrumentation and Controls (I&C) and Information Systems Technologies Research and Development (R&D) Pathway within LWRS, is designed to assist commercial nuclear power industry with their MCR modernization efforts. As part of this framework, a survey was issued to utility representatives of the LWRS Program Advanced Instrumentation, Information, and Control Systems/Technologies (II&C) Utility Working Group to obtain their views on a range of issues related to MCR modernization, including: drivers, barriers, and technology options, and the effects these aspects will have on concepts of operations, modernization strategies, and staffing. This paper summarizes the key survey results and discusses their implications.

Key Words: Control room modernization, Light Water Reactor Sustainability, human factors, instrumentation & controls

1 INTRODUCTION

Commercial nuclear power plants (NPPs) in the United States need to modernize their main control rooms (MCR). Many NPPs have done partial upgrades with some success and with some challenges, but none of the 104 commercial reactors in the United States have completed a full control room modernization effort. The Department of Energy's (DOE) Light Water Reactor Sustainability (LWRS) Program, and in particular the Advanced Instrumentation and Controls (I&C) and Information Systems Technologies Research and Development (R&D) Pathway within LWRS, is designed to assist commercial nuclear power industry with their MCR modernization efforts [1]. As part of this framework, a survey was issued to utility representatives of the LWRS Program Advanced Instrumentation, Information, and Control Systems/Technologies (II&C) Utility Working Group to obtain their views on a range of issues related to MCR modernization, including: drivers, barriers, and technology options, and the effects these aspects will have on concepts of operations, modernization strategies, and staffing. This paper summarizes the key survey results and discusses their implications.

It is also important to note that the Electric Power Research Institute (EPRI) has recommended that NPPs have a comprehensive endstate vision for modernization before proceeding [2]. Existing control rooms are almost entirely analog, hardwired, and manually operated control systems. Since analog technologies are no longer readily available, digital control systems are the required replacement systems for modernization. In the course of analog-to-digital upgrades, it is first necessary to develop a digital backend in which sensors and controls are digitized on a supervisory control and data acquisition (SCADA) system. Once it is possible to monitor and control the plant digitally (with potential redundant analog and mechanical backup I&C), the MCR interface can be addressed. Digital technologies introduce the opportunity for new functionality in the form of advanced displays and automated or soft controls.

Yet, such new functionality may go beyond the current licensing basis of plants and require significant licensing amendments. Moreover, although there is operating experience with digital technologies in other safety critical process control environments, advanced digital I&C is largely untested in the nuclear energy domain. There are unique challenges to nuclear power plants, including the close proximity of the MCR to the actual plant, which makes it difficult even to find adequate space to stage the components of a replacement control room. Additionally, the short outage windows of the plants require rapid changeout of components in order to maintain targeted production levels for each plant. In many cases there may be no readily available commercial I&C solutions that generalize from other industries to meet the requirements of nuclear power plants. This gap is the key role of the LWRS Program—to help disseminate upgrade experiences across utilities and to identify areas where more research is needed before new technologies can be successfully deployed at nuclear power plants. Where research is needed, it can be carried out in the form of proof-of-concept demonstrations, whereby the findings from such demonstrations can be translated back to the utilities for refinement and implementation with vendors.

There are significant hurdles in adopting new technologies as part of a MCR modernization strategy in nuclear power plants. As such, utilities must decide the extent of modernization that is desired and needed and prioritize the process by which they will achieve that modernization. The endstate vision outlines both the extent of digital upgrades and the course of deployment. For example, a utility may decide to keep its existing panel-based control room and phase in digital control system (DCS) displays to replace aging analog I&C. Another utility may decide to adopt a complete control room update—doing away with panels completely and moving toward soft controls and plant overview displays at local operator workstations. Yet a third strategy might find a graded approach in which the utility plans for introduction of DCS in the short-term with an eventual goal of introducing a completely new control room concept as part of long-term plant sustainability.

As part of the LWRS effort to support MCR modernization, a survey was conducted to assess utility views toward modernization. The purpose of collecting the survey data was to help identify current utility thinking with regard to the opportunities and challenges inherent in modernization. Ultimately, the survey will be pooled with additional data to help establish uniform pathways by which utilities can develop and implement their endstate vision for MCR modernization.

2 METHOD

2.1 Survey Background

A survey was developed to obtain the commercial nuclear utility's perspective on NPP MCR modernization. The survey was issued during the 2012 Winter LWRS Utility Working Group Meeting through the use of a real-time audience polling technology. Real-time audience polling is a technology that presents a survey electronically (e.g., via a PowerPoint presentation) to an audience of respondents in a room, collects the responses from the participants after each survey question is presented, and immediately provides an summary of the results. This real-time and interactive data collection process is achieved by issuing to each individual survey respondent a wireless remote, or "clicker," that they use to indicate their response to each question. After each question is presented, the respondent indicates their response on the remote. Their choices are transmitted wirelessly and recorded in a database on the computer used to issue the survey. The software then calculates a frequency distribution of the responses, and presents a bar graph showing the aggregated responses to the audience.

For this survey, the questions were shown via a PowerPoint presentation. The proctor instructed the respondents to answer the questions at the utility/corporate level. Each question appeared at the top the presentation slide, and the response options were shown below in an enumerated list. After the proctor read the question to the audience, the proctor started a countdown timer that appeared in the lower right hand corner of the slide that indicated how long the window to register the response was open. Respondents were asked to indicate their response to the question by pushing the button on their "clicker"

that corresponded to the response option in the list. Participants were told that if they changed their minds, or hit the wrong button, that they could press a new button, but that their response must still occur within the time window. After the time window closed for each question, the computer recorded the responses in a database, and then presented a bar graph showing the aggregated results.

It is also worth noting that prior to answering any survey questions, respondents were told that their identities would not be tied to the results obtained in the survey, and that their participation was completely voluntary. After the proctor made these disclaimers, the survey respondents were asked to provide their consent to having their input on the survey be used in technical reports and publications to aid utilities in their control room modernization efforts. All respondents provided their consent.

2.2 Overview of Survey Questions

There were 31 questions related NPP MCR modernization in the survey. The first question collected basic demographic information (i.e., whether the respondent worked for a utility, worked at research institution, or other). This question allowed the utility responses to be separated, and in some cases compared to, the responses from researchers. The next two questions were high-level conceptual questions related to MCR modernization (i.e., what is the main {driver of}/{barrier to} your modernization effort?). The next eleven questions asked about the extent to which utilities planned to use different kinds of technologies in their MCR modernization efforts (e.g., workstations, panels, soft controls, etc.). The next five questions asked utilities to evaluate different concepts of operations across a number of dimensions. Seven more questions asked utilities to evaluate different approaches to, or types of modernization across a number of dimensions. Both the concepts of operations and types of modernization questions were based on [2]. The next three questions asked utilities the extent to which changes that would likely occur to staffing, qualifications, and training as a result of MCR modernization were factored into their plans. There was one question asking about the timeframe for utilities' modernization efforts, and the last question asked about what guidelines they were planning to follow.

3 RESULTS

3.1 General Findings

For this survey, there were eleven respondents that indicated they were affiliated with a utility, and ten respondents that indicated they worked for a research institution (e.g., the Idaho National Laboratory, or the Halden Reactor Project). One respondent indicated their affiliation as 'other'.

With respect to the main drivers of MCR modernization, the survey results indicated that 55% of people affiliated with utilities believe that improving performance, safety, and reliability is the main driver, and 45% believe avoiding obsolescence was the main driver. Other drivers such as reduced costs through staffing reductions, and enhanced functionality received no votes from utility representatives.

With respect to the main barriers to MCR modernization, the survey showed that 50% of utility respondents believe that cost is the main barrier. 20% of utility respondents believe a lack of an endstate vision is the main barrier. Another 20% believe the regulatory approval process is the main barrier, and 10% believe the lack of process expertise and operational experience is the main barrier.

For the survey questions that asked about the extent to which utilities plan to use various technologies in their MCR modernization efforts, the overall trend showed that most utilities plan to use a number of "new" technologies extensively, versus not at all, or in a limited fashion. The only exceptions to this trend were the planned use of workstations (i.e., computers with displays often configured on a desk with operators sitting), and panels (i.e., controls and displays that are often arranged in a rack or upright configuration with operators standing). In these cases, a high percentage of utility respondents indicated they were not sure to what extent their plans for MCR modernization would include these technologies. Table I provides a summary of these results.

Table I. Plans for using various kinds of technologies in MCR modernization

	No plans	Limited use	Extensive use	Not sure	Not applicable
Workstations	0%	11%	44%	44%	0%
Panels	0%	30%	40%	30%	0%
Soft Controls	0%	30%	60%	10%	0%
Advanced Diagnostics	10%	40%	40%	10%	0%
Intelligent Alarms	0%	20%	70%	10%	0%
Overview Displays	10%	10%	70%	10%	0%
Computerized Procedures	10%	30%	50%	0%	10%
Automated Controls	11%	33%	44%	11%	0%
Operator Aids	0%	20%	70%	10%	0%
Technologies and integrate CR and Balance of Plant information	0%	30%	60%	10%	0%

The next section of questions on the survey asked respondents to evaluate different concepts of operations across a number of different evaluative dimensions. The different concepts of operations were: 1) Operator is hands-on at a detailed level, 2) Operator performs higher-level monitoring, 3) Operator is supervisor of automation, 4) The operator operates the plant at all 3 levels, depending on the situation or plant status, and 5) None of the above. The evaluative dimensions included which concept of operations they a) preferred, b) thought was the most feasibly implementable, c) thought will improve their plant's performance, safety, and reliability the most, d) thought was least likely to meet NRC regulatory resistance, and e) thought was most likely to be adopted at their utility. As such, there were five variations on the following generic question in the survey: "Of the different Concepts of Operations [listed below], which one {do you prefer?}/{is the most feasible...?}", etc.

Table II. Different concepts of operations

	Hands-on	Monitor	Supervise Automation	All of the above	None of the above
Prefer	0%	10%	30%	60%	0%
Feasible	30%	40%	0%	30%	0%
Improve Performance, Safety, & Reliability	0%	10%	10%	80%	0%
Least likely to meet Regulatory resistance	60%	0%	20%	20%	0%
Likely to be adopted	10%	40%	0%	50%	0%

As Table II shows, the concept of operations where the operator has varying levels of control was most preferred by respondents affiliated with utilities. They also thought this concept of operations would improve their plant's performance, safety, and reliability the most, but was also likely to meet regulatory resistance (as evidenced by the fact that 60% said that the hands-on concept of operations was least likely to meet regulatory resistance). There was no consensus on which concept of operations was the most feasible, or on what concept of operations would likely be adopted across different utilities.

The next section of questions on the survey asked respondents to evaluate different approaches or types of modernization across a number of different evaluative dimensions. The types of modernization were: 1) Piecemeal (i.e., where individual pieces of equipment are replaced over time), 2) Partially modernized I&C and Human System Interfaces (HSI), 3) Behind-the-boards modernization (of I&C only), 4) Fully modernized I&C and HSI, and 5) None of the above. The evaluative dimensions included which type of modernization they a) preferred, b) thought was the most feasibly implementable, c) thought was cost effective in the short term (3-10 years), d) thought was cost effective in the long term (20-30 years), e) thought will improve their plant's performance, safety, and reliability the most, f) thought was least likely to meet NRC regulatory resistance, and g) thought was most likely to be adopted at their utility. As such, there were seven variations on the following generic question in the survey: "Of the four types of MCR modernization [listed below], which one {do you prefer?}/{is the most feasible...?}", etc.

As Table III shows, utility representatives reported that they preferred the fully modernized I&C and HSI approach to MCR modernization, and also thought this approach was the most cost effective in the long term, and would improve plant performance, safety, and reliability the most. Interestingly, utility representatives indicated that the partially modernized I&C and HSI approach was the most feasible, cost effective in the short term, and most likely to be implemented. Utility representatives also indicated that the approach least likely to meet regulatory resistance was the behind-the-boards modernization of I&C only.

Table III. Types of CR modernization

	Piece-meal	Partially modernized I&C and HSI	Modernized I&C only	Fully modernized I&C and HSI	None of the above
Prefer	0%	33%	0%	67%	0%
Feasible	10%	50%	20%	20%	0%
Cost effective - Short term	30%	50%	0%	10%	10%
Cost effective - Long term	0%	20%	0%	80%	0%
Improve Performance, Safety, & Reliability	0%	10%	10%	80%	0%
Least likely to meet Regulatory resistance	10%	20%	60%	10%	0%
Likely to be implemented	10%	60%	10%	20%	0%

The next three questions asked utilities the extent to which their plans factored in likely changes to staffing, qualifications, and training that would result from modernizing the MCR. Overall, the utilities indicated that they have factored in the effect MCR modernization would have on staffing and training. In particular, no utility indicated that these repercussions were being disregarded. Table IV summarizes the results.

Table IV. Additional factors to consider in MCR modernization

	Completely factored	Somewhat factored	Somewhat disregarded	Completely disregarded	Not sure
Maintenance	67%	22%	0%	0%	11%
Qualifications	80%	10%	0%	0%	10%
Training	80%	10%	0%	0%	10%

For the question asking about the timeframe for utilities' modernization efforts, 50% of respondents affiliated with utilities indicated that the timeframe was 3-10 years, and 50% indicated their timeframe was 11-20 years. Finally, 86% of utility respondents indicated that they plan to use NUREG-0711, NUREG-0700, EPRI Report 1008122, and IEEE 1023 as guidelines in their MCR modernization efforts. Only 14% of utility respondents indicated that they plan to follow just NUREG-0711 and NUREG-0700.

3.2 Notable Differences in Responses from Researchers in this Survey Sample

As mentioned previously, this survey was issued at an LWRS Utility Working Group meeting, where representatives from the United States commercial nuclear industry and researchers met to discuss instrumentation, information, and control systems modernization activities. As such, a number of researchers were in attendance and were invited to provide their input to the survey. For the most part, the researchers responses were consistent with the utility responses. However, there were a few notable deviations that are worth mentioning.

The first difference is with respect to the question asking what the main driver is to MCR modernization. Utility respondents indicated that avoiding obsolescence (45%) and improving performance, safety, and reliability (55%) were the main drivers. Comparatively, 0% of researcher respondents indicated they believed avoiding obsolescence was the main driver, and 80% indicated improving performance, safety, and reliability as the main driver. The second difference is with respect to the question asking what the main barrier is to MCR modernization. 50% of utility respondents believe that cost is the main barrier, and another 20% believe the regulatory approval process is the main barrier. In contrast, 64% of researcher respondents believe that the regulatory approval process is the main barrier, and only 9% of researchers thought that cost was the main barrier. The third difference is with respect to the question about which concept of operations is more feasible for implementation. 38% of researchers indicated that operator being the supervisor of automation was the most feasible, whereas 0% of utility representatives thought this was feasible. Moreover, 30% of utility respondents indicated the hands-on approach was most feasible, where none of researchers selected this option (0%). The fourth is with respect to the question about which type of modernization is the least likely to meet NRC regulatory resistance. 60% of utility respondents indicated the behind-the-boards modernization of I&C only was least likely to meet regulatory resistance, whereas only 11% of researchers realized this.

4 CONCLUSIONS

To a great extent, these survey results validate a number of previously held, but also implicit, beliefs about 1) the drivers, barriers, and technology options for MCR modernization, and 2) the effects these aforementioned items have on concepts of operations, modernization strategies, and staffing. Broadly speaking, the results show there is general consensus among utilities regarding the issues and challenges related to NPP MCR modernization. There were no big surprises with respect to most of the utilities' responses, but at the same time, there were a few notable instances where the research community does not have the same understanding of, or appreciation for, these issues and challenges.

Yet at the same time, this is one of the few surveys, if not the first, that has collected quantitative data on this topic in a systematic fashion. These survey results therefore make a substantive contribution to our collective understanding of this topic. It is recognized that there are some limitations to this survey, including sample size, the difficulty in drilling down into more nuanced detail in a multiple choice question format, and the fact that the results are a 'snapshot in time'. But at the same time, it is also very easy to overcome all of these limitations, and it should be noted that there are many follow up activities to this survey already planned, including issuing the survey to more utility representatives, and conducting a user needs assessment with selected utility partners. The user needs assessment will involve a number of additional data collection methods, including focus groups and semi-structured interviews. A more reliable and accurate understanding of the issues and challenges of MCR modernization will clearly emerge once all of the data from these activities is analyzed all together.

Furthermore, all of these activities are the first steps to creating an endstate vision for MCR modernization across utilities. The survey revealed commonalities across industry partners in their objectives for MCR modernization and a common set of barriers that must be overcome for successful modernization. At the same time, the survey identified differences between researchers and utilities, which highlights the potential for disparity in translating utility needs into research to support modernization. Identifying such differences serves to help avoid pitfalls a priori as researchers and utilities work together. The survey summarized in this paper is a helpful starting point, in which industry has identified its MCR objectives. Future work will refine this industry vision and identify milestones and processes by which LWRS research can help utilities achieve their endstate vision.

5 DISCLAIMER

6 REFERENCES

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