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INSTRUMENTATION AND CONTROL ACTIVITIES AT THE ELECTRIC POWER RESEARCH INSTITUTE TO SUPPORT OPERATOR SUPPORT SYSTEMS

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Abstract

Most nuclear power plants in the United States continue to operate with analog instrumentation and control (I&C) technology designed 20 to 40 years ago. This equipment is approaching or exceeding its life expectancy, resulting in increasing maintenance efforts to sustain system performance. Decreasing availability of replacement parts and the accelerating deterioration of the infrastructure of manufacturers that support analog technology exacerbate obsolescence problems and resultant operation and maintenance (O&M) cost increases. Modern digital technology holds a significant potential to improve the safety, cost-effectiveness, productivity, and, therefore, competitiveness of nuclear power plants. Operator support systems provide the tools to help achieve this potential.

Reliable, integrated information is a critical element for protecting the utility's capital investment and increasing availability, reliability, and productivity. Integrated operator support systems with integrated information can perform more effectively to increase productivity, to enhance safety, and to reduce O&M costs. The plant communications and computing architecture is the infrastructure needed to allow the implementation of I&C systems and associated operator support systems in an integrated manner. Current technology for distributed digital systems, plant process computers, and plant communications and computing networks support the integration of systems and information.

Introduction

Instrumentation and control (I&C) systems in nuclear power plants need to be upgraded in a reliable and cost-effective manner to replace obsolete equipment, to reduce operation and maintenance costs, to improve plant performance, and to enhance safety. The primary impetus, however, for the replacement of the safety, control, and information systems in nuclear power plants is the obsolescence of the existing hardware and the need for more cost-effective power production. The majority of nuclear plants in the United States are operating with hardware that was designed 20 to 40 years ago and is no longer fully supported by the original equipment manufacturer. Thus the procurement of replacement modules and spares under current requirements is costly, time consuming and, in some cases, not even possible. Competition between power producers is dictating more cost-effective power production.

Modern digital technology holds a significant potential to improve the safety, cost-effectiveness (competitiveness), and productivity of nuclear power plants. Digital systems and associated operator support systems have the potential for solving the utilities' current problems of increasing equipment obsolescence, rapidly escalating operation and maintenance costs, lost generation due to system unavailability, spurious operation, and human error, and the inability to increase plant capacity due to equipment limitations. However, frequently utilities use digital equipment for like-for-like replacement of analog systems. This does not allow the utilities to take full advantage of the digital technology to support the production of electricity in the most cost-effective manner. Operator support systems are one of the most effective ways to fully utilize digital technology for reducing the costs of producing electricity.

EPRI Instrumentation and Control Upgrade Initiative

Nuclear utilities are confronted by a growing equipment obsolescence problem which is a significant contributing factor to increasing costs for plant operation and maintenance. Plant age combined with the rapid pace of evolution of electronic technology is a significant factor in equipment obsolescence. Technological improvements, particularly the availability of digital systems, offer improved functionality, performance, and reliability; solutions to obsolescence of equipment; and reduction in operation and maintenance costs. The flexibility and performance of modern digital technology could be used as the basis for replacing obsolete modules or systems in a cost-effective manner in nuclear power plants. The realization of the benefits of digital technology is currently restrained by the relatively high cost of initial applications of new technology in a highly regulated environment. Work is needed to establish reliable and cost-effective methodologies for designing, qualifying, and implementing digital systems in nuclear power plants. This should utilize, as much as possible, relevant information and experience from other process industries. Commercial-grade hardware and software have proven reliable in other process industries for applications including safety systems. Cost-effective approaches are needed to implement and qualify commercial-grade hardware and software for nuclear power plant applications. To address these issues and facilitate the upgrading of nuclear plants, EPRI has put together an industry-wide Integrated Instrumentation and Control Upgrade Initiative.

The EPRI Instrumentation and Control Upgrade Initiative (1) is designed to help utilities upgrade the I&C systems in their plants. This I&C initiative consists of research and development activities, demonstration plant activities, and licensing stabilization activities. The research and development activities support the development and implementation of digital systems as well as providing a technical basis for qualification and licensing responses. It also provides part of the technical bases for the requirements and methodologies needed to design, develop, test, qualify, implement, operate, and maintain digital systems. These activities also support the cost-effective implementation and qualification of commercial-grade hardware and software. An example of this is the work that has been done on commercially available programmable logic controllers (2-4). The demonstration plant activities identify utility's needs, provide part of the bases for requirements and methodologies, provide a testbed for and feedback on requirements and methodologies for upgrade systems, and capture experience from implementing new digital systems. The licensing stabilization activities provide technical support, as requested, for the industry licensing positions on digital systems which are being developed by utility working groups.

Integrated Plant Systems

While analog equipment is becoming obsolete and more costly to maintain, the requirements on nuclear power plant personnel to improve availability, reliability, and productivity and to reduce safety challenges to the plant have increased. These personnel are working with more complex systems, and responding to increasing operational, regulatory and productivity demands. As tasks become more complex, involving large numbers of subsystem interrelationships, the potential for human errors increases. Therefore, reliable, integrated information is a critical element for protecting the utility's capital investment and increasing availability, reliability, and productivity. Integrated operator support systems with integrated information access can perform more effectively in supporting operations, maintenance, and engineering personnel to increase productivity and enhance safety.

Traditionally systems have been implemented in a stand-alone manner which has resulted in increased operation and maintenance costs. Increased competition in the utility industry in the United States makes it essential that these operating and maintenance costs are minimized. Technology can be used to assist plant personnel and reduce the potential for human errors. At the same time, it can support improved productivity and the reduction of overall operating and maintenance costs. The modern technology available for distributed digital systems, plant process computers, and plant communications and computing networks is fully capable of supporting integration of systems and information. In fact, this capability has been proven in other process industries including fossil power plants.

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Integration of the plant systems and information are essential to cost-effectively enhance cooperation between systems and to reduce unnecessary duplication of functions and information. The objectives of integrating plant systems, including operator support systems, and information are to improve plant availability and reliability, to reduce operations and maintenance costs, to reduce safety challenges, and to improve performance with existing and new equipment systems. The plant communications and computing architecture of the plant supplies the infrastructure which allows the integration of systems and information. This infrastructure supports integrated upgrades, provides access to all of the plant's information sources, and facilitates common interfaces between the human and the machine. This architecture will support the interoperability of systems and the interchangeability of equipment. It will also be designed to be easily expandable. This architecture is defined by a plan that includes a migration strategy to get from the current plant architecture to the final, desired architecture.

Plant Communications and Computing Architecture Plan

Many nuclear power plants have become automated and computerized through evolution rather than overall system planning. That is, each I&C system was looked on as a separate problem, without analyzing the interactions of adjacent and interrelated I&C or other plant systems. Problems resulting from the evolution of non-integrated I&C systems are having a serious effect on the performance, connectivity, and maintainability of these systems as well as causing duplication of effort.

In order to minimize these problems and maximize the return on investments in their I&C systems, utilities need to carefully plan the upgrading of these systems by developing their own plant communications and computing architecture plan. Once this plan has been completed, the utility will be able to implement fully-integrated I&C systems which will help to extend plant life, improve efficiency, availability and reliability, reduce maintenance costs, and enhance safety. In addition, the plant communications and computing architecture plan will provide an overview of what the plant architecture is like today, what it is envisioned to look like in the future, and a migration plan for getting there.

The Plant Communications and Computing Architecture Plan Methodology (5) provides the utilities with a detailed set of instructions for preparing a plant communications and computing architecture plan based on open systems that will allow them to upgrade their I&C systems in a logical, cost-effective, and non-disruptive fashion. The plant communications and computing architecture plan methodology provides all of the information necessary to allow utilities to develop their strategic plant communications and computing architecture plans in the most cost-effective manner possible. The Browns Ferry Nuclear Plant has developed its plant-specific strategic plant communications and computing architecture plan (6). The plant communications and computing architecture will play an integral role in the implementation of effective operator support systems.

Productivity Enhancement Systems

Digital technology can support improved power output from nuclear power plants. The improved accuracy of digital systems and the associated reductions in uncertainties can allow the utility to increase its plant's power rating. Digital operator support systems also have the potential to support faster startups for increased power output. They can also support the faster determination of the root causes of an unanticipated trip. At the same time, they can support the faster evaluation of the performance of the equipment and systems during the unanticipated trip. Both of these will allow a faster return to power after the unanticipated trip and; therefore, allow more power to be produced by the plant.

The abilities of digital operator support systems offer many ways to reduce O&M costs. Besides improved reliability and availability, two examples of ways to reduce O&M costs are derived from the continuous monitoring, trending and reporting capabilities, as well as the archival capabilities, of digital systems. The first is the instrumentation calibration reduction program which can reduce the number of instruments to be calibrated and increase the interval between calibrations. The second is a condition-based maintenance program which would allow maintenance to be performed when needed rather than on some predetermined interval.

The technological advances of the last few years have made it possible to develop sophisticated operator support systems, which can not only process and present information, but can also give advice to the human. With appropriately implemented operator support systems, humans can be augmented substantially in their capacity to monitor, process, interpret, and apply information; thus reducing errors and increasing reliability and availability. These operator support systems can increase productivity by eliminating routine human-power-intensive efforts such as recording, collecting, integrating, and evaluating data; and by assisting in monitoring and control activities. They can improve the consistency and completeness of decision-making activities by performing the role of diagnostic and decision-support advisors. Operator support systems can assist in reducing safety challenges to the plant by presenting more complete, integrated, and reliable information to plant staff to better cope with operating and emergency conditions. Reducing safety challenges leads directly to improved reliability and availability and hence productivity.

Advances in technological and human engineering offer the promise of helping nuclear power plant staff to reduce errors, improve productivity, and reduce the risk to the plant and plant personnel. A plant-wide infrastructure for coordinated operator support systems should be created to enhance these systems and to reduce their implementation costs. This infrastructure will include information communication capabilities, database and knowledge base managers, and a unified human-machine interface. This infrastructure, which is the plant communications and computing architecture, will permit incremental additions of operator support systems in all domains.

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Digital System Concerns

Examples of the areas of concern for digital systems, including operator support systems, in nuclear power plants are licensing, software verification and validation (V&V), hardware qualification including electromagnetic interference/radio frequency interference (EMI/RFI) and seismic, reliability, performance, separation, redundancy, fault-tolerance, common-mode failures, diversity, man-machine interfaces and integration through communications networks. Approaches to address many of these concerns are given in recent EPRI reports (7-14).

The test for future digital system upgrades will be whether they are cost beneficial to the plant. Digital systems with their inherent advantages will be implemented in nuclear power plants only if reliable and cost-effective implementation and licensing acceptance is achieved and if the upgraded system supports reduced power production costs. This will also require good, reliable techniques for evaluating the cost/benefits of proposed systems (15).

Many other industries have taken advantage of the cost and performance improvements provided by digital I&C technology. However, cost issues, including the cost of licensing, have inhibited this transition in nuclear power plants. Maintaining digital technology as a viable I&C option for nuclear power plant applications requires the achievement of cost-effective system upgrade implementation processes.

Besides the development of cost-effective processes, the current financial environment for utilities and utility industry organizations requires new approaches for developing new systems. It is getting harder for a single organization to support the entire cost of developing many large complex systems. This is true for both utilities and suppliers. Therefore, the approach of strategic alliances needs to be considered. These partnerships amongst organizations would share resources and benefits. This will allow more systems to be developed and made available to the utilities.

Conclusions

The implementation and integration of digital I&C systems enhances the ability to achieve the goals of improved availability and reliability, enhanced safety, reduced operations and maintenance costs, and improved productivity in nuclear power plants. The plant communications and computing architecture provides the infrastructure which allows the integration. The modern technology of distributed digital systems, plant process computers (both monolithic and distributed), and plant communications and computing networks have proven their ability to achieve these goals in other industries and in foreign nuclear power plants. The use of this modern, proven technology is a key contributor to improved competitiveness in nuclear power plants.

To reduce the implementation costs of digital systems, many utilities perform only like-for-like replacements in the vast majority of their upgrades. This does not look at the entire life cycle cost of the systems and the system's effects on the plant overall. To

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achieve the full benefit of digital technology to reduce the cost of producing electricity, increased functionality for existing systems and the implementation of new operator support systems is essential. An example of this is the CRT-based Reactor Water Cleanup System that contains both automatic control and soft manual control capabilities (16).

References

1. "Integrated Instrumentation and Control Upgrade Plan, EPRI Report NP-7343 Revision 3, December 1992.

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3. "Programmable Logic Controller Requirements and Evaluation Guidelines for BWRs", EPRI Report TR-103734, to be published in 1994.

4. "Experience with the Use of Programmable Logic Controllers in Nuclear Safety Applications", EPRI Report TR- 104159, to be published in 1994.

5. "Plant Communications and Computing Architecture Plan Methodology", EPRI Report TR-102306, Vols. 1&2, (Nov. 1993).

6. "Process Data Network Architecture Plan for the Browns Ferry Nuclear Plants", EPRI Report TR-103445, December 1993.

7. "Guideline on Licensing Digital Upgrades", EPRI Report TR-102348, (Dec. 1993).

8. "Guide to Electromagnetic Interference Susceptibility Testing for Digital Safety Equipment in Power Plants", EPRI Report TR-102323, to be published in 1994.

9. "Handbook for Electromagnetic Compatibility of Digital Equipment in Power Plants, Vol. 1: Fundamentals of EMI Control", EPRI Report TR-102400, (June 1994).

10. "Handbook for Electromagnetic Compatibility of Digital Equipment in Power Plants, Vol. 2: Implementation Guide for EMI Control", EPRI Report TR-102400, to be published in 1994.

11. "Handbook of Verification and Validation for Digital Systems", Vols. 1-3, EPRI Report TR-103291, to be published in 1994.

12. "Survey and Assessment of Conventional Software Verification and Validation Techniques", EPRI Report TR-102106, February 1993.

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13. "Guidelines for Verification and Validation of Expert System Software and Convention Software", Vols. 1-8, EPRI Report TR-103331, to be published in 1994.

14. "Verification and Validation Guidelines for High Integrity Systems", EPRI Report TR-103916, to be published in 1994.

15. "Application of a Cost-Benefit Analysis Methodology to Nuclear I&C System Upgrades", EPRI Report TR-101984, December 1992.

16. "Development of Process Control Capability Through the Browns Ferry Integrated Computer System", EPRI Report TR-104378, to be published in 1994.

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EPRI/NPD

Instrumentation and Control Activities at the Electric Power Research Institute to Support Operator Support Systems

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Research Co-ordination Meeting on Operator Support Systems in Nuclear Power Plants

October 10-14, 1994
Rome, Italy

JAN.0174.P Control Diagnostics & Information 1

EPRI/NPD

Operator Support Systems

- Part of overall instrumentation and control program
- For efficient operation
  - digital systems
  - integration of systems and information
  - communications and computing infrastructure

JAN.0174.P Control Diagnostics & Information 2

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EPRI/NPD

Instrumentation and Control System Concerns

- Analog equipment obsolescence
- Lack of spare parts and support
- Increased O&M costs to maintain systems
- Increased O&M costs to maintain acceptable safety levels

===> Makes it more difficult to compete with other power suppliers

JAH.0174.P Control Diagnostics & Information 3

EPRI/NPD

I&C Digital Upgrades

- Address analog equipment obsolescence concerns
- Utilize technology proven successful in other process industries
- Potential for
  - Increasing reliability and availability
  - Increasing productivity
  - Reducing O&M costs
  - Reducing anticipated and unanticipated outage duration
  - Reducing human errors
  - Enhancing safety

===> Supports improved competitiveness

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EPRI/NPD

Increased Productivity

- Increased plant reliability and availability
- Increased functionality
  - Increased plant output
  - Increased personnel productivity

===> Reduced cost of producing electricity

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EPRI/NPD

Integrated Instrumentation and Control Upgrade Initiative

- Research and Development activities
- Demonstration plant activities
- Licensing stabilization activities
- EPRI report NP-7343 revision 3 "Integrated Instrumentation and Control Upgrade Plan" (Dec. 1992)

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EPRI/NPD

Research and Development Activities

- Development and implementation of digital systems
- Functional requirements specifications
- Methodologies
  - Planning
  - Implementation
- Technical support for licensing responses

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EPRI/NPD

Integrated I&C Systems

- Enhance cooperation between systems
- Reduce unnecessary duplication of functionality and information
- Improve information availability and accessibility
- Potential for even more
  - productivity increases
  - reduction of human errors
  - reduction of unplanned outages

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EPRI/NPD

Digital Upgrades

- Three main issues
  - Licensing
  - Life-cycle costs
  - Benefits

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EPRI/NPD

Examples of EPRI Activities To Address Upgrade Issues

- I&C planning methodologies
  - Plant communications and computing architecture
- Digital upgrade implementation guidelines
  - Licensing stabilization
  - Electromagnetic compatibility
  - Software verification and validation
- Plant demonstrations

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Plant Communications and Computing Architecture

- Importance of network architecture planning
- Interconnected, interoperable systems
- Flexible and easily expandable framework
- Cost-effective implementation of future systems
- EPRI report TR-102306 "Plant Communications and Computing Architecture Plan Methodology" (Nov. 1993)

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Licensing Stabilization

- EPRI report TR-102348 "Guideline on Licensing Digital Upgrades" (Dec. 1993)
- Licensing workshop held in June 1994
  - 160 participants
  - USNRC presentation encouraging use of TR-102348
- Expectation
  - USNRC endorsement of TR-102348
  - No major USNRC qualifiers

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Electromagnetic Compatibility

- EPRI report TR-102323 "Guide to Electromagnetic Interference Susceptibility Testing for Digital Safety Equipment in Power Plants" (to be published in 1994)
- EPRI report TR-102400 "Handbook for Electromagnetic Compatibility of Digital Equipment in Power Plants"
  - Vol. 1: Fundamentals of EMI Control (June 1994)
  - Vol. 2: Implementation Guide for EMI Control (to be published in 1994)

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EPRI/NPD

Software Verification And Validation

- EPRI report TR-102106 "Survey and Assessment of Conventional Software Verification and Validation Technologies" (Feb. 1993)
- EPRI report TR-103291 "Handbook of Verification and Validation for Digital Systems" (draft available)
- EPRI report TR-103331 "Guidelines for Verification and Validation of Expert System Software and Convention Software" joint EPRI/NRC activity (draft available)
- EPRI report TR-103916 "Verification and Validation Guidelines for High Integrity Systems" joint EPRI/NRC activity (draft available)

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EPRI/NPD

Cost-Effective Systems

- Methodologies for design, implementation, and qualification
- Commercial-grade hardware and software
- EPRI report TR-101984 "Application of a Cost-Benefit Analysis Methodology to Nuclear I&C System Upgrades (Dec. 1992)

EPRI/NPD

Programmable Logic Controllers

- EPRI report TR-103699 "Programmable Logic Controller Qualification Guidelines for Nuclear Applications" (to be published in 1994)
- EPRI report TR-103734 "Programmable Logic Controller Requirements and Evaluation Guidelines for BWRs" (to be published in 1994)
- EPRI report TR-104159 "Experience with the Use of Programmable Logic Controllers in Nuclear Safety Applications" (to be published in 1994)

Demonstration Plant Activities

- Identify Utility's needs
- Provide part of technical basis for requirements and methodologies
- Provide test bed and feed back
- Capture experience from implementing new systems

Example of Demonstration Plant Implementation

- EPRI report TR-103445 "Process Data Network Architecture Plan for the Browns Ferry Nuclear Plants" (Dec. 1993)

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EPRI/NPD

Reactor Water Cleanup System for BWRs

- CRT-based control
- Manual and automatic control
- Schematic representation of system, controllers and data
- Check lists
- EPRI report TR-104378 "Development of Process Control capability Through the Browns Ferry Integrated Computer System" (to be published in 1994)

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EPRI/NPD

Resources For Developing Systems

- Tighter budgets, fewer available resources
- Need for faster payback on investments
- Need to use resources more wisely
  - Standard solutions and processes
  - Do not reinvent solutions
  - Cooperate to leverage resources

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EPRI/NPD

Strategic Alliances

- Mutually beneficial partnership
  - Utility
  - Group of utilities
  - Supplier(s)
  - EPRI
- Conduct a key project
- Develop and commercialize
  - Components
  - Systems
- Shared risks and shared benefits

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EPRI/NPD

Partnership Benefits

- Leveraged resources
  - Financial
  - Information
- Reduced costs for each participant
  - General interest projects
  - Developing upgrades
  - Implementing upgrades
- Better use of resources to produce available cost-effective products

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Conclusions

- Integrated digital I&C systems can support the reduction of the cost of producing electricity.
- Benefits of digital systems have been proven in other process industries.
- Operator support systems are a contributor to improved competitiveness.
- Digital technology should be taken advantage of rather than implementing just like-for-like replacements.