Instrumentation and Control

Program Overview

Program Description
Instrumentation and control (I&C) systems affect all areas of plant operation and can profoundly impact plant reliability, efficiency, and operations and maintenance costs. Plants are facing changes that involve serious I&C-related challenges—equipment is getting older and cost-effective operation is more critical.

The Electric Power Research Institute's (EPRI's) Instrumentation and Control Program provides the technical bases to apply advanced I&C and information technologies so that existing and new nuclear plants can tap into functionality and capabilities underutilized to date in the nuclear sector. These capabilities will enable nuclear plants to maintain safe operation while managing I&C obsolescence with higher equipment reliability and personnel productivity. EPRI research focuses on improving the reliability of existing I&C systems and components, enabling the implementation of replacement I&C systems, and advancing the use of I&C to enhance plant health and productivity.

Research Value
Research results from the Instrumentation and Control Program enable nuclear plants to apply I&C systems in an effective manner that supports safe, reliable plant operation. Advanced I&C research provides the technology and knowledge base so plant owners can potentially realize direct and indirect cost savings, make technically sound system- and component-level decisions, and comply with regulatory requirements. Instrumentation and Control Program participants gain access to the following:

- Strategic roadmaps outlining research gaps confronting key issues—such as digital I&C implementation and existing I&C component reliability improvement—and the collaborative actions needed to address these gaps
- Life-cycle management and maintenance guidelines for existing I&C systems and components
- Technical bases for the generic resolution of regulatory issues for new and operating plants, such as risk-informed defense-in-depth and diversity assessment guidance, cyber security guidance for critical digital assets, and guidelines for electromagnetic interference testing and digital upgrades
- Technical evaluations for new technologies in nuclear applications, such as programmable controllers, “smart” sensors, and wireless communications
- Guidance in setting up automated asset- and equipment-monitoring systems that will improve overall plant reliability
- Improved decision-making tools such as control room human factors guidelines, improved information access and visualization, and visualization-enhanced approaches for tacit knowledge capture and training
- Training, operating experience, and lessons learned on I&C replacement projects that will enable plants to avoid costly mishaps and electromagnetic interference events and to implement plant strategies to cost-effectively manage I&C obsolescence

Approach
The I&C Program is designed around three main initiatives:

- Improve Reliability of Existing Systems and Components: I&C systems such as printed circuit cards must be reliable to avoid unplanned plant trips and down-powers. This project develops generic technical bases for effective maintenance and life-cycle management of I&C systems and components already installed in the plant. Such technical guidance is required to maintain and improve the reliability of existing I&C systems and equipment. Key research products include maintenance guidance for analog and digital circuit card systems and industry-accepted preventive maintenance guidelines for digital systems to reduce failures and inappropriate maintenance activities.
• Enable Replacement System Implementation: As the nuclear industry transitions from analog to digital technology, there are several I&C-related issues for which the available technical and regulatory guidance is unclear, incomplete, or evolving. Examples include failure analysis, cyber security, defense-in-depth and diversity, various design considerations for control rooms, and the impact of new technologies such as field programmable gate arrays. This project develops the technical bases to support the deployment and licensing of I&C and human system interface (HSI) replacement systems; develops guidelines for implementing new I&C, information, and HSI technologies in nuclear applications; and documents operating experience and lessons learned.

• Use Advanced I&C to Improve Overall Plant Health and Productivity: Existing plant I&C equipment and functionality do not accommodate up-to-date features and techniques that can reduce costs and enhance reliability and productivity. Expanded capabilities can streamline many plant tasks and procedures to reduce operations and maintenance costs while improving reliability and extending component lifetimes. This project will pursue advanced technologies such as remote monitoring, wireless communication, early prognosis, and data visualization, which could yield benefits such as calibration interval extension, on-line equipment condition assessment, self-testing and diagnostics, and improved access to plant data.

To address strategic objectives established for each of its programs, EPRI has developed roadmaps to plan, coordinate and execute needed research among multiple entities. For the I&C Program, a roadmap has been developed to address the technical barriers that have precluded widespread digital I&C implementation. A second roadmap has been developed for circuit card aging and obsolescence management.

Through separate supplemental projects, nuclear plant owners can gain access to additional research opportunities, including implementation support for I&C maintenance and life-cycle management programs, development and demonstration of new technologies for improving I&C productivity, and forums for sharing lessons learned on reliability, digital I&C implementation, and fleet-wide monitoring. Supplemental training courses are also available, addressing key digital I&C implementation and regulatory issues, electromagnetic compatibility qualification testing, and human factors engineering.

Accomplishments

EPRI's Instrumentation and Control Program has provided much of the fundamental basis supporting digital implementation in the nuclear industry and in identifying and overcoming many of the barriers to implementing newer technology. The Instrumentation and Control Program has also provided the fundamental basis for implementing reliability and productivity improvements.

• Assessed the benefits of I&C defense-in-depth and diversity from a risk perspective. Higher-frequency events such as turbine trip and loss-of-feedwater showed greater safety benefits than rarer accident sequences such as loss-of-coolant.
• Developing a failure analysis guideline for digital systems that can be used to reduce the likelihood of costly I&C related mishaps and to inform decisions on I&C architecture and overall system reliability.
• Obtained U.S. Nuclear Regulatory Commission approvals in safety evaluation reports on various guidelines/requirements, including digital platforms, commercial off-the-shelf components, and electromagnetic interference testing.
• Developing guidance for cyber security procurement requirements for critical digital I&C systems/components.
• Developed technical guidelines for using field programmable gate arrays (FPGAs) in nuclear safety-related applications.
• Developed human factors engineering (HFE) guidance for control room and digital human-system interface (HSI) design and modification covering planning, specification, design, licensing, implementation, training, operation, and maintenance. Also developed detailed HFE guidance for computerized procedure systems and for HSIs to supplement computer-based workstations and automation.
• Produced a Nuclear Sensor Roadmap that describes sensor-related issues, needs, and technologies relating to aging and obsolescence, I&C retrofits, power uprates, long-term operations, and new builds. A
key conclusion is that the relatively small market for nuclear-grade sensors leaves the industry vulnerable to near-term supply shortages and may lead to under-investment in emerging technologies.

- Developed a guidance document for circuit card reliability programs. The report provides guidance to increase the reliability and operating life of existing circuit cards and components, such as guidelines for the proper handling of printed circuit cards and their components.
- Developing implementation guidance and summary of all research to date on instrument calibration extension.
- Issued guidance for the implementation of wireless networks in nuclear power plants, with a secondary emphasis on the use of wireless sensors for asset condition monitoring. Guidance includes technical details and real-life experiences from industry and addresses concerns such as cyber security and electromagnetic and radio frequency interference.

Current Year Activities

I&C Program research and development for 2013 will focus on life-cycle management, new I&C system implementation, equipment reliability, and plant productivity. Specific efforts will include:

- Develop a digital I&C system failure analysis guideline
- Develop requirements and constraints for I&C architectures for high dependability and broad regulatory acceptance
- Develop guidance on replacement of analog circuit cards with FPGA-based substitute cards
- Develop guidance for maintenance of programmable digital-based systems
- Update computer-based training modules on implementing digital I&C to facilitate utility application with reduced cost and greater convenience
- Develop algorithms and techniques to integrate modeling and monitoring results to provide better indication of equipment health
- Develop computer-based training modules for use of the cyber security procurement requirements guidance

Estimated 2013 Program Funding

$3.2 million

Program Manager

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Summary of Projects

<table>
<thead>
<tr>
<th>Project Number</th>
<th>Project Title</th>
<th>Description</th>
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<tbody>
<tr>
<td>P41.05.03.01</td>
<td>I&amp;C Productivity Improvements</td>
<td>The ability to improve plant performance and reduce operations and maintenance costs over the extended life of plants is becoming increasingly difficult with current technology and workloads. The I&amp;C Productivity Improvements project will identify implementation opportunities through new technologies and new work task definitions that can cost-effectively improve performance, reduce costs, and lead to new plant capabilities.</td>
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<tr>
<td>P41.05.03.02</td>
<td>Digital I&amp;C Implementation</td>
<td>The Digital I&amp;C Implementation project group coordinates at least one workshop per year to promote discussion and resolution of problematic digital I&amp;C implementation issues and development of new solutions, guidance, and training materials when needed.</td>
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<tr>
<td>P41.05.03.03</td>
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I&C Productivity Improvements (supplemental)

Key Research Question

The nuclear power industry is concerned about its ability to maintain current high plant performance levels due to aging and obsolescence, knowledge drain, fewer plant staff, new requirements and commitments, and increased difficulty to hire and retain younger staff. Current plant operations are labor-intensive due to the vast number of operational and support activities required by the commonly used technology in most plants. These concerns increase as plants extend their operating life. In order to meet the desire by many plants to further improve performance while reducing human errors, nuclear plants increasingly focus on operations and maintenance costs, of which labor is typically the largest contributor. New productivity improvement capabilities and concepts of operation with measurable economic benefits are needed so that a successful business case can be made for their use.

Approach

Improved and new instrumentation and control (I&C), human-system interface (HSI), information, and communications technologies can address concerns about cost-effectively maintaining current performance levels and enable shifts to even higher performance levels. This project will facilitate new technology implementation to improve productivity. Efforts will include demonstration of new technologies and how they can be used for plant and personnel productivity improvements, as well as providing pros and cons of their uses. Based on member input, required guidance for the application of technologies and pilot demonstration applications will be developed or requested to be developed.

Impact

Implementation of modern technologies such as those listed here (not a comprehensive list of the technologies) can provide multiple benefits:

- Automation of appropriate tasks will reduce workload and human stress levels, remove human error-prone activities, and perform repetitive and time-consuming activities more effectively, allowing humans to better focus on essential activities requiring human capabilities.
- Simulation and visualization will support planning and decision-making, improve designs and facilitate early input from users, support development and testing, facilitate knowledge capture and training, improve job performance, and reduce the likelihood of human errors.
- HSIs and information technology will provide better user-friendliness, reduce the likelihood of human error, improve situation awareness, enable rapid access to data, and support decision making.
- Communications technologies will enable collaborative activities, including rapid access to remote expertise, which will be even more effective with the use of visualization and simulation.

How to Apply Results

Members will apply the results of this project by learning how to implement advanced technologies for productivity improvements into plant modernization and workload definition plans. Potentially, pilot projects will be developed from which members can implement plant-specific applications. Members will learn about related pilot projects being supported by DOE's LWR Sustainability Program in the area of Advanced Instrumentation, Information and Control Technologies.
Digital I&C Implementation (supplemental)

Key Research Question
Digital upgrades at several plants have involved significant unanticipated costs due to problems coping with various implementation issues. Examples of problematic issues with digital upgrades include unanticipated behaviors of digital equipment, software verification and validation, configuration management, evaluation of failure modes and effects, commercial grade dedication, and inadequate vendor oversight. Adverse impacts have included the following:

- Large increases in vendor and utility staff costs
- Significant project delays, as much as one or two refueling cycles
- Plant trips
- Extended outages to correct problems
- Additional engineering to correct problems
- Increased regulatory scrutiny

The problems are typically caused by inadequate knowledge and processes at the utility and its suppliers that prevent utility staff from managing the issues cost-effectively. In some cases, emerging instrumentation and control (I&C) and human-system interface (HSI) technologies include standard features that can eliminate or mitigate problems.

Approach
Many nuclear plant operators have requested EPRI assistance in improving plant programs for managing the problematic issues associated with digital upgrades. In some cases, industry guidance and good practices already exist, but have not been broadly communicated or widely practiced. In other cases, practical guidance for utility engineers is simply not available.

This project coordinates at least one meeting per year to address specific application issues that are proving problematic for current digital upgrade projects. Topics include ensuring high reliability in non-safety systems, performing failure modes and effects analyses (FMEA) for digital systems, vendor interaction and oversight, and factory acceptance testing. Participants propose meeting topics, share plant experiences, discuss lessons learned, and identify areas that need additional research or guidance for utility engineers. Where appropriate, participants may develop or request new guidance and technical transfer mechanisms to provide practical, useful tools to plant engineers.

Impact
This interest group develops and promulgates practical guidance that will help utilities anticipate, detect, and mitigate potential problems before they result in expensive learning-curve events that can cost millions of dollars. The group promotes technology transfer of the latest industry and EPRI guidance on key issues and opportunities to identify current and future research needs for solutions that will smooth the transition to digital instrumentation and control (I&C) and ensure its long-term viability. The group has sponsored development of guidelines on configuration management, commercial grade dedication and testing of digital systems. Specific technical benefits include the following:

- Practices that will improve utility handling of problematic digital system issues
- Practices that will increase utility engineers’ ability to detect and manage weaknesses in suppliers’ designs and processes for key issues, such as failure analysis, software verification and validation, and software configuration management
- Technologies, strategies, and guidance that enable plant engineers to ensure long-term obsolescence management of digital systems using "design for replacement" approaches
- Practical guidance and training materials for utility engineers
How to Apply Results

Members will incorporate the lessons learned, guidelines, and training materials generated in this project into their processes, procedures, and training for digital upgrades.
I&C Reliability (supplemental)

Key Research Question
Aging or poorly maintained instrumentation and control (I&C) systems have resulted in numerous plant trips and power derates and have culminated nuclear plants to take repair or replacement actions to maintain plant availability and reliability. The Institute of Nuclear Power Operations has identified I&C components, in particular circuit cards, as an "Area for Improvement" at many plants. Because of the time and resources required to replace older I&C systems with modern systems, it may never make business sense in some instances to upgrade these systems. Plants will have to maintain existing systems long past the period where effective vendor support is available. In addition, replacement systems will require maintenance and life-cycle planning for eventual replacement.

Approach
Many nuclear plant operators have requested EPRI assistance in developing programs for managing I&C obsolescence focused on maintaining existing components. The I&C Reliability project provides a forum to exchange plant experience, best practices, and lessons learned. Such interactions support the implementation of effective I&C maintenance and life-cycle management technology and approaches for generic I&C maintenance issues that cut across multiple systems and suppliers. The group ensures that EPRI research and guidance documents respond to, and evolve with, the expanding knowledge base regarding I&C maintenance and life-cycle management.

Impact
I&C system and component failures are expected to increase as plants age, unless aging is carefully managed. This project provides many benefits:

- Broad cross-section of operating experience from which to capture lessons learned
- Identification of high-priority research activities to resolve I&C maintenance and life-cycle planning issues
- Opportunity to advise EPRI on I&C research to ensure activities address industry needs

How to Apply Results
Members apply the results of this project by adapting industry lessons learned into their plant I&C programs to more effectively maintain existing I&C systems and components.