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.

Three initiatives support the I&C Program mission:

1. Improve reliability of existing I&C systems & components
2. Enable the implementation of replacement I&C systems
3. Use advanced I&C to enhance plant health and productivity

Research Value

Research results from the Instrumentation and Control Program enable nuclear plants to realize direct and indirect cost savings, to make technically sound system- and component-level decisions, and to comply with regulatory requirements. Instrumentation and Control Program participants gain access to the following:

- Life-cycle management and maintenance guidelines for generic existing I&C systems and components
- Regulatory compliance support such as the generic resolution of regulatory issues for new and operating plants, risk-informed defense-in-depth and diversity assessment guidance, cyber security guidance, 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 Existing I&C System and Component Reliability — Develop generic technical bases for effective maintenance and life-cycle management of I&C systems and components already installed in the plant, which will always be required to maintain and improve the reliability of the existing I&C systems and equipment.
- Enable Replacement I&C System Implementation — Develop the technical bases to support the deployment and licensing of I&C and human system interface (HSI) replacement systems; develop guidelines for implementing new I&C, information, and HSI technologies in nuclear applications; and document operating experience and lessons learned.

- Use Advanced I&C to Enhance Plant Health and Productivity — Reduce costly downtime and repairs by integrating new technology and techniques such as remote monitoring, wireless communication, early prognosis, and data visualization into operating and new nuclear plants. Adopt simulation and visualization technologies to streamline tasks such as training, maintenance planning, and testing, while reducing the likelihood of information overload and human error.

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. These include the following:

- 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.
- Developed technical guidelines for using field programmable gate arrays (FPGAs) in nuclear safety-related applications.
- Captured the implementation challenges and benefits associated with on-line monitoring to support transmitter calibration interval extension at the Sizewell B plant in the United Kingdom. The use of on-line maintenance allowed a significant amount of safety-related calibrations to be removed from the outage schedule, resulting in savings of more than $1 million per outage day saved, or $5 million per operating cycle.
- 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.
- 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.
- Obtained U.S. Nuclear Regulatory Commission approvals in safety evaluation reports on various guidelines/requirements (digital platforms, commercial off-the-shelf components, electromagnetic interference testing).

Current Year Activities

I&C Program research and development for 2011 will focus on life-cycle management, new I&C system implementation, equipment reliability, and plant productivity. Specific efforts will include the following:

- Develop generic life-cycle management guidance for printed circuit card systems
- Develop improved failure analysis techniques for replacement I&C systems
- Develop training modules for implementing cyber-security technical solutions in new I&C system designs
- 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

Estimated 2011 Program Funding

$2.7 million

Program Manager

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Summary of Projects

Project Number	Project Title	Description
P41.06.01.01	I&C - Improve Reliability of Existing Systems and Components (base)	This project provides generic maintenance and life-cycle guidance for existing nuclear plant I&C systems and components, such as printed circuit card systems.
P41.06.01.01b	I&C Reliability (formerly Maintenance & Life Cycle Management) (supplemental)	Instrumentation and control (I&C) maintenance and life-cycle management has emerged as a critical reliability issue for operating nuclear plants. The I&C Reliability project provides participants with implementation support for I&C maintenance and life-cycle management programs and a forum for sharing experiences and identifying research needs to address emerging problems.
P41.06.01.02	I&C - Enable Replacement System Implementation (base)	Research activities in this project aim to develop the technical bases to support the licensing of I&C and human-system interface (HIS) replacement technologies with nuclear regulators; develop guidelines for implementing new I&C and HSI technologies in nuclear applications; and document operating experience and lessons learned.
P41.06.01.02a	Digital I&C Implementation (supplemental)	The Digital I&C Implementation project group coordinates two workshops per year to promote discussion and resolution of problematic digital I&C implementation issues and development of new solutions, guidance, and training materials when needed.
P41.06.01.03	I&C - Use Advanced I&C to Improve Overall Plant Health and Productivity (base)	Research activities in this project aim to reduce costly downtime and repairs by integrating new technology and techniques such as remote monitoring, wireless communication, early prognosis, and data visualization into operating and new nuclear plants. The project also develops simulation and visualization technologies to streamline tasks such as training, maintenance planning, and testing while reducing the likelihood of information overload and human error.
P41.06.01.03c	I&C Monitoring (supplemental)	The I&C Monitoring project provides a forum for participants to discuss the latest progress in centralized on-line monitoring. The meeting includes a member roundtable to discuss open issues in the application of fleet-wide monitoring tools and identify gaps that can be addressed through separate research projects. A website bulletin board provides a forum for correspondence among members as well as an archive of meeting materials and links to related projects.
P41.06.01.04d	I&C Productivity Improvements (supplemental)	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&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.

I&C - Improve Reliability of Existing Systems and Components (base) (060634)

Key Research Question

Nuclear plants pursuing extended operation will continue operating aging and obsolete instrument and control (I&C) systems and components such as printed circuit cards past the period of effective vendor support. Many of the maintenance and reliability concerns associated with these components are generic to component classes, independent of a particular manufacturer. Further, the transition to digital technology presents many new challenges for nuclear utilities and traditional suppliers for operating long-term, and industry guidance is needed.

Approach

This project develops generic technical bases for effective maintenance and life-cycle management of I&C systems and components already installed in the plant. Near-term research includes the following:

- Life-cycle management guidance for analog and digital circuit card systems: EPRI will work with industry to provide useful tools to plant engineers to improve circuit card reliability. EPRI will develop a “Gold Card” life-cycle management program for circuit cards and perform research to develop new or improved capabilities such as monitoring, testing, diagnosing, and estimating remaining life.
- "Digital" I&C systems preventive maintenance: The lack of industry accepted preventive maintenance guidelines for digital systems may be leading to failures and inappropriate maintenance activities. EPRI will evaluate the data for components of interest and develop preventive maintenance guidelines.
- Electronics Laboratory: EPRI will study the feasibility of starting an "EPRI Electronics Laboratory" where I&C research, operating experience consolidation, test techniques, and other items can be further developed.

Impact

I&C systems and components such as printed circuit cards must be reliable to avoid unplanned plant trips and down-powers. However, too much maintenance or surveillances can lead to maintenance- or operator-induced errors. The results of this project will enable plant owners and operators to specify system tests and maintenance that will minimize the risk of plant transients while maximizing the use of scarce plant resources.

How to Apply Results

Members apply project results to internal procedures for plant monitoring and maintenance to ensure that potentially problematic issues are specifically addressed and tracked through implementation. Members also should train systems engineers and maintenance personnel on the overall findings of this research for general awareness and appreciation.

I&C Reliability (formerly Maintenance & Life Cycle Management) (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 compelled 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/or 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.

I&C - Enable Replacement System Implementation (base) (052365)

Key Research Question

The nuclear industry is transitioning from analog to digital technology. For both operating and new plants, 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 (software common-cause failure), various design considerations for digital control rooms, and the impact of new technologies such as Field Programmable Gate Arrays (FPGAs). Having to develop technical guidance and resolve unsettled regulatory issues as part of an I&C upgrade or a licensing submittal significantly increases project costs and risks and can introduce substantial delays.

Approach

Recognizing that the plant and workforce of tomorrow will demand advanced I&C and human-system interface (HSI) technology, the transformation to digital systems is inevitable. Such a transformation will equip the workforce with tools to drive improvements in plant design, operation, and maintenance. EPRI research

identifies new I&C and HSI technology for the nuclear industry and develops the technical bases necessary for use in nuclear plants.

Specific research activities include the following:

- Provide generic methodology and guidance in support of licensing efforts for nuclear safety-related I&C systems
- Develop improved safety and non-safety capabilities and establish the technical bases for their implementation
- Develop guidelines to address new issues that arise due to technology advances (such as cyber security and electromagnetic interference)
- Develop guidelines reflecting operating experience and lessons learned from implementing digital I&C systems

Impact

- Facilitate shift toward more predictable licensing process for operating plant modernization through generic approaches to digital I&C and human factors technical and regulatory issues.
- Reduce the risk, cost, and time for regulatory approval of license amendment requests and new plant operating licenses through generic resolution of digital I&C and human factors technical and regulatory issues.
    - For operating plants, avoiding uncertainty and delays in regulatory reviews can save years on schedules and millions of dollars per upgrade project in extra work.
    - For new plants, unresolved regulatory issues can add months to years to the schedule and result in significant lost revenue opportunities, on the order of $1 million per day.
- Enable acceptable application of plant simulators and alternate simulation devices for engineering design and evaluation through early user input on new designs and earlier evaluations of new designs for operating plants and new plants.
- Reduce the risks and costs of implementing new technologies such as field programmable gate-array-based safety systems.
- Reduce the risks and costs of responding to new issues such as cyber security
- Feed operating experience and lessons learned into design and maintenance processes to avoid past mistakes and leverage past successes.

How to Apply Results

Research results and interactions with industry groups enable nuclear plant owners and operators to identify, evaluate, and resolve outstanding technical issues with industry-developed guidelines. Utilities, suppliers, and third parties will use these generic solutions for design and license submittals to reduce licensing risk, cost, and time. Regulators will use the technical guidance to develop review and acceptance criteria.

Guidance on new technologies such as field programmable gate-array-based safety systems will allow nuclear plant staff to carry out activities acceptable to the regulator for reducing implementation costs and risks. Guidance on new or evolving issues such as cyber security and electromagnetic interference (EMI) will reduce the risks of these external events impacting plant operations. Early use of plant simulators and alternative simulation devices will improve designs and reduce potential costly redesigns.

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 two meetings per year to address one or two 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/or 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. 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 - Use Advanced I&C to Improve Overall Plant Health and Productivity (base) (052363)

Key Research Question

Existing plant instrumentation and control (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 of I&C equipment and emerging technologies can streamline many plant tasks and procedures to reduce operations and maintenance costs while improving reliability and extending component lifetimes. Examples of such benefits include calibration interval extension, on-line equipment condition assessment, self-testing and diagnostics, and greatly improved access and presentation of plant data via simulation and visualization.

Approach

Tapping into the capabilities of advanced I&C, human-system interface (HSI), and information technologies can increase reliability and productivity while supporting safe, cost-effective, long-term nuclear plant operation. By integrating new technology and techniques such as remote monitoring, wireless communication, early prognosis and data visualization into design, operation, and maintenance practices, nuclear plants can reduce costly downtime and repairs. Digital I&C, HSI, and information technologies also allow greater personnel productivity with expected smaller future workforces.

Adoption of simulation and visualization technologies, for example, can streamline tasks such as training, maintenance planning, and testing while reducing the likelihood of information overload and human error. This research area will identify, develop, and demonstrate advanced I&C, human-system interface (HSI), and information technologies that offer enhanced equipment reliability and plant productivity.

Impact

- Improve work efficiency of plant engineers through the use of automated on-line monitoring tools
- Improve plant equipment reliability by providing more information on equipment condition
- Improve instrument monitoring, allowing extension of instrument calibration intervals
- Reduce cost of adding sensors by using wireless technology rather than cabling to support equipment condition assessment and other applications
- Improve efficiency and reduce cost associated with capturing tacit knowledge from experts and presenting it to others along with simulation and visualization of design and work planning

How to Apply Results

On-line monitoring products will be applied by using the guidance and lessons learned to improve current and future on-line monitoring implementations. The wireless technology products serve as guidance when planning and implementing wireless sensors and networking technology.

Results from the tacit knowledge capture task will be used to determine where and how visualization can be used to benefit the capture and dissemination of expert tacit knowledge.

I&C Monitoring (supplemental)

Key Research Question

The advancing state of centralized on-line monitoring (COLM) provides a broad range of technical solutions to asset management. Several early adopters have progressed to establishing and operating fleet-wide monitoring control centers, but the industry has much to learn with respect to best practices, implementation challenges, and problem resolution. Sharing of such information among users could accelerate COLM application and value.

Approach

The I&C Monitoring project provides a forum for high-level technical information exchange, distribution of current information, identification of common problems and barriers, identification of needed actions by members and EPRI, and a platform for introducing centralized on-line monitoring technology to new adopters. This forum will serve as the gateway for supporting the development and distribution of EPRI technologies.

Meetings are held twice per year to discuss the latest progress in centralized on-line monitoring. The meeting includes a member roundtable to discuss open issues in the application of fleet-wide monitoring tools and to identify gaps that can be addressed through separate research projects.

Impact

Project participation will further the use of COLM in the nuclear power industry. Research and development advances for COLM in the nuclear industry lag behind those in the fossil generation sector. Greater interaction and sharing of lessons learned with participants in the fossil generation sector's Fleet-wide Monitoring Interest Group will support faster distribution and application of the technology in the nuclear sector.

How to Apply Results

The meeting activities will highlight application results. Attendance at the meeting will provide technology implementation opportunities through sharing of information, experience sharing, and technology transfer.

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, and fewer plant staff. Current plant operations are labor-intensive due to the vast number of operational and support activities required by the current technology. These concerns increase as plants extend their operating life.

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 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 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.