Managing I&C reliability and obsolescence

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Exelon Nuclear has developed a strategy for managing I&C obsolescence and phasing in new technology, with the benefits applied to all of its nuclear power plants.

OPERATING NUCLEAR PLANTS are developing strategies for maintaining and replacing aging and obsolete instrumentation and control (I&C) equipment, balancing the need for high reliability against the budget constraints of a highly competitive business environment. Upgrading from the obsolete analog I&C to digital technology offers many new capabilities that can improve reliability and plant performance, but cost-benefit justifications have proven problematic in the current business environment.

Most plants are now extending their operating licenses, which makes a long-term plan for managing I&C obsolescence even more imperative. Exelon Nuclear, which operates a fleet of nuclear plants—the Braidwood, Byron, Clinton, Dresden, La Salle, Limerick, Oyster Creek, Peach Bottom, Quad Cities, and Three Mile Island nuclear power stations—has developed a strategy for managing I&C obsolescence and phasing in new technology that both meets the needs of the fleet and captures the benefits of applying proven solutions to multiple plants, with reduced incremental costs. This article explains Exelon's approach and briefly describes selected industry guidance documents that can be helpful in developing strategies for managing I&C obsolescence.

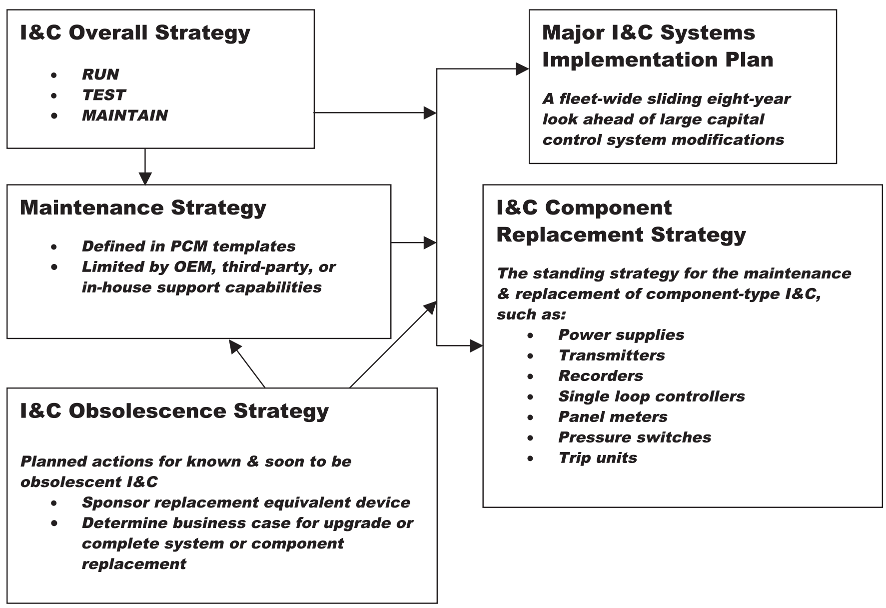

Fig. 1. The Exelon I&C strategy

Ensuring I&C performance

Operating nuclear plants still use a great deal of analog I&C equipment that was designed and built decades ago. Unlike the piping, pumps, valves, and motors in the plants, the I&C equipment that controls all facets of plant operation reaches obsolescence long before the end of a plant's useful life. Piping, pumps, and valves can be welded and remachined and motors can be rewound, but I&C equipment has fundamental components that are no longer manufactured or even available on a secondary market. Circuit boards must be reengineered or the entire component replaced.

I&C obsolescence is exacerbated by the fact that most nuclear plants are now planning to extend their operating licenses by 20 years. As a result, nuclear plants will need to take steps to ensure that each I&C system will be able to perform its intended function until the plant is retired, without contributing to transients or loss of unit output as the hardware ages. Allowing I&C systems to become obsolete can lead to de-

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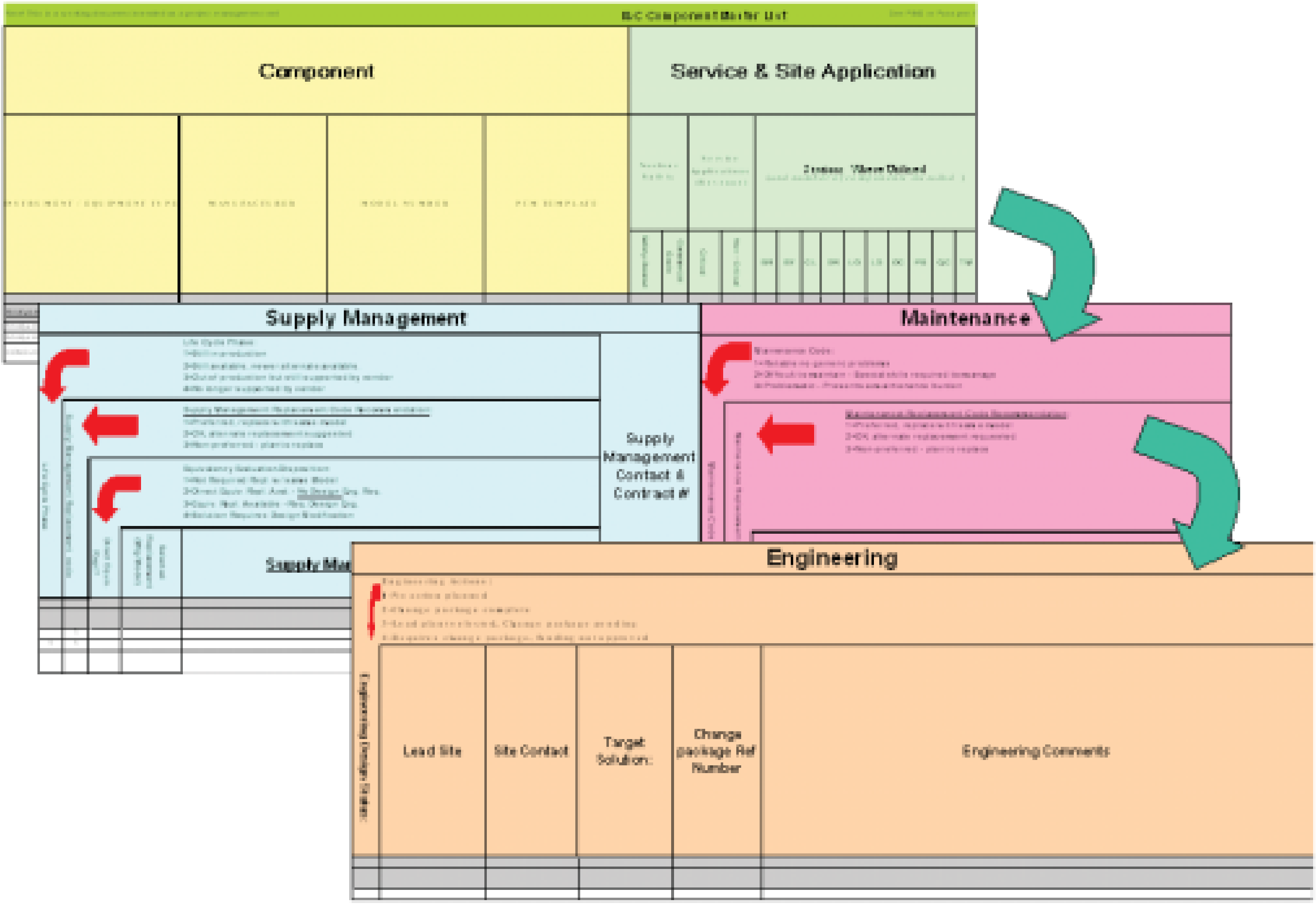

Fig. 2. The Web-based spreadsheet for I&C information management

graded plant reliability and increase the cost of electricity production.

Various industry guidance documents are available to help utilities develop strategies for managing obsolescence. Some are useful in targeting systems for upgrading and in planning and installing upgrades. These effectively take the position that replacement of the obsolete analog equipment is ultimately unavoidable, but that much can be done to optimize the upgrade process and the ways in which new technology is utilized to improve plant reliability and operability. These guidelines also address problematic implementation issues, including regulatory issues, such as electromagnetic compatibility, software common-cause failure, and the use of commercial digital equipment in high-integrity applications. In addition, there are various maintenance and life cycle management guides that are useful for finding ways to use upgrades to reduce plant operating costs.

Exelon Nuclear has applied the industry guidance to formulate an approach to managing I&C reliability and obsolescence at its nuclear plants. The Exelon I&C Asset Management Strategy is intended to maintain existing plant control systems to achieve high plant reliability while coping with component obsolescence. It assigns priorities based on a system's potential for compromising plant availability. Also, to meet system reliability goals in future years, the strategy uses a combination of options: periodic maintenance, refurbishment, and component or system replacement.

A comprehensive plan will define the current system configuration and all time horizons for the changes necessary to implement the desired future state of the system, including consideration of vendor product life cycle and phaseout schedules, and the evaluation of long-term component options, such as run-to-failure and maintaining until end of plant life. Interim maintenance of obsolete equipment will be supported by various methods, including equipment service agreements, spare parts stocking, and lists of acceptable substitute products for component replacement. This approach creates a framework within which decisions are made to guide system maintenance, refurbishment, and strategic component replacement to minimize failures while preparations are made for replacements or upgrades.

I&C Asset Management Strategy

Exelon's I&C Asset Management Strategy (see Fig. 1) is a comprehensive and dynamic plan to manage existing and future plant control systems within Exelon's nuclear fleet. The strategy comprises two major segments: the Major I&C Systems Implementation Plan and the Component Management Strategy.

The Systems Implementation Plan

Exelon developed its long-term Major I&C Systems Implementation Plan to improve plant operations, eliminate operator challenges, reduce maintenance costs, and cope with the challenges of component obsolescence. This plan is an eight-year projection for large outage-dependent control system upgrade projects where a complete upgrade, rather than component changeout, is the best course of action. The plan identifies fleet-wide I&C upgrades, coordinates capital budgets, identifies a lead plant, and works to develop modification packages that can be implemented at multiple sites.

The Component Management Strategy

Exelon's I&C Component Management Strategy was developed to cope with the "here and now" of managing the existing I&C at its plants. This includes a deliberate coordination with the Major I&C Systems Implementation Plan to ensure a seamless transition between small incremental upgrades and a complete system changeout in the future. Regardless of the status of any large-scale system modifications, however, it is neither cost-justifiable nor necessary to revamp all plant I&C systems. In addition, even if a large-scale renovation is scheduled, a short-term coping strategy may be necessary to provide more immediate incremental reliability performance improvements.

The strategy facilitates a disciplined approach to identifying those components that have become a support challenge and also helps to prioritize solutions. The approach is fleet-wide and provides a common point of documenting existing alternative replacement solutions.

Managing the information

The specific I&C model types at Exelon's plants vary because of differences in plant age, nuclear steam supply system vendor, and architect-engineer. Part of managing such a diverse complement is to lay it all out for all the stakeholders to see. To do this, a Web-based spreadsheet (see Fig. 2) was developed. The spreadsheet uses a performance-centered maintenance (PCM) approach to capture the data. It organizes the components by product type and manufacturer product line, making it easy to document existing maintenance practices and where solutions are identified or needed.

Spreadsheet description

The spreadsheet is organized as follows:

■ *What is it?* and *What are you doing now?*—Existing I&C Components and Maintenance Practices are listed by generic category, generic name, manufacturer, model number, and the appropriate PCM template (EPRI 1003586, 2002). Since the intent is to manage obsolescence, the spreadsheet is organized by vendor product line and *not* by plant function. (See the discussion of configuration management versus obsolescence management that follows).

■ *Where is it?* and *How many?*—Service & Site Application lists where, how used, and how many I&C components are installed at a site.

■ *Where is the component in the life cycle?*—Supply Management (procurement engineering) is a stakeholder in the process, and normally is the first to know when a vendor has decided to stop supporting a product line.

■ *How is maintenance coping?*—Maintenance is responsible for managing the site complement of I&C components. The spreadsheet provides a method for communicating where maintenance management is difficult or resource-intensive.

■ *What is Engineering doing about it?*—The spreadsheet provides a spot for Engineering to identify existing solutions, plans for a solution, or where a solution is needed.

Spreadsheet implementation

The spreadsheet is intended to be a resource, a common point for communication, and a broad cross-fleet project management tool. As such, all stakeholders post information and use the spreadsheet as a cross-communication tool, with specific uses and benefits for each, as follows:

■ *For system managers, supply managers, and maintenance personnel*—I&C Component, Service & Site Application provides information on I&C components installed at a site, and provides a cross-reference to the same information at other sites.

■ *For supply managers and maintenance managers*—The spreadsheet provides a common location to document where the component is in the life cycle. This information is important because awareness can provide early warning on components that will be harder to manage in the future, since replacement parts may become more difficult (and more expensive) to find. In addition, the Maintenance Department may need to adjust its maintenance practices because maintaining an obsolete component limits maintenance options.

■ *For maintenance managers*—The spreadsheet can be used to identify clearly which components are difficult to maintain and to help prioritize a schedule for a solution. For example, new replacement parts may not be available, the quality of obsolete parts available on the spot market may be less than satisfactory, the options for in-house or third-party support may not be acceptable, or special skills or training may be necessary to perform the maintenance.

■ *For engineers*—The spreadsheet provides a quick reference for existing solutions, enabling other sites to take advantage of existing pre-engineered solutions as appropriate. Also, use of the spreadsheet's sorting capabilities can push to the top all the components that have been identified by Supply Management as "obsolete" and by Maintenance as "difficult to maintain." This can enable Engineering to plan its resources and create solutions for maximum fleet-wide benefit.

Additional considerations

Configuration vs. obsolescence management

Although the component records do an adequate job with regard to plant configuration management, from a standpoint of component maintenance and obsolescence management, there is a need for a broader grouping—namely, since the spreadsheet is intended to manage obsolescence, it groups components the way a vendor would group them: by product family (the root model number—for example, Rosemount 1151) and not specific model numbers (model numbers identifying specific options—for example, Rosemount 1151GP9G22B2). Grouping components according to what they are, not what they do in a particular application in the plant, is important. For example, a dp transmitter could be labeled as both a "flow transmitter" and a "differential pressure transmitter." That is all right from a plant component record standpoint, but for purposes of obsolescence manage-

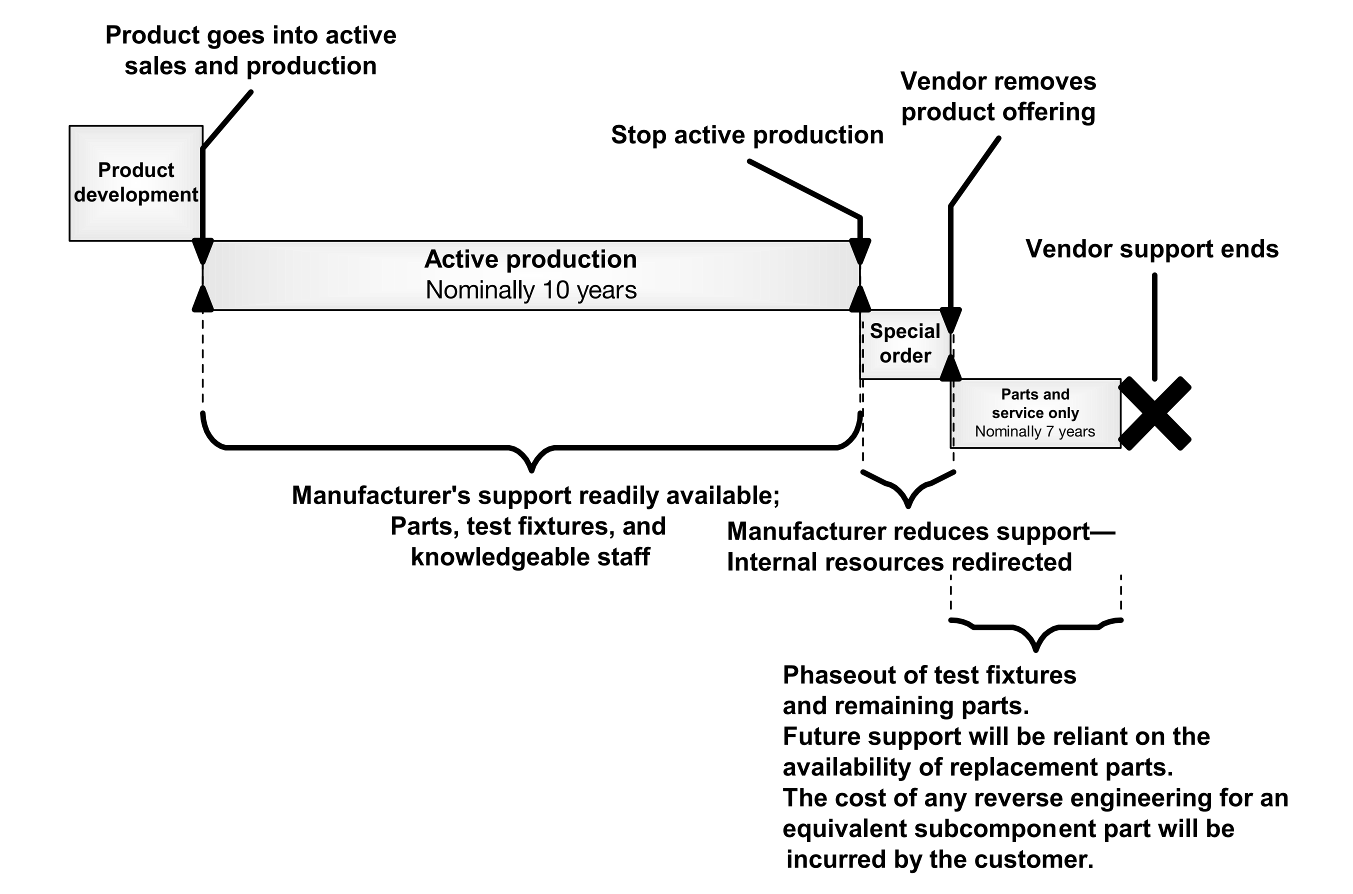

Fig. 3. The I&C product life cycle

ment, the list shows it only as a differential pressure transmitter.

Product life cycle considerations

A product's life cycle phase influences the available options and the basis for decisions regarding the nature of repair/refurbishment/replacement activities. Figure 3 shows a generic product life cycle for I&C equipment. Table I. shows Exelon's repair/refurbishment strategies for each of the life cycle phases.

In general, if the original equipment manufacturer (OEM) can provide support, the repair should be guided by OEM recommendations. Unless it is determined to be otherwise, parts supply for products in Phase 4 (no longer supported by OEM) should be purchased from an Exelon preferred parts supplier. I&C components in Phase 4 that have proven to be unreliable are the first candidates for alternate replacement consideration.

Barriers to success

New solutions, different technology

The basic (internal) functioning of newer I&C designs operate using completely different principles. Previous designs incorporated continuous multiple dedicated paths of analog circuits to process signals. Now, a single microcontroller processes multiple independent signals by time-sharing.

Earlier generations of control design used dry switch contacts, while newer designs incorporate solid-state switches. Previously, basic options and functions were set by the vendor or by internal switch/jumper selection. Now, a general-purpose multifunction device is "configured" by downloading a setup program. Calibration once involved balancing multiple interactive adjustments; now "calibration" is by keypad.

At one time, internal process signals could be traced by way of schematic and wiring diagrams to specific internal components. Now, internal "schematics" are functional representations of the device as configured, not as wired.

Infrastructure changes

Existing 1960s and 1970s nuclear plants are a hybrid mix of point-to-point multigenerational 120-VAC, 125-VDC, 4–20-mA thermocouple and pneumatic I&C schemes. A tour of a typical plant equipment room reveals rack upon rack of cabling. All higher-voltage control was dutifully segregated from lower-voltage signal cables.

Newer designs run the motive force only to the final element. Control and monitoring are multiplexed onto a common networked fiber bus in a multidrop configuration. Conversion from point-to-point cabling to multidrop is labor-intensive and expensive.

New failure modes

Although new technology I&C may appear externally to be processing multiple signals concurrently, in reality, the signals are "time-sliced" and processed in discrete steps. Because of this, digital devices can fail in ways that are different from their analog counterparts.

■ *Electromagnetic interference (EMI)*—An analog device may react to an EMI-

TABLE I. REPAIR/REFURBISHMENT STRATEGIES BY PRODUCT PHASE

Product Phase		**Source of refurbishment/ replacement services:**
• Phase 1	Product in active production	Original equipment manufacturer (OEM)
• Phase 2	OEM has stopped active marketing of model	Determine if OEM provides a suitable part equivalent replacement option
• Phase 3	OEM phaseout of model line	Continue with OEM support; start transition to third party repair services
• Phase 4	OEM no longer supports model or part replacement	Third party source for parts and repair services

Note that third-party services may actually be a generic supplier of repair services, a niche "specialty" vendor, or in-house resources.

induced disturbance by deflecting upscale or downscale. When the disturbance is removed, most analog devices will return to their previous state. Under the same circumstances, a digital device's processor may "halt" and not return to its previous state after the disturbance. Awareness of this failure difference becomes even more significant during the retrofitting of newer devices into the highly EMI-active environment of a 1960s–1970s generation electromechanical nuclear plant. Fortunately, the effects of EMI susceptibility can be quantified, and vendors test their products and publish their compliance to established industry standards.

■ *Radiation*—Standardized testing of EMI susceptibility exists in commercial products, but this is not the case in radiation testing. MOS-FETs (metal-oxide semiconductor field-effect transistors) used in processor technology have a lower tolerance to radiation than previous control system designs, so quantifying the reliability of digital I&C under mild radiation dose becomes a new requirement.

■ *Silent failures*—A processor halt may not be so obvious. In the event of an internal failure, the processor may be halted, but the display may still show the last value. The operator may not be aware that instrumentation is asleep at the switch.

■ *Physical fail-safe not possible*—When power is removed from an electromechanical relay, the relay will drop in a predictable configuration. Such predictability is not necessarily achievable with digital designs. Although the functionality of relay interlock logic may be similar, for a digital device the represented relay logic is replaced with a software program. Coils are no longer connected to contacts. The outputs hold until the next instruction.

Quantifying reliability

Failures within a digital device may be caused by component or program. Although there is a preponderance of field evidence that digital systems are more reliable, quantifying this reliability has been elusive. Component failures can be predicted by typical statistical component reliability methods. There is no accepted methodology, however, to quantify the failure probabilities of a control application operating within a multitasking operating system environment.

Challenges to infrastructure

New failure types, new technology, and new topography all present challenges to the existing physical, procedural, and organizational infrastructure. Economical movement to new design can be successful only if the solutions are packaged in a manner that renders a positive business case over continued maintenance of the existing equipment.

With 10 plants, Exelon is in a position to take advantage of economies of scale by using design-once/install-many concepts. The sites within the Exelon fleet, however, are different vintages, so implementing common solutions will require site-unique adaptive changes, which include the need to identify clearly the regulatory and structural differences among sites. Upgrade efficiency will be realized only when these differences are identified and understood prior to the development of pre-engineered solutions.

Evaluation adequacy

Considering the nature of newer digital solutions, when are the typical "form-fit-function" evaluations good enough? At present, if digital technology is involved, Exelon's process drives all evaluations of I&C replacements to an engineering evaluation. In the future, could there be a lower limit at which such evaluations of simple devices are unnecessary?

Combination of functions

Newer solutions may provide opportunities to simplify design by combining existing disparate functions into a single device. When could this be an issue? Although plant probabilistic risk assessments (PRA) may quantify core damage due to the failure of a system, the PRA often does not break a system down into subcomponent parts. Quantifying incremental reliability improvements becomes difficult. It is important to know where credit is taken for diversity and defense-in-depth, such that the basis assumptions are not violated when new designs are incorporated into an older plant.

Challenges to configuration management

Digital equipment suppliers, and especially commercial-grade digital equipment suppliers, are continuously updating their software and hardware components. At what level is a subpart replacement below the level of configuration management detail? How and when do we need to control vendor configuration management? When is it appropriate to perform incremental maintenance upgrades to keep in step with the vendor? Existing guidance does not always provide answers.

Business case development

The present plant accounting structure may track the operating cost of a system. For the most part, however, accounting does not quantify the cost of component maintenance and the time expended by supply managers in locating replacement parts for obsolete systems. As such, the existing accounting of system costs is rarely relied upon to help develop a business case for replacement alternatives beyond like-for-like. Even without the cost of support in the business case equation, newer designs tend not to fail as often. Fewer component failures equates to higher system reliability. Unfortunately, system failure risk reduction is not easily quantifiable, so including a monetary value for risk reduction in a business case in justifying system modifications has been elusive.

Industry guidance

The electric power industry has sponsored EPRI's work on this subject since the early 1990s, and many guidance documents are now available. Topics addressed include upgrade planning (EPRI 1003103, Dec. 2001; EPRI TR-105555, Aug. 1995; EPRI TR-106029, Dec. 1996; EPRI TR-104963, July 1996), cost-benefit analysis (EPRI TR-101984, Dec. 1992), and various implementation and regulatory issues such as licensing, electromagnetic compatibility, software verification and validation, control room modernization, and evaluation of commercial-grade digital equipment. EPRI TR-107980 catalogs the documents by topic through 1997. Information on all the available materials can be found at <www.epri.com>.

Strategy development

Exelon Nuclear has applied available industry guidance to develop a strategy for managing I&C obsolescence and phasing in new technology that coordinates activities among the company's 10 nuclear stations for maximum efficiency. The approach both meets the short-term needs of the plants and captures the benefits of applying proven solutions to multiple plants, with correspondingly reduced incremental costs.

Cost-benefit justification for I&C upgrades on a component-by-component or system-by-system basis remains problematic in the current business environment. The approach described here has great flexibility, however, and can easily accommodate changes in the business outlook, good or bad, to manage I&C obsolescence in a systematic, cost-effective manner.

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