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THE PLANT-WINDOW SYSTEM

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Abstract

Power plant data, and the information that can be derived from it, provide the link to the plant through which the operations, maintenance and engineering staff understand and manage plant performance. The increasing use of computer technology in the U.S. nuclear power industry has greatly expanded the capability to obtain, analyze, and present data about the plant to station personnel. However, it is necessary to transform the vast quantity of available data into clear, concise, and coherent information that can be readily accessed and used throughout the plant. This need can be met by an integrated computer workstation environment that provides the necessary information and software applications, in a manner that can be easily understood and used, to the proper users throughout the plant. As part of a Cooperative Research and Development Agreement with the Electric Power Research Institute, the Oak Ridge National Laboratory has developed functional requirements for a Plant-Wide Integrated Environment Distributed On Workstations (Plant-Window) System. The Plant-Window System (PWS) can serve the needs of operations, engineering, and maintenance personnel at nuclear power stations by providing integrated data and software applications (e.g., monitoring, analysis, diagnosis, and control applications) within a common environment. The PWS requirements identify functional capabilities and provide guidelines for standardized hardware, software, and display interfaces to define a flexible computer environment that permits a tailored implementation of workstation capabilities and facilitates future upgrades.

Introduction

The growing obsolescence of analog technology, the possibility of improved plant performance, and the potential for reduced operations and maintenance costs have led to the increased use of computers and digital technologies in upgrades of instrumentation and control (I&C) systems by the U.S. nuclear power industry. As a result, the Electric Power Research Institute (EPRI) established the Integrated I&C Upgrade Initiative¹ to foster research and development on the use of

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modern I&C technologies and to develop and demonstrate unified, plant-wide upgrade strategies. One technical objective stated in the Upgrade Initiative plan is that the plant control room should provide compact human-computer interfaces that can "sort, concentrate, suppress, recall, display, and interface information" in support of all day-to-day operations. Further, upgraded I&C systems should assist the operator in accessing any information necessary to understand a problem situation, make appropriate decisions, and effect responses. The primary objectives of the Upgrade Initiative include enhanced safety, improved plant availability, and reduced operating and maintenance costs. Meeting the EPRI program goals to support plant-wide upgrade strategies involves developing system integration methods and mechanisms that have the flexibility to satisfy the specific needs of individual plants and the expandability to address the demands of a phased upgrade approach.

As part of the EPRI Integrated I&C Upgrade Initiative, the **Plant-Wide Integrated Environment Distributed On Workstations (Plant-Window) System Project** was established to define a distributed computing environment that provides needed software capabilities and I&C system access to support the activities of nuclear power plant personnel through a common, integrated interface. The Plant-Window System (PWS) targets the difficulties presented by phased I&C system upgrades at power plants, and it counters the tendency toward isolated systems with unique interfaces, diverse interaction mechanisms, and duplicate functions. An integrated interface to the plant I&C systems provides the necessary information and software applications, in a manner that can be easily understood and used, to the proper users throughout the plant. A system of workstations connected to plant communications networks can supply the common computing environment to facilitate access to data and applications by plant personnel. PWS workstations are conventional computing platforms ranging from personal computers with windowed, multitasking operating systems to high-end engineering workstations. The PWS can serve as the vehicle through which modern I&C systems and distributed data sources are integrated, at the user interface, to support operations, maintenance, and engineering tasks in the plant. The underlying system architecture provides the expandability and flexibility to permit a phased introduction of PWS functionality at a plant and to allow a tailored implementation of the system by a utility. This approach allows the introduction of computer technology in an efficient, cost-effective manner while optimizing the benefits to the plant.

Without a coordinated approach to plant system upgrades, nuclear utilities are faced with the prospect of stand-alone systems or data sources with incompatible interfaces. Typically, new I&C systems have been added to a nuclear power plant under independent projects without enough attention to the integration of these systems into a consistent overall architecture. Many of these systems are implemented on "closed" architectures where the supplier uses proprietary or vendor-specific user interface, software, operating system, or network components. As a result, utilities have been forced to purchase upgrades from a specific supplier, which may not offer all the desired capabilities, or to construct a piecemeal system of applications and computers from various suppliers with special-purpose interconnections. Utilities have gained experience with this nonintegrated approach as they have installed new plant systems such as add-on safety parameter display systems (SPDSs), upgraded plant computers, and digital feedwater control systems. This approach can lead to many unfavorable consequences, such as a propensity for single-purpose user interfaces in the control room, an increased burden on plant operators to access and assimilate information from multiple disparate sources, and a greater demand on maintenance staffs to manage diverse digital systems.

Plant-Window System Project

In 1992, EPRI and Oak Ridge National Laboratory (ORNL) initiated a multiyear Cooperative Research and Development Agreement (CRADA) to address issues concerning the upgrade of I&C systems at nuclear power stations. As one task under this CRADA, the U.S. Department of

Energy and EPRI jointly funded the development of the PWS concept. The primary result of this project is a functional requirements document defining the PWS. The *Plant-Wide Integrated Environment Distributed On Workstations (Plant-Window) System Functional Requirements*² is currently undergoing an industry review and can be obtained in draft form from EPRI. The requirements provided in that document can be used by utilities and vendors to design and develop the following:

- a detailed architecture for the PWS,
- the PWS environment software,
- PWS application programs,
- consistent PWS human-computer interface conventions,
- interfaces between application software and the PWS environment,
- interfaces between plant systems and the PWS environment, and
- development tools in support of PWS applications and interfaces.

The functional requirements define the PWS concept by describing the necessary characteristics and attributes of a functionally integrated computing environment, supported on a distributed architecture of interconnected workstations and I&C equipment, that provides personnel with plant systems access and software applications. The functional requirements attempt to be sufficiently complete to

- guarantee that the PWS achieves its goals and
- provide a useful starting point for the utility's detailed specifications.

At the same time, the requirements provide flexibility in establishing the detailed PWS design so that a utility can make the most efficient and cost effective use of the existing computing architecture, expertise, and equipment at its plant. The approach taken in defining the functional requirements is to identify open systems standards and existing guidelines, where possible, for use as reference models and to establish a strategy for providing consistency and interoperability through shared functional libraries and interface conventions. The functional requirements establish "what" capabilities the PWS must provide without being prescriptive on "how" these requirements are met as part of the detailed design and specification process. The flexibility of this approach allows a utility to adapt the PWS to the site's evolving computing architecture.

The requirements provide a framework that each utility can use to develop a detailed PWS design and system specification for its plant. The utility produces plant-specific requirements, giving consideration to its present computing architecture and future plans, the technologies available for implementation, and the activities for which PWS support is desired. As part of the design process, the utility should determine the tasks the PWS will perform, select the applications that will run on the PWS, and identify the plant personnel who will use them. Specifications for the PWS detailed design can be derived from the functional requirements based on the tasks selected for PWS support, commercially-available software products (e.g., middleware), existing plant computing and I&C systems, and the plant's computing and communications architecture plan.

Plant-Window System Overview

PWS Objectives

The PWS is intended to support the activities of operations, maintenance, and engineering personnel at a nuclear power plant. Many activities for controlling, maintaining, and managing a nuclear power plant are performed with computer applications. Additionally, modern I&C systems with video display interfaces are being introduced as upgrades. Therefore, a distributed,

workstation-based support structure that provides plant-wide computing capabilities and serves as a common interface to I&C systems can be used by plant personnel in the performance of numerous tasks.

The objectives of the PWS are to

1. Provide a common, consistent user interface to I&C systems;
2. Enable uniform, transparent access to distributed data sources;
3. Establish a computing environment that facilitates the integration of information and applications;
4. Furnish a system architecture that permits flexibility in implementation and expandability of functional capabilities; and
5. Define an approach to application support that lays the foundation for standardizing functions and interface conventions for the nuclear power industry.

Simply establishing network links among the various systems and installing workstations as network nodes addresses only part of the desired support for plant personnel. Meeting the objectives of the PWS involves more than just providing a common workstation platform with which to interact with the I&C systems in the plant. Each PWS workstation must provide a consistent, easy-to-use interface to plant systems based on established human factors guidelines. In addition, distributed data management capabilities with uniform data interaction services and a consistent data representation are necessary. Transparency implies plant-wide data access without requiring the user to become involved in the details of locating and connecting to data sources on the network, interacting with different data sources through diverse transaction mechanisms, and converting data from different sources to a common representation.

Access to systems and distributed data sources through a common platform brings together the functions and data that are necessary for many plant activities. Furthermore, integrating the display of data and the interaction with plant systems can lead to enhanced applications to support station personnel. Thus, the integrated computing environment of the PWS supports the capability to simultaneously access data from different sources and perform multiple functions and makes possible the development of new applications that integrate functions which are complementary but have customarily been performed separately by isolated applications.

To be practical, the PWS must address the realities of introducing new capabilities and system upgrades to existing nuclear power plants. It is not feasible to shut down a nuclear power station to engage in an immediate site-wide upgrade of the plant computing and communications architecture and all I&C systems. As a result, the PWS must provide a system design that can adapt to the existing plant architecture (i.e., some mixture of original I&C systems; upgraded digital systems; and a variety of computing resources such as mainframes, workstations, and personal computers). In addition to providing flexibility in implementation, however, the PWS must also provide the capability to expand the system through more extensive networking or the addition of functional capabilities through new applications. As I&C systems are upgraded during plant outages, a distributed PWS structure can accommodate new systems without requiring significant modification and support additional functional capabilities by providing modular application support libraries and using consistent interface protocols for applications.

The objective of establishing a flexible system architecture and an expandable computing environment implies that the PWS should adhere to open systems principles and adopt developing computing standards where practical. Such an approach supports platform independence and application portability, allowing existing computing resources to be accommodated and ensuring compatibility with upgrades made over a period of years by different vendors. The PWS computing environment can provide the basis for a standardized integrated environment by defining an approach to accomplish the integration of information and applications within a

computing support structure. The functional capabilities of the PWS are established by the functional requirements, but the successful application of those capabilities can be met by a variety of different implementations. The PWS does, however, provide a vehicle for developing a nuclear industry consensus on the functionality and form of applications and their interfaces.

PWS Concept

The PWS concept involves a computing support infrastructure that facilitates the integration of data and applications in a nuclear power plant. The PWS provides common user workstations (or consoles) to interface with plant systems and to serve as standard computing platforms to support existing software applications. In addition, the PWS provides an integrated application environment for the development and use of new software capabilities drawing on the functional integration of diverse data sources and shared information between applications. The system architecture consists of workstations, distributed throughout the plant, that are connected to the plant communications networks.

The PWS supports the activities of personnel throughout the plant by furnishing a common computing environment in which to execute required applications and access digital plant systems. Each PWS workstation provides a user interface to connected I&C systems and gives functional support for a variety of applications involved in monitoring, analysis, diagnosis, and control activities. As a result, it is possible to perform many tasks simultaneously from a PWS workstation while accessing multiple I&C and data systems. The distributed capabilities of the PWS allow plant personnel to interact with digital systems and perform data processing and computing tasks using PWS workstations in the control room, in their offices, or at remote sites in the plant.

The PWS can support a variety of software applications, some of which are currently available from various I&C system suppliers and others of which will be unique applications possible only with shared information and integrated functionality. These applications can be implemented in a modular fashion to allow a utility to select functions for initial installation while maintaining the option of easily adding applications in future upgrades. General PWS application categories include monitoring, annunciation, diagnosis, analysis, control, decision support, management, and training. In the case of existing applications, the PWS will provide a common computing platform for accessing and executing plant software. In addition, the PWS provides an integrated application environment for the development and use of new software capabilities, drawing on the functional integration of diverse data sources and shared information between applications. Through the Plant-Window environment, information not previously available (in the form of data from the many sources within the plant or as processed information from other applications) can be used by applications to enhance the performance of their intended function and to provide well-founded, more reliable information to the user.

The PWS can be implemented across segmented subnetworks with interconnecting devices providing managed communications (e.g., network bridges that provide a pass-through link, filter messages to limit traffic, or permit only one-way information flow). Using this strategy, plant systems and data sources that support related activities and have similar functional capability needs can be grouped on subnetworks. Interconnections to other subnetworks can be provided to support any required data flow to distributed users in the plant. In addition, additional subnetworks can be added to accommodate subsequent upgrades of other plant systems or new user groups. The PWS concept does not prescribe the structure or communications details of a plant network architecture. It is assumed that the utility has established or will establish the necessary plant network arrangement to provide the physical connections between PWS workstations and the digital I&C and computing systems existing in the plant.

It is possible for the PWS user to access and interact with any digital I&C system or computing system connected across the plant communication networks. However, implementation decisions may lead to limited access or user interaction capabilities from some or all Plant-Window consoles. Certain access restrictions must be enforced to provide an appropriate level of information and functional security (e.g., nonoperations personnel should not be allowed to initiate control actions, and control room workstations should not be burdened by performing engineering drawing updates). The functions performed from individual Plant-Window consoles and the system interconnections provided across the plant network are selected by the utility. The distributed architecture of the PWS accommodates the establishment of "domains" of protected data, applications, and I&C systems. This allows the utility to address plant security issues, to ensure the integrity of data and plant system functions, and to protect critical activities from any harmful interactions with other tasks within the plant. The means for protection are network control, personnel access management, and physical isolation. Network control includes providing network management of communications pathways and configuring the network architecture so that only selected workstations are linked to protected resources. Personnel management involves physical access control and personnel supervision for certain plant areas such as the control room. Physical isolation can be performed by permanent or manually-activated isolation devices to prohibit or limit interaction between the PWS and selected plant systems (e.g., reactor protection system).

The multipurpose mission of the PWS makes it undesirable for use as a primary operator interface for control and interrogation of plant safety systems. The interface needs for safety systems are best handled by specialized, dedicated display terminals or through conventional control board devices. Therefore, the use of the PWS workstations as safety system interfaces for more than passive monitoring has been excluded from the PWS concept. Additionally, PWS workstations are not expected to be integral parts of plant control systems. Plant control systems require dedicated functions and deterministic closed-loop response that are best provided by digital systems designed specifically for that purpose. Therefore, automatic plant controls are not included in the PWS concept. However, the PWS is intended to act as a common interface to plant control systems by supporting manual control, setpoint control, and other user interactions.

Plant-Window Framework

Each PWS workstation provides a base hardware platform connected as a node to a plant network. This platform supplies general-purpose computing system services through its resident operating system, its user console, and its network communications services. To this point, a conventional workstation has been described. The PWS, however, provides also an application environment that is common to all PWS workstations connected to the networks within the plant. This application environment supplies standard functional modules to support integrated software applications. It forms the basis of a "plug-and-play" support environment through standard services and interface conventions.

Essential elements of the PWS are data access, resource management, control access, human-computer interface, and application support. Figure 1 shows the major functional layers of the Plant-Window framework. This functional architecture provides the inherent capabilities required in the PWS concept. The layers of the Plant-Window environment are:

1. **Platform Applications**—This layer includes the existing, nonintegrated applications at a plant and the native operating system interface of the workstation platform. Such applications are supported to allow for incremental introduction of the PWS at a plant.
2. **PWS Applications**—This layer includes user applications that perform plant tasks, standard utilities that provide user access to basic PWS capabilities, and the user shell that provides the user's interface to PWS applications.

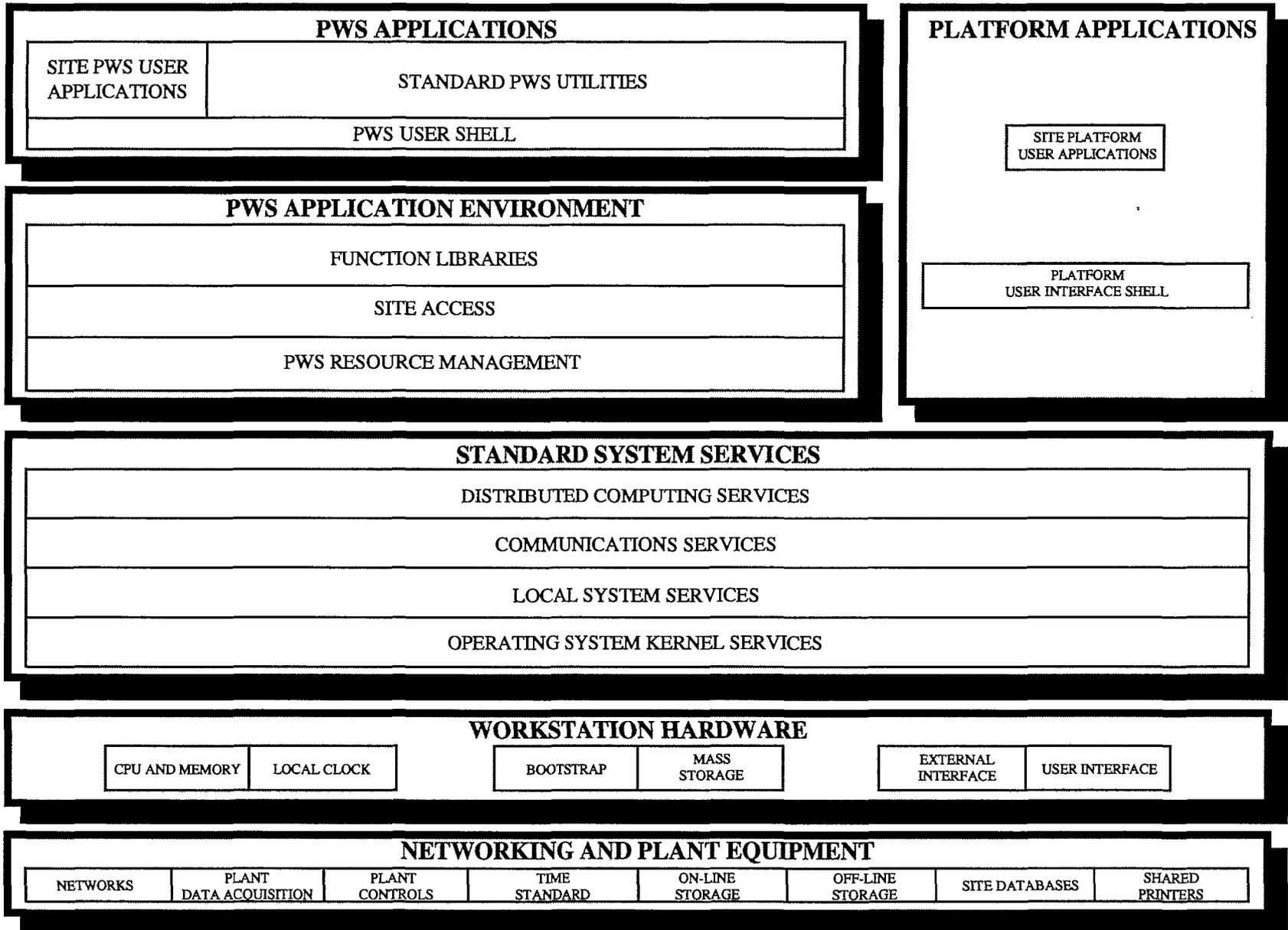


Figure 1. Plant-Window framework.

3. PWS Application Environment—This layer provides the application support functionality of the PWS that facilitates integration. It includes function libraries that provide standard modules to perform tasks for applications, distributed operations for coordinating activities throughout the PWS, site access services that facilitate interaction with plant systems, and resource management that administers PWS configuration and authorized access to Plant-Window capabilities.
4. Standard System Services—This layer includes the basic operating system functions provided by typical engineering workstations. In addition, industry-standard distributed computing and communications services are provided. These functions and services provide the core capabilities of workstation platforms. The Plant-Window environment manages the access and use of these services to give integrated computing support across the distributed PWS architecture.
5. Workstation Hardware and Networking and Plant Equipment—These layers provide the computing, communications and I&C equipment involved in the PWS architecture. The workstation hardware for a Plant-Window console is selected and configured according to the primary tasks it is intended to support. The network and plant systems depend on the existing plant configuration and the plant computing and communications architecture plan for the utility.

The functional architecture illustrated in Fig. 1 provides a layered organization for the PWS applications, software services, and hardware components. Each layer provides functional entities to support the accomplishment of plant tasks using PWS workstations. The requirements presented in the PWS functional requirements document are arranged according to this framework.

Integration Issues

To provide the desired functionality with flexibility and expandability, the Plant-Window environment must be characterized by interoperability, portability, and integration. Interoperability is the characteristic of a system that allows system functional modules and applications to communicate and interact with each other even if they reside on different computer platforms. This is accomplished by defining the integrated computing environment of the PWS based on standards for communication, distributed computing, and data interchange.

Portability ensures that applications are decoupled from the computing hardware and operating systems such that they may be transported from one system to another. Thus, PWS application software developed on one PWS platform should be portable to another PWS platform, (e.g., to a different computer, plant, or utility) with a minimum of effort. As a result, applications are not tied to a particular computing platform or vendor so the effects of digital system obsolescence can be minimized. Portability is accomplished through well-defined interfaces, generically termed application programming interfaces (APIs) in this document. APIs are used to support communication and interaction between plant systems and data sources and the Plant-Window environment, and between PWS application software and the Plant-Window environment. Standardized APIs allow application software developers and system vendors to be isolated from implementation-specific details.

Integration contributes significantly to the useability of a system. The PWS provides three types of integration.

1. Access integration provides a familiar and consistent interface for application software and uniform means to access plant data sources. Consistent user interfaces benefit the user by increasing the efficiency of interface interactions, decreasing the likelihood for user errors, and

reducing the learning curve for new applications. Uniform, integrated access mechanisms to data greatly reduces the complexity of accessing and managing data for the user and for applications.

2. Spatial integration brings applications and data from remote or diverse systems to the user through a common access point (i.e., a PWS workstation). Thus, separate workstations or terminals are not required for each function or data source being accessed. This feature helps alleviate the proliferation of vendor-specific video display units (VDUs) such as CRTs, particularly in the control room. Further, spatial integration allows for the simultaneous display and manipulation of disparate information (e.g., CAD drawings, computerized plant procedures, and real-time plant data) in ways that provide more functionality than is possible using single-purpose displays. Spatial integration can be accomplished through a combination of access integration, multiple processes, and a windowed display system.
3. Functional integration permits interactive cooperation among applications and provides shared functionality. Interprocess transactions allow an application to request computation or information support from other applications. For example, an operator advisor application could interact with a faster-than-real-time simulation to acquire performance prediction calculations. Shared software modules provide integrated functionality by making high-level functions jointly available among applications. For example, a common node-connectivity module, which can establish and manipulate links between equipment, can be used by cable router, separation analysis, and equipment tag-out application software in the maintenance, operations, and engineering departments. Traditionally, each of these applications would require its own specific node-connectivity code; the PWS approach is to provide a standard software module and make it available to all applications through functional libraries. Finally, functional tasks can be integrated, given data access integration. For example, maintenance planning, equipment tag-outs, system markups, and limiting conditions of operation (LCO) tracking can be implemented in an integrated fashion once the data are integrated.

These features are characteristic of open systems. An open system environment is transparent to the underlying hardware, software, and communications systems and will allow utilities to build systems using diverse suppliers. Commercially available open system communications and distributed computing products have not yet settled into fully defined standards. However, the advantages of these concepts are sufficient to be included in the PWS definition, and PWS implementations should take advantage of the available technology.

Benefits and Advantages for Utilities

The PWS has been devised to support and facilitate the goals of the EPRI Integrated I&C Upgrade Initiative. Those goals involve enhanced productivity, reduced operations and maintenance costs, and a greater assurance of safety. The use of the PWS to coordinate data access and to interface with upgraded plant systems can lead to more efficient operation of the plant, a reduction of unnecessary operations and maintenance costs, and a decreased propensity for errors while performing plant tasks. The approach taken in defining the PWS provides inherent advantages that may be broadly expressed as follows:

- Support of newer applications is provided to enhance the presentation of information to the user. Advanced display applications could require sophisticated graphical displays not possible using older technologies, such as the integration of plant drawings with plant equipment status.
- Transparency of data source access is available for users and developers, allowing the acquisition of all necessary data in a timely, consistent fashion. Data access is accomplished by using uniform transaction services, and data are interchanged according to a consistent data

representation. Information describing the plant data that are available through the system is maintained to identify what data can be accessed and where its source is located on the plant communications architecture. As a result, users need not address the details of connecting to remote data sources or be concerned with diverse data structures or interaction mechanisms for each data source.

- Provision is made for a common, consistent user interface that can lead to reduced errors by plant operators and other users and contribute to improved training.
- Portability of applications and standardized interface conventions which reduce the costs for management of systems, vendor development, and computer resources and which alleviate the effects of digital system obsolescence is included.
- Interoperability and integration of functions that support new functions not possible in stand-alone systems is provided.

These high-level advantages are expected to realize more measurable benefits for utilities by minimizing the growing support costs for plant systems and by facilitating more effective performance of operations, engineering, and maintenance activities by plant personnel.

An overall benefit of the PWS for a nuclear utility is enhanced productivity of plant personnel in the performance of their tasks. This is accomplished first by providing the needed information and required software "tools" to the plant staff in a readily accessible manner through an easy-to-use interface into the plant computing environment. The integrated capabilities provided by the Plant-Window environment allow the users to have ready access to knowledge and functional applications crucial to their tasks without having to be directly involved in the management and trafficking of data. In effect, the PWS user becomes a supervisor of access activities rather than an implementor. This higher-level involvement frees users to concentrate on plant operations tasks rather than on gathering the information they need to perform those tasks.

The provision of a well-engineered, consistent human-computer interface can improve user efficiency in interacting with digital graphical interfaces and lead to cost savings by reducing the training demands on plant personnel. Enforcing a graphical user interface (GUI) style for the PWS with consistent display strategies and interaction mechanisms allows the users in the plant to develop a familiarity with the "look and feel" of the applications provided. One result of this familiarity can be an improved ability for plant personnel to focus on the important information being presented rather than on the methods of display and interaction. Applying sound human factors guidelines in a consistent manner to the user interface design can lead to more intuitive use of the digital interface by the plant staff, possibly reducing the cognitive load on the users. In addition, the effort required to train plant personnel to use computer applications can be managed more effectively by providing a common computing environment and user interface with which to access and use each program. As a result, less time is needed to train the plant staff in the use of new applications, and retraining is less demanding because the human-computer interaction skills that are initially developed in training are consistently reinforced through the use of each PWS application.

The integrated environment of the PWS makes possible advanced applications that can improve the efficiency with which a nuclear plant is operated, maintained, and managed by providing information on which plant personnel can base decisions in a consolidated, structured form. Examples of activities that can be enhanced by sophisticated applications using integrated information include prediction of incipient equipment failures, timely determination of system performance degradation and analysis of its causes, or operator guidance to avoid an undesirable operating state. The result of providing new applications with greater capabilities can be better, faster decision making by plant personnel.

Enhanced personnel productivity, in turn, can lead to improved performance for the plant. The availability of clear, concise information through the Plant-Window environment can lead to greater comprehension of existing plant conditions and developing trends. Additionally, the possibility of new applications with expanded functional capabilities can provide an improved ability to manage plant behavior and respond correctly to situations. In addition, improved information access and data presentation for operators can reduce the likelihood of errors and permit the operator to properly respond to changing operational conditions. As a result, fewer challenges to the plant safety systems should occur. These effects lead to a greater assurance of safety in the operation of the plant.

Finally, the maintenance costs for new plant systems could be reduced if they are interconnected with the PWS. Because PWS workstations can provide a common interface to many systems, maintaining the common platforms of the PWS should require less effort than maintaining a number of unique, single-purpose user interfaces based on a variety of computer types. In addition, an open systems approach for the PWS leads to greater choice in vendors that support compatible equipment. Therefore, replacements and upgrades can be obtained under more competitive conditions with greater assurance of a continued, high-quality source. In addition, adherence to open systems principles can lead to the development of software systems that can be ported to new computing platforms. This can reduce the risks and costs associated with digital system obsolescence.

Conclusions

The use of computers and digital I&C systems in nuclear power plants can provide a significant increase in the amount of information available to plant personnel. By making effective use of information technology, the nuclear power industry can realize a greatly enhanced capability for using the available information in an integrated way to support an increasing range of activities. The integration and use of operator advisors, diagnostic aids, maintenance advisory and scheduling applications, and engineering analysis and planning applications can lead to improved performance, ameliorated availability, enhanced reliability, increased safety, and, potentially, reduced operations and maintenance costs.

The PWS provides a support structure that makes information from diverse systems and disparate sources readily available in a consistent, easy-to-use manner. The PWS involves a functional approach for developing a system of workstations to act as common interfaces to plant resources (e.g., digital I&C systems and computers) and to provide a distributed computing environment. By providing common functionality throughout the PWS architecture, the efficiency of plant personnel can be enhanced, the possibility of error while interacting with multiple systems and data sources can be reduced, and the cost-effectiveness of interfacing with several upgraded plant systems can be improved.

The PWS facilitates an integrated approach to plant system upgrades. This is accomplished in two ways: (1) by providing a flexible, expandable distributed computing environment based on an open-systems architecture and (2) by serving as a common interface to diverse systems and data sources. This approach allows the PWS to be adapted to the multivendor environment that exists at many sites without necessitating a costly and immediate redesign and upgrade of all plant systems. Utilities can tailor the initial implementation of the PWS at their plants while maintaining the ability to easily expand the range of systems and functions supported by the Plant-Window environment. As a result, a unified plant computing support architecture can be established at a nuclear plant via the PWS.

The Plant-Window framework is based on a layered approach with the capabilities and services of lower levels supporting the functionality of higher levels. The PWS Applications provide software functions to the user to perform the activities involved in managing, operating, and maintaining a nuclear plant. The PWS Application Environment supports applications through the use of standardized interfaces to system services and through function libraries supplying needed capabilities that can be consistently applied. The Standard System Services provide the core capabilities required to operate the platform, interact with distributed resources, and execute the applications. The PWS Workstation Hardware and Plant Equipment and Network Hardware provide the fundamental building blocks for implementing a plant computing support system. As the technologies involved in providing the functionality of the PWS mature and consensus builds in the computing and nuclear industries, the Plant-Window framework can evolve into a nuclear industry standard computing environment with fully distributed functionality.

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