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THE INTEGRATED WORKSTATION: A COMMON, CONSISTENT LINK BETWEEN NUCLEAR PLANT PERSONNEL AND PLANT INFORMATION AND COMPUTERIZED RESOURCES

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ABSTRACT

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. Data concerning a power plant's design, configuration, operational and maintenance histories, and current status, and the information that can be derived from them, provide the link between the plant and plant staff. It is through this information bridge that operations, maintenance and engineering personnel understand and manage plant performance. However, it is necessary to transform the vast quantity of data available from various computer systems and across communications networks into clear, concise, and coherent information. In addition, it is important to organize this information into a consolidated, structured form within an integrated environment so that various users throughout the plant have ready access at their local station to knowledge necessary for their tasks. Thus, integrated workstations are needed to provide the required information and proper software tools, 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 between the U.S. Department of Energy and the Electric Power Research Institute, an effort is underway at the Oak Ridge National Laboratory to address this need by developing Integrated Workstation functional requirements and implementing a limited-scale prototype demonstration. The Integrated Workstation requirements will define a flexible, expandable computer environment that permits a tailored implementation of workstation capabilities and facilitates future upgrades to add enhanced applications. In presenting the Integrated Workstation concept, the functionality to be supported by the Integrated Workstation and inherent capabilities to be provided by the workstation environment will be described. In addition, general technology areas which are to be addressed in the Integrated Workstation functional requirements will be discussed.

INTRODUCTION

The potential for improved plant performance resulting from greater automation of routine activities, the availability of an expanded set of control, surveillance, diagnostic and advisory tools, the enhanced reliability and availability provided by digital hardware, and the impending obsolescence of existing analog technology have all led to the increased use of computers and digital technologies by the U.S. nuclear power industry. Typically, the introduction of new digital instrumentation and control (I&C) systems into the power plant environment has proceeded as independent, segmented tasks without much attention to the integration of these systems into a consistent overall architecture. Many of these systems are implemented on "closed" architectures, i.e., the supplier uses proprietary or vendor-specific user interface, software, operating system, or network resources. As a result, the utility is faced with choosing between less-than-desirable options. One option involves purchasing upgraded I&C systems delivered exclusively by a specific supplier, which may not offer all the desired capabilities or continue product support to allow for plantwide upgrades over an extended time period. Another course consists of constructing a piecemeal overall system of applications and computers from various suppliers that may or may not share resources and information.

An additional concern is the issue of operator loading. The use of advanced computing capabilities in I&C systems has greatly expanded the capability to obtain, analyze, and present data about the plant to station personnel. However, voluminous amounts of data presented in inconsistent formats can overwhelm the cognitive resources of station personnel to extract information germane to their needs. Therefore, it is necessary to process the data and reduce it to clear, concise, and coherent information. In addition, it is vital to organize the deduced information into a consolidated, structured form within an integrated architecture so that users have ready access to knowledge and functional applications crucial to their tasks. Failing this, the utility may be left with isolated systems (i.e., islands of information), each with its own peculiar interface, leading to a plethora of "single-purpose" user interfaces throughout the plant. These isolated systems, with their varied interface styles, physically distributed displays, and segregated information sources, can place an undue burden on plant operators and maintenance staff. These effects, in turn, can lead to inefficient operation of the plant, unnecessary operations and maintenance costs, and an increased propensity for operator error.

In response to the needs of the nuclear power industry, the Electric Power Research Institute (EPRI) has devised a plan to foster research and development on the use of modern I&C technology and to perform selected power plant I&C upgrade demonstration projects.[1] The plan targets difficulties presented by phased I&C system upgrades at power plants and the potential for isolated systems with duplicate functions and diverse interaction mechanisms. An integrated interface to the plant I&C systems is needed to provide the necessary information and correct tools, 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 provide the common computing environment to

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facilitate access to new and existing data and applications. An Integrated Workstation (IWS) system can serve as a standard human-machine interface for the use of functional applications throughout a nuclear power plant. It will facilitate plantwide data access and provide sufficient inherent functionality so that the various applications envisioned can be accommodated. As part of a Cooperative Research and Development Agreement (CRADA) between the U.S. Department of Energy and EPRI, an effort is underway at the Oak Ridge National Laboratory (ORNL) to set guidelines for such a system and to demonstrate prototypes that address implementation issues. The tasks under the CRADA include the development of IWS functional requirements and the establishment of a development plan for the IWS, which would include limited-scale prototype demonstrations at Oak Ridge and, possibly, at power plant sites.

INTEGRATED WORKSTATION CONCEPT

The task of defining an integrated I&C system interface provides implementation choices for a power utility that include redesigning all the candidate applications to develop a unified software and hardware system or integrating applications functionally by constructing data connections among the systems, developing special interface software, and devising a common computing environment to integrate the individual functions. Obviously, the first choice is undesirable because of the inefficient use of existing resources and/or potentially excessive implementation costs. The better choice of functional integration provides the more acceptable option because it utilizes diverse support capabilities in separate hardware/software environments. However, without an overall support system plan by the utility and some attention to open system requirements, integrating a multi-vendor support system is difficult. The purpose of defining functional requirements for the IWS system is to address the issues of integration and provide guidelines for developing the needed standard interface system and common computing environment for use throughout a nuclear power plant.

The IWS concept provides for a system that facilitates access to information management, data processing, analysis, and control capabilities for the integration of I&C system activities within a plant. This system of workstations will provide a common computer environment in which to utilize analytic, diagnostic, and decision-aid tools and will act as an interface to the monitoring, control, and protection systems in the plant. Each IWS user station will be connected as a node to existing plant communications networks, accessing the plant information needed for analysis and decision-making via transparent data management support functions. Each IWS node will manage the access to classes of applications and functional capabilities based on predefined user authorizations and platform configurations. The IWS will provide a standard interface that is functionally reconfigurable to meet the needs of selected applications. The common IWS interface will be based on human factors guidelines so that the user can concentrate on the functional applications rather than on the characteristics of the interface and the mechanisms of interaction. The range of software tools for operations, engineering, and maintenance activities that will be available through the IWS will be implemented in a modular fashion to allow a utility to select a tailored set of functions for initial installation while maintaining the option of easily adding tools in future upgrades. The IWS can act as a smart terminal/data server for access to information and software tools resident on other plant computer systems and it can serve as a standard computing environment providing functional capabilities necessary to accomplish plant tasks.

The integration supported by the IWS is of three types. First, access integration must be provided to allow transparent access to disparate, distributed sources of data for user and applications. Second, spatial integration is necessary so that applications can be available through a common interface on the workstation platform. Third, functional integration must be promoted to yield application cooperation to perform functions for the user. This final form of integration provides for the development of unique applications to process information and support plant activities. As a result, the IWS will provide three levels of capabilities. It can serve as a standard user interface station (or data server). It can act as a common application program platform to support existing computer tools. It can provide an integrated application program environment for the development and use of new software capabilities drawing on the functional integration of diverse data sources, existing applications, and the shared information between functions.

The integration of applications and the computing systems on which they reside into a coherent information and support system encompasses three major issues. First, there is connectivity. This issue addresses the connections between computing systems and the communications network. Essentially, connectivity involves different computers and the associated applications "talking" to one another; in effect, it deals with the physical and logical connections among systems. Second, there is interoperability, which relates to the interaction among software tools and functional modules. Interoperability is achieved by sharing information among the applications, which process the volumes of data and distill it into concise intelligence about the condition of equipment, components, or the overall plant. This data-sharing depends on the availability of information that is consistent in meaning and structure and its accessibility by the appropriate functional applications. Third, there is the transparency of the user interaction with the support and information system. Transparency incorporates the method of information display, the means of user/system interactions, and the framework for activating and accessing the variety of tools. The first two points address a consistency or common "look and feel" to the human/machine interfaces provided by the different applications. The third point involves accessing information and activating particular support tools. User interaction with plant information and support systems should not unduly complex. Therefore, functions and information must be provided to the users in a consistent, easy-to-use manner. The system architecture should permit access to the range of tools and information from any workstation within the plant and the integrated structure relating the applications should not be so obscure that the user has to constantly consult manuals to discover how to launch a tool or retrieve needed information. Of course, certain restrictions on tool and data access must be applied to provide the appropriate level of information and functional security (e.g., maintenance personnel should not be changing control system setpoints and control room workstations should not be tied up performing engineering drawing updates).

While addressing the issues of integration, attention must be given to the conditions and constraints under which utilities upgrade their I&C systems. Typically, individual systems are upgraded during a scheduled plant outage. Therefore, a full I&C system upgrade, including implementation of an IWS system, could occur in phases over an extended time. This implies several things for the IWS:

(1) it should be modular to allow incremental additions of capabilities,
(2) it should be platform independent to allow for upgrades, and
(3) additions made over a period of years by different vendors should be compatible.

In essence, the IWS should be flexible and expandable. Flexibility permits tailored implementation of the capabilities and functions supported by the IWS system. Expandability allows a phased implementation of the IWS while providing for the introduction of additional functionality in future upgrades. Thus, the definition of the IWS (i.e., environment, functional modules, interfaces) and the development of its functional requirements should promote these goals.

Since the IWS for each plant would be an evolving system rather than a static system, a functional integration approach will be more suitable than providing for total data integration, which would require a holistic system redesign and upgrade. As a result, application program interface routines are required to isolate platform- or software application-dependent characteristics of existing I&C systems. As functions and systems are included in the IWS architecture, adherence to open system guidelines and standards will define interface conventions to allow direct plug-in of subsequent upgrades. In addition, the IWS implementation philosophy will emphasize modularity in both hardware and software.

The approach to developing the functional requirements that will define the IWS system involves identifying candidate user applications and their needs, determining the IWS capabilities which support the user functions, and expressing these capabilities in terms of requirements. Evaluating the user needs first defines an information architecture (i.e., the data flow), which must then be supported by a system architecture (i.e., the computing environment). Therefore, to provide the desired integration support structure, the IWS functional requirements must address information needs, data access, communications and interprocess interfaces, the man-machine interface, security, access and configuration control.

INTEGRATED WORKSTATION ENVIRONMENT

The IWS is a computer environment resident on a workstation platform which facilitates access to all plant data by the operators, engineers, maintenance staff, and administration personnel of a nuclear power station and provides applications to make use of this data. Essential elements of the IWS environment are data access, resource management, control access, human-machine interface, and functional application support.

To further define the fundamental elements of the IWS environment, a preliminary, high-level design is necessary. Figure 1 shows the major functional entities of the IWS environment and their points of interaction. These functional entities, which provide the inherent capability of the IWS, are:

(1) User Applications – perform functions for the user;
(2) Resource Manager – manages all IWS resources and controls configuration and access to IWS functionality to ensure that applications can meet their prescribed function for an authorized user;
(3) Application Support Functions – supply support services to user applications and act as the interface with the Resource Manager to request IWS resource allocation for user programs;
(4) Data Manager – provides database service for access to all plant information and the interface to the plant's data acquisition system for real-time plant signal access;
(5) Control Server – delivers plant control commands from the IWS environment to the plant control system;
(6) Standard Workstation Functions – includes typical engineering workstation functions; and
(7) Human-Machine Interface – provides a display server capability, with screen builder and input transaction modules, for standardized display styles and interaction mechanisms based on human factors guidelines to facilitate a consistent "look and feel" for the IWS system.

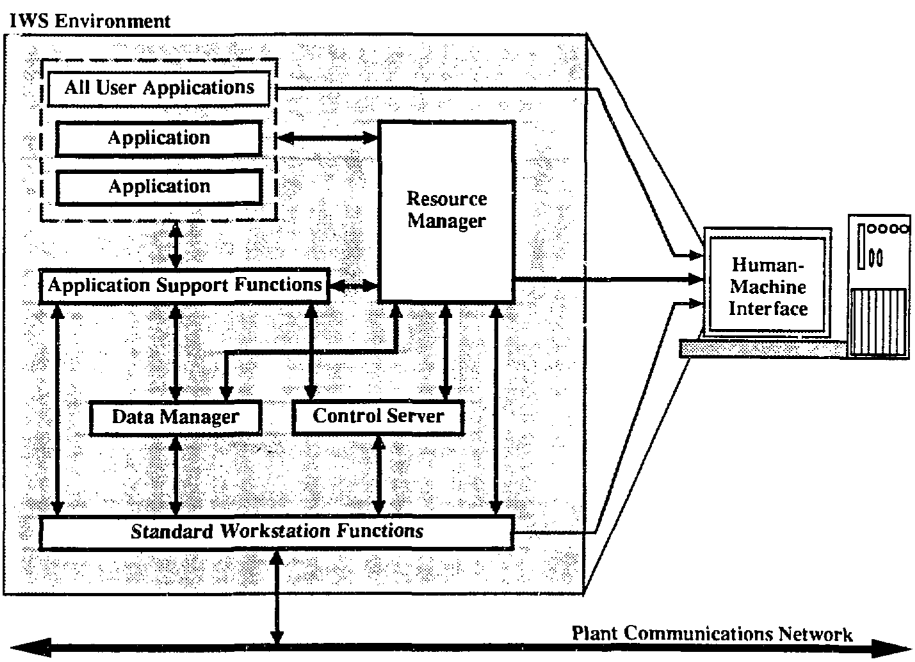

Figure 1 – High-level Diagram of the Integrated Workstation Environment Showing the Main Functional Elements.

The user applications supported by the IWS represent the variety of computerized functions that plant personnel utilize in the performance of their assigned activities. Commercial as well as custom software can be used to provide the desired functions for the user. The IWS system will provide the computing environment and workstation platform through which the selected user application is accessed and on which the software may be executed. User applications interact directly with the application support functions to access the inherent functionality of the workstation. Use of configured workstation resources is allocated by the resource manager based on priority and overall resource demand. In addition, the user application defines the display content and mode of interaction for its user screens on the human-machine interface.

The resource manager provides the integration of the IWS resources, plant data resources, and user applications. Essentially, it defines the configuration of an IWS by specifying the access control for functional applications, the availability of resources, and the relative priority of each resource customer. The resource manager supports authorization management and security control by determining and enabling the appropriate access capabilities to permit the activation and usage of the requisite software tools for each user and application (e.g., operations personnel can use control tools at IWS consoles with the required station attributes). As a result, the resource manager must process and maintain information about the network resources that the IWS can access, the local resources available for use, the user applications available (locally or via the network), and user profiles describing the resources and applications each IWS user is permitted to access. The user applications run under the control of the resource manager, which can dynamically shift some resource allocations (e.g., priority access to the workstation CPU or the network to critical tasks). The resource manager identifies resource requests from applications and controls their access to resources through the application support functions. The user interaction with the IWS environment is provided through the resource manager, which acts as a system shell.

The application support functions provide the interface between user applications and the functional capabilities of the IWS. These modular functions perform operations to simplify and optimize processing, such as consolidation of data requests, local caching of data from remote systems, etc. The application support functions provide application program interface modules that coordinate access to standard operating system functions and shield user applications from the implementation-dependent details of the workstation platform. In addition, the support functions serve as a mechanism for the resource manager to control the allocation of resources. In most cases, the application support functions will intercept application requests for services only if the Resource Manager needs to be involved (e.g., managing user interface or network communication services) or if an implementation uses a nonstandard service or convention. For example, while the mechanism for inter-process communication for user applications would be implemented by the standard workstation functions; the application support functions may define the meaning and structure of the messages exchanged. Some of the application program interfaces that could be provided include a data manager interface, a control server interface, a resource manager interface (this may not be explicitly provided to the application but would route resource requests), a standard workstation function interface (which would typically pass through service requests), and a user application intercommunication interface.

The information management facility within the IWS is provided by the data manager. The data manager will support a distributed database structure with interface modules accessing data maintained in existing local databases. The data manager will provide access to data using standards-compliant relational database access service modules, maintaining a data directory and data dictionaries for available databases. Real-time data will be accessed through a measurement server that interfaces to the plant data acquisition system. The data manager will address issues such as data security, concurrency control, and access constraints, as well as accounting for differences in data representation and translating and processing inquiries.

The control server delivers plant control commands in real-time from the IWS environment to the plant control system. It can be implemented as the internal interface to a dedicated network server directly connected to the plant control system. This server must provide a reliable, fail-safe interface to all plant control systems. In addition, it must also enforce control of IWS access to plant control systems. Control validation and constraints may be imposed through the control server.

The standard workstation functions are the basic capabilities generally provided by computing environments and would include:

(1) Operating System Kernel Services (e.g., multi-tasking, memory management, inter-process communication, date/time/timer services, and device access);
(2) File System Handling (both local and network);
(3) Network Services (e.g., addressing, task-to-task communication);
(4) Basic User Interface functions (e.g., text and graphical display drivers).

The human-machine interface must apply consistent display and interaction guidelines to reduce the possibility of over-burdening the users and unnecessarily complicating user training. The human-machine interface will provide a display server to facilitate conformance to congruous styles and means of interaction. The display server will involve standard display and user transaction modules that will enable a standardized environment interface to be implemented and that can be provided to user applications to serve their interface needs. The general environment interface is directed by the resource manager and provides the means through which users can select applications and other IWS services. In addition, it manages the interaction of the user with the IWS environment outside of the various application interfaces.

Any hardware requirements for the IWS system would be application-specific. This allows flexibility in configuring individual consoles for their primary function. An example might be a multi-display station with specialized user input/output devices for use as an operators console. The intent is to allow the utilities to utilize the hardware which best fits into its established computing environment.

SUPPORTED USER FUNCTIONS

The IWS will support a number of user functions or 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. In the case of existing applications, the IWS will serve as a common platform for accessing and executing plant software. This role for the IWS yields a form of spatial integration in that the users at the plant can access a variety of software tools through their individual workstation consoles. Network connection via the plant communications architecture to the range of data sources available and the data management functionality of the IWS also support this spatial integration by serving the basic data needs of each function and by making desired information available to the user through a common access point.

The accessibility of disparate data sources and the ability to execute applications in a common environment permits the IWS to provide a platform for functional integration of user tasks. Essentially, the definition of standard program interface conventions and the supply of application interface modules as part of the core functionality of the IWS operating environment can lead to the development of interprocess communications and cooperative transactions between functional applications. As a result, information not previously available can be used by applications to enhance the performance of their intended function and to provide well-founded, more reliable information to the user. Additionally, new functions or applications can be developed which use the information available through the IWS environment either as data from the many sources within the plant or as processed information from other applications.

The user applications which the IWS is intended to support cover many specific software tools (e.g., emergency operating procedure tracking, preventative maintenance scheduling, root cause analysis) and support a variety of plant activities (e.g., plant status determination, component performance monitoring, fuel management). However, these applications may be classified into several broad functional groups. The IWS application categories include monitoring, diagnosis, analysis, control, decision support, management, and training. Each category involves applications that support the activities of plant personnel in the areas of operations, maintenance, engineering, training, and administration.

Monitoring (or surveillance) is a function that would be common throughout the plant. The presentation of plant, system, and component status information (both current and historical data) represents a core application that the IWS environment will support. Plant data access and the management of the data available to the IWS are key to the performance of this function. Another important IWS functionality involves the display capabilities of the workstation platform. Obviously, in the area of operations, plant status monitoring is a critical activity with special needs (e.g., real-time data display and update, dedicated displays, attention to human factors engineering) to support the effective control of the plant. However, other disciplines have need of status information to remain aware of current conditions and to effectively manage and execute their activities around the plant. Thus, each console in the IWS system will support status monitoring applications by providing for access to and presentation of status information about the plant and its constituent systems.

Aside from the display of current or past status and configuration information, monitoring in the plant also involves the determination and designation of the condition of the equipment or system(s) being observed. This includes alarm and alert conditions, performance evaluation, and early fault detection. Some diagnostic functions are integral to the basic capabilities provided by I&C systems and thus will be outside the scope of the applications that reside on the IWS system. However, many diagnostic applications can be performed on workstation platforms, providing the initial processing of raw system data or further processing of diagnosed information about system condition or performance. In addition, the common computing environment permits the development of new diagnostic applications which bring together data from distributed sources and combine diagnostic information from diverse systems and their associated diagnostic applications. The unique diagnostic applications possible through the integrated environment can provide enhanced support for tasks throughout the plant, such as operations or maintenance activities.

Control capabilities and decision support can be provided through the IWS. Soft control for manual actuation of particular control elements, user interaction with control systems (e.g., changing setpoints or choosing alternate algorithms), or supervisory control functions that coordinate and constrain control actions will be possible through IWS applications communicating with the plant control system hardware. Access to control applications will necessarily be restricted by the IWS system to authorized users at specific consoles. Since control is performed under the guidance of procedures based on the system status, control applications should be linked to procedure guidance and plant monitoring. In the IWS environment, the user can be provided with control capabilities, procedure advisors, and plant status information. Each discipline within the plant can use the data access and integration capabilities supplied by the IWS environment to support task advisors which offer guidance in the performance of their assigned activities and to ensure proper compliance with the appropriate procedures and specifications.

The analysis, planning, scheduling, and management activities throughout the plant can be supported and enhanced through the IWS by its service as an application platform and by its data and functional integration capabilities. With the integration possible through the IWS environment, analysis tools can be coordinated with other applications to improve the management of the plant and the effectiveness of station personnel. In addition, configuration management of the plant and its systems can be facilitated through the use of applications accessing information from engineering (e.g., design drawings), maintenance (e.g., equipment service schedules), and operations (e.g., systems line-ups). Training can be provided by embedding training in applications and by accessing simulation tools (or even the plant simulator) to provide a mechanism for on-line tutorial sessions. In addition, the consistency of user interactions through the common user interface provided by the IWS may lessen the training demands on plant staff.

CONCLUSIONS

The IWS system concept will provide the framework for achieving functional integration of the digital I&C and computer systems introduced in phases as upgrades to a nuclear plant. The approach taken in the work at ORNL is to first develop functional requirements for the IWS to serve as guidance to utilities for implementing a system of workstations to act as the common interface to plant data and to serve as the platform for accessing a range of computer applications that support operations, engineering, and maintenance activities at a nuclear power station. Following the development of the functional requirement guidelines, several implementation issues will be addressed through prototype demonstrations of the IWS concept. An initial small scale demonstration will be performed at ORNL to show approaches to achieve the desired level of integration. The subject of the demonstration will be chosen to focus on tasks of interest to the nuclear industry, such as integrating electronic procedures with diagnostic and manual control capabilities for operations support. An expanded demonstration, possibly conducted with utility participation, will be pursued to further illustrate the potential industry benefits of the IWS concept.

The requirements development process involves defining the scope of the intended use of the IWS by identifying the data resources to be provided, the functional applications to be supported, and the computing capabilities required. Attention will be given to the issues of connectivity for data and computing resources, interoperability of applications and functions, and transparency of interactions and access. Addressing these issues will facilitate access, spatial, and functional integration through the IWS system. To meet the goals of flexibility and expandability, industry standards and guidelines in the areas of networking, computing, and human factors are being adopted where possible to define interfacing conventions and standardized support modules.

The nuclear power industry is faced with an explosion in the availability of information technology and can realize a greatly increased capability for using it in an integrated way to support an increasing range of activities. The integration and use of operator advisors, diagnostic aids, maintenance advisory and scheduling tools, and engineering analysis and planning applications can lead to improved performance, ameliorated availability, enhanced reliability, increased safety, and, potentially, reduced operations and maintenance costs. First, the information architecture needs to be established. The issues to be addressed include: what information needs to be deduced, collected, and stored; which users require access to which information; and what form or structure should the information assume. Methods and guidelines need to be developed to assure that the decentralized information pool is current, consistent, and correct. Accuracy and consistency are essential since direct control actions and advisory support on operations, maintenance, and design will be made based on this information. Next, the system architecture, which provides an overall support structure to ensure compatibility and ease of integration, must be based on open system principles. Adherence to open system standards will permit information to be shared at, and between, all levels of the plant information hierarchy and will facilitate the interconnection of multi-vendor equipment and applications. In addition, it will allow portability of display software and user screens for access to the various functional applications throughout the plant. Ultimately, system integration based on industry standard interfaces, a common information pool, modular functional implementation, and distributed processing assures maximum flexibility and allows for continued system expansion.

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