DESIGN PRINCIPLES FOR CANDU CONTROL CENTRES IN RESPONSE TO EVOLVING UTILITY BUSINESS NEEDS

Eric Davey
Crew Systems Solutions
Deep River, Ontario, Canada K0J 1P0

ABSTRACT

Nuclear generation operators are facing a challenging business environment at the beginning of the new millennium. Evolving changes in business context, competitive commercial pressures, and changes in technology have dictated recurring evaluation of operational practices and the adequacy of supporting tools, and the pursuit of opportunities for operational improvement.

A key area of utility operations that has been impacted by these changes is the nuclear plant control centre. Changes to workspace layout, equipment provisions, staffing, and work organization are examples of some of the adjustments being introduced to improve operational and safety effectiveness.

This paper discusses some of the key factors influencing these changes and identifies additional design principles for CANDU control centres that will enable new control centre designs and retrofits of existing control centres to remain relevant and responsive to utility needs.

PLANT CONTROL CENTRES

Power plant control centres comprise a number of specific workspaces that provide the facilities and tools to support operating staff in centralized supervision, control, and management of station safety and power production. These workspaces range from very specialized facilities (e.g., Emergency Response Centre for coordination of station response in large accidents) to conventional office and staff support facilities (e.g., office areas for shift work and outage planing, documentation and equipment storage, break and eating areas, and washrooms). The conventional practice has been to cluster the control centre workspaces adjacent to the plant control room.

Operational experience worldwide has demonstrated that the accuracy, completeness and efficiency with which work is performed in the plant control centre is a key enabling factor in attaining effective plant operation. To achieve top regulatory and peer performance ratings, utilities require control centres whose workspace layouts, functions, support tools, and resources effectively support shift staff in working together to meet station operating objectives.

The development of CANDU control centre workspaces has proceeded under two influences:

- Atomic Energy of Canada (AECL) has focussed development efforts on the control room workspace - the centralized operator interface for plant process information and equipment controls. The fundamental features of CANDU control rooms were established by AECL in partnership with Ontario Hydro in the early 1970's [1,2]. Plants constructed since then have, for the most part, retained the same basic control room design and capabilities, comprising instrumentation panels organized on a system-basis and a central operating console for supervision of overall plant operation.

- Canadian utilities have led the definition and development of many of the other control centre workspaces and work management tools. This has led to experience with a diversity of workspace layouts, staff roles and organizations, work organization, and supporting information tool development. As part of this workspace evolution, a broad array of computer-based tools to support work planning, plant performance tracking, and reporting have been developed.

SYSTEM SPECIFICATION AND PRINCIPLES

The desirable attributes for any system can be specified using statements of goals, functions, usage expectations, principles, user needs and technical specifications:

- Goals are statements of the operational objectives the system must perform.

- Functions are statements of the primary ways in which goals are to be achieved.

- Usage Expectations are statements of how a user is expected to use the system to achieve operational objectives.

- Principles are statements of guidance that outline the preferred ways in which system functions should be structured and perform, and are based on proven experience.

- User Needs are statements of the information and control characteristics the system should provide in order to adequately support users in using the system functions to achieve goals and comply with usage expectations.

- Technical Specifications are statements of the physical and behavioural characteristics to be applied in implementing a system that achieves goals, complies with functions and principles, and satisfies user needs.

Statements of principles are important in that they complement the design content specification of other attributes by providing guidance to designers on how system goals should be achieved and functions implemented.

At the same time, all these specification attributes are related hierarchically, in that changes to attributes higher in the list (e.g., goals, functions) will lead to changes in attributes lower in the list. Thus, as system goals and usage expectations change, there is a resultant need to re-examine the relevancy of existing principles and technical specifications and develop new ones as appropriate [3].

FACTORS INFLUENCING CHANGE

A number of factors are driving the need to re-examine the original assumptions and adequacy of existing control centre implementations, and consequently the sufficiency of existing design principles to continue guiding control centre development in the future. These factors can be classified into three trend areas:

- Business trends are changes in commercial, regulatory, and societal factors that establish the commercial context within which utilities will operate nuclear plants.
- Operational trends are changes to operational needs and practices that establish the scope of control centre activities and the manner in which they are carried out.
- Technology trends are changes in the types of technology applied to implement control centre functions.

Examples of business, operational, and technology factors likely to influence control centre improvement directions and emphasis in the future include:

Business Trends

- Deregulation and privatization leading to a stronger business competitiveness imperative, valuation of assets based on profit generation potential, electricity pricing volatility, and the need to continually re-earn customer loyalty.
- Increased plant availability to ensure the ability to generate power when the market demands, upset and outage minimization, and daily, perhaps hourly coordination of operations and maintenance activities with electricity sales opportunities.
- Cost reduction emphasis leading to revision of work practices, more competitive tendering for services, staff reductions, promotion of multi-skilling among staff to allow more flexibility in assignments, and greater use of contractors.

- Continual assessment and improvement of all aspects of business and operations led by external peer review where the best performance of international peers establishes the local standard for performance achievement.

- Safety enhancement via more conservative margins and a reduced dependence on human and active system response for large accidents.

- Plant life extension to 60 years resulting in mid-life refurbishment projects, support of equipment beyond its intended service life, increased regulatory oversight, and challenges to preservation of design basis understanding.

- Organizational partnerships to gain market advantage, preserve capabilities, share critical resources, develop cost efficiencies, and more competitively align products with customer needs.

Operational Trends

- More conservatism in operating practice to reduce risk of upset and safety challenges, and inadvertent non-compliance with operating limits and rules.

- Recognition that monitoring and maintaining awareness of unit changes is the prime control room supervisory duty resulting in dedication of staff to this task and minimization of potential monitoring distractions (e.g., annunciation deficiencies, control room noise and traffic).

- Addition of more licensed staff per shift to allow division of workload to improve workflow, and provide more comprehensive direction and oversight for all operations and maintenance work.

- Standardization and formalization of operating practices with re-emphasis on procedural compliance.

- Performance assurance activities demanding definition of standards of practice, regular assessment of work performance and the adequacy of workplace processes and tools, and increased effort in supervisory oversight of operations and maintenance practices.

- Human error prevention through adoption of individual and peer operating practices (e.g., event free tools), increased use of hardware and software barriers to prevent error occurrence, and a better understanding of operating task needs during equipment design.

- Ongoing workplace change to accommodate evolving business requirements, response to peer and regulatory reviews, introduction of improvements, and changes to staff roles and work processes.

- Continued inflation of control room operating information and support resources resulting in increased dependence on computer-based applications, and requiring a shift in design emphasis to support information use rather than just information accessibility.

- Introduction of equipment health monitoring and a stronger focus on preventative maintenance to reduce the amount of unscheduled equipment repair work.

Technology Trends

- Increased application of digital instrumentation and automation to improve awareness of process and equipment conditions, and reduce operating errors and workload.

- Replacement of obsolete systems with digital, modular, software-configurable, and commercially available alternatives in preference to custom designed solutions.

- Reduced standardization of operating interface conventions as a result of the use of commercially available equipment for cost and servicing considerations in preference to custom designed solutions.

- Replacement of operating panels containing dedicated instruments and controls by general-purpose workstations with plant information and equipment controls presented through computer display interfaces.

NEW DESIGN PRINCIPLES

In adapting to these business, operational, and technological influences, it may be useful to consider establishing additional control centre design principles for guiding future control centre development and renovation. Examples of candidate new principles could include:

Workspace Change

Principle: Accommodate control centre workspace re-configuration and enhancement.

Operating experience has demonstrated the need to regularly change and enhance control centre workspace layouts and functionality in response to evolving business and operational needs. To facilitate response to future changes, designers should select workplace equipment that affords re-configuration, and provide resource and capability capacities that will readily accommodate future workspace enhancements.

Distribution and Specialization of Operating Responsibility

Principle: Enable distribution of operating information and control authority consistent with utility staff models and operating role specialization.

Utilities are evolving to shift models with more than one licensed operator per unit. To best use this additional resource, the former operating responsibilities centralized in one operator are being distributed across two or more operators. To support the division of responsibilities, the interfaces to control centre information systems should allow operating information and control authority to be distributed to different work areas consistent with the new staff structures, staff roles and workspace assignments.

Reduced Shift Staffing

Principle: Design control centre workspaces and information systems to facilitate plant operation with reduced staffing complements.

To substantially reduce plant operating cost, ways must be achieved to attain high production efficiency with reduced plant staff complements. To enable staff reductions, a combination of strategies are likely to be employed, involving task elimination, task automation, and task re-assignment. Further improvements in control centre work management automation and introduction of information tools to facilitate equipment health monitoring from the control centre are two areas that may offer promise of facilitating plant staff reductions.

Operating Conservatism

Principle: Structure information displays and decision-making aids to promote conservatism in control centre decision-making and operating actions

To maintain operating margins, protect plant investment and reduce the creation of latent event initiating or contributory factors, operating actions must be relevant for the operating situation and well planned. Conservative operating behaviours promote the achievement of these objectives, and control centre displays and controls should be designed to support this practice and reduce the need to 'cut corners' in the face of competitive production pressures.

Human Error Detection

Principle: Support self-detection of human error.

Human error remains a major contributing factor to the loss of plant production and availability, and safety challenges across the industry. A number of human, environmental and workplace characteristics, some of which can not be eliminated, can promote human error initiation. When errors do occur, humans readily detect and self-correct a high percentage of errors before the consequences of the error are realized. To exploit this error detecting and correcting behaviour, system interfaces and work practices should be designed to assist users in detecting and recovering from errors. Ideally, the solutions chosen should be independent of the need to standardize equipment interface features and coding conventions.

Monitoring

Principle: Structure workplace responsibilities and tools so that assigned individuals can provide undistracted supervision of monitored operations.

Analysis of operating events in a number of work domains has highlighted the risks to safety, production and plant investment that loss of supervisory oversight can cause. To minimize the potential for losses in monitoring oversight in the future, control centre workspaces where monitoring is a prime function should be structured to better support those individuals in monitoring roles. This requires the provision of monitoring displays customized to the operating situation, and designed to readily promote recognition of process and equipment changes. It also requires configuration of monitoring workspaces to minimize the disruption from other work and environmental distractions.

Information Organization and Use

Principle: Structure information accessibility and integration to support task use.

Information accessibility and display organization should be customized to task needs. As control centre operational needs evolve, there will be continued expansion in control centre information resources, systems, and capabilities. To exploit these added resources effectively, the secondary tasks in accessing, managing the display space, and mentally translating and integrating information from multiple sources must be minimized. This requires a shift to a deeper information design practice in support of information use rather than just simple information accessibility.

Information Sharing

Principle: Design information systems to facilitate sharing of information between functions and databases in support of control centre tasks.

A limitation with many current control centre systems is that information in one system may not be readily sharable with information in adjacent systems. This can be due to communication barriers, and application of differing information conventions and formats. As a consequence, control centre staff must manually integrate or transcribe the information across systems where information or functions from differing systems are used in support of a common task. Again, these secondary support tasks create unnecessary workload and introduce increased risk of information error. Designing information systems to support ready communication of information between functions and databases can improve overall control centre work efficiency

CONCLUSION

This paper has outlined some of the factors likely to influence control centre improvements now and in the future, and discussed possible new design principles in response to specific control centre influencing factors. As control centre solutions to each factor and trend become established, it will be beneficial to characterize preferred design practices in the form of additional principles to provide guidance for future control centre designs and retrofit implementations.

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