A Work Process And Information Flow Description Of Control Room Operations

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Abstract

The control room workplace is the location from which all plant operations are supervised and controlled on a shift-to-shift basis. The activities comprising plant operations are structured into a number of work processes, and information is the common currency that is used to convey work requirements, communicate business and operating decisions, specify work practice, and describe the ongoing plant and work status.

This paper describes the motivation for and early experience with developing a work process and information flow model of CANDU control room operations, and discusses some of the insights developed from model examination that suggest ways in which changes in control centre work specification, organization of resources, or asset layout could be undertaken to achieve operational improvements.

1. Introduction

1.1 Role of Information in Plant Operation

The operation of electrical generation facilities such as nuclear power plants involves the continuous and co-ordinated operation of a multitude of physical processes to support and sustain productive electricity generation. To conduct this co-ordinated operation of physical processes, a number of flows of information are required to support communication between and among plant staff and automation which direct, supervise and control plant processes and equipment configuration from shift to shift.

The types of information comprising this communication span a number of purposes and levels. At the highest level, information in terms of production and safety goals is conveyed via such elements as work plans, strategies to be followed, and specification of overall plant operating configuration. At the lowest level, information in terms of specific work and operating description is conveyed via such elements as procedures, equipment modes and process setpoints, and reports of process, equipment, and work status. These information elements and corresponding communication flows and transformations are the means by which plant staff and automation perform their roles in support of overall plant operation.

1.2 The Control Room and Information Support Tools

The plant control room is the key location through which all information necessary to support shift operations must be communicated. Plant experience worldwide has demonstrated that the

accuracy, completeness, and efficiency with which information is managed within the control room is a key enabling factor in attaining effective plant performance. To achieve optimum production, safety, and regulatory and peer performance ratings, utilities require control rooms whose workspace layouts, functions and support tools, and resources support effective acquisition, communication, transformation, recording, and storage of information in support of all operating objectives.

The specification and development of CANDU control rooms has proceeded under two influences:

- Atomic Energy of Canada (AECL) has focussed development efforts on the operator interface for plant process information and equipment controls. The fundamental features and organization of this interface was established by AECL in partnership with Ontario Hydro in the early 1970's [1]. The interface comprises a series of instrumentation and control panels organized on a major system-basis, and a central operating console for supervision of overall plant operation. All CANDU plants delivered to date have incorporated this same interface style [2].

  The scope of information provided by this interface spans process and system status for plant safety, nuclear steam supply, and balance of plant functions. Greatest information depth and interface emphasis is given to safety and nuclear steam supply functions. Information is presented to operations staff via a hybrid implementation of system oriented panel indications, device controls, and computer displays.

- Canadian and foreign CANDU utilities have led the definition and development of supplementary monitoring systems, and business and operational support information management systems. This has led to experience with a diversity of workspace layouts, staff roles and organizations, work organization, and supporting information tools. A broad array of paper and computer-based information aids have been developed and refined to facilitate performance of control room tasks outside of basic process supervision and control.

  The supplementary monitoring systems provide increased depth of information on the performance of balance of plant and support systems, and health information for important plant systems. This additional information is presented via systems and monitoring displays that are generally independent of the main control centre process information displays.

  The business and operational support systems provide the information to support the conduct of all aspects of shift work. This involves provision of such information items as workplans and work specifications, procedures and operating guidance, decision aids, and reference lists of equipment properties; and capabilities to facilitate generation of such information items as test records, deficiency reports, and operating logs.

Enhancements to control room workspaces have been ongoing and driven by evolving business and operational expectations, commercial competitiveness, the availability of new technical capabilities, and regulatory changes. This has led to control room workspaces where the original functionality has been extensively complemented with additional operating and work support

information tools. The resulting workspaces have become hybrid implementations with a mix of new of old technology, tools, and usage practices. This expansion and hyridization of information functionality has been largely implemented within to the footprint of the original control room workspace; resulting in examples of individual workspace crowding and non-optimum placement and arrangement of some information tools.

2. Objectives and Motivation

We are developing a work process and information flow model of control room operations with the intent of creating a comprehensive overview representation of work processes, the tasks comprising these processes, and the information elements that are accessed, created, communicated, and exchanged between processes as the processes are executed.

The application goal is to use the representations of control room information processes that the model will provide to develop insights for how both work processes and information elements may be refined or redefined to offer improved support for future control room and station operations.

The model uses control room work processes as the framework for characterizing how information elements are accessed, organized, transformed, created, communicated and stored in support of control centre work performance. We are giving emphasis to information element characterization since we anticipate that it will be through the refinement of information flows the future improvements in control room work efficiencies may be realized. For example, we are giving description emphasis to the following information aspects:

- Sources and Sinks - Where information originates and where it goes or is stored temporarily during use.

- Content - What types of information is used in support of specific control centre tasks.

- Form - What representations are used and needed for the communication, storage, and presentation of information.

- Flows - How specific information originates, is communicated, used, shared and stored.

- Transformations - How information is transformed in support of use, in particular those transformations that occur as staff take in and comprehend multiple information elements and, convert information to new forms and organization in support of specific tasks.

- Burdens - Characterizing those instances where control room staff must undertake appreciable secondary information management actions that takes them away from primary duties. Examples of such burdens include effort to access, organize, or transform information elements prior to use, or effort to transform, communicate, or store information elements after use.

We have the following motivations for undertaking this model development:

- Lack of Description Overview - The current specification and description of control centre tasks and information flows is partitioned among many sources (e.g., operating and work management procedures, operating standards, and business process models). These descriptions of individual functionality provide a patchwork of requirements developed over time with variations in description detail. Currently, there is no unifying framework or overview description that serves as a common content to represent the main features of each process in relation to all other processes in a unified way.

- Interfaces as Refinement Opportunities - Utilities have recently invested extensively in formalizing and optimizing the specification of individual work processes. We believe the next round of work management improvement opportunities may be realized in refining the interfaces (i.e., the exchange of information) between work processes.

- Specification for New Applications - We anticipate that clients for future control centre implementations, whether for new build or retrofit applications, will demand greater specification of task support requirements consistent with the ongoing trend in striving for operational excellence. We believe that a comprehensive work process and information flow model of control centre operations can help support these anticipated specification needs.

- Changes in Design Paradigm - A user or human-centred approach to design that emphasizes 'design for use' is practiced today for control centre design. Such an approach requires a comprehensive understanding of task and information element expectations. This contrasts with past design practice where control centre information systems were implemented using a 'design for accessibility' paradigm, relying on eventual users to adapt system capabilities to support usage.

- Representational Tools - Lastly, we are interested in identifying and assessing the merits of tools that will simplify model development and representation. We see opportunities in moving beyond textual descriptions and tables to the use of databases and coupled graphical representations to improve information accessibility and re-organization for use, ease of update and modification, and communication.

3. Approach

3.1 Model Scope

Initial model development is targeted to provide representation for the control room work processes and information flows applicable for a single shift when the plant is at full power steady state. We are using information from Darlington as the basis for model description.

3.2 Project Activities

The work to undertake model development can be described by the following activities:

- Work Process Identification

We are preparing a list of the station individual work processes that are fully or partially performed by staff in the control centre, and identifying the station documents where the characteristics of each process is specified. We are grouping each identified work process into one or more of seven functional task categories [3] for control centre work as a means to begin associating work processes with potential task and information element inter-relationships.

- Methods and Tool Selection

  We have examined a number of methods and computer-based tools that could be adapted and applied in support of model development, representation, and eventual optimization studies. Ideally, we would like to use methods and tools, that simplify the categorization and recording of work process and information element properties, and the generation of graphical model representations with minimal adaptation effort.

  We have chosen to use a simple database for categorization and recording of individual work process and element properties. We have also chosen to adapt the 'Multi-Level Flow Modelling' method [4] developed for industrial process mass and energy flow representations; for representation of both work processes and information element flows in our model. To produce graphic representations for the model, we are initially using a simple computer-based drafting application.

- Pilot Studies

  We are using pilot studies of selected work processes and tools to confirm project assumptions, refine proposed methods, and uncover unanticipated issues. For example, we have used information about the Plant Status Awareness work process to evaluate adaptation options for applying the Multi-Level Flow Modelling method with the selected drawing tool.

- Individual Work Process Characterization

  We are using a bottom-up approach to model definition, through the characterization of the relevant properties for each individual work process and supporting information elements. In doing so, we are trying to retain the nomenclature used in Darlington specifications and achieve a uniformity of specification detail across work processes and information elements at equivalent hierarchical levels.

  The objective of this activity is to develop simplified models of the key individual control room work processes in a way that they can easily be merged into an overview representation of all control room work for a shift. We anticipate that a large portion of the work on the project will comprise reviewing applicable station documentation to identify specific work process and information element properties.

- Overall Model Integration

Once information from all individual work processes has been collected, we envision additional work to integrate the individual work process model representations into a simplified, yet comprehensive model of control room work.

- Peer Review

  As components of the model are developed, we intent to distribute them to workplace peers for review and suggestions for improvement.

3.3 Related Work

We are maintaining a watch for projects in other organizations developing similar models of control centre work in order to learn from the experience of others. To date we have identified one project of interest, being undertaken by a consortium of North Sea petroleum companies [5].

As remaining oil reservoir capacities rundown, producers are examining alternative work management and work support organizations to permit reductions in off-shore staffing and improve overall production work effectiveness and economics. In support of this examination, they are developing a comprehensive model representing current on- and off-shore work processes and the supporting information flows. They envision the insights provided by this model to enable them to identify opportunities for re-structuring work processes and responsibility allocations to meet evolving economic and operational needs.

4. Experience to Date

We are still at an early stage of model development. Most work to date has been focussed on work process identification and properties categorization with reference to station documents, and selection and assessment of methods and tools.

4.1 Challenges

Some of the challenges that we have encountered to date include are:

- Process Identification - The specification of station work processes and supporting information needs are identified in several different types of station documents. This can involve an overlap of information in procedures, standards, and/or behavioural expectations that were developed at different times and with different emphasis.

- Nomenclature - We have encountered instances where there are variations in naming within station specifications or between station and external standards or guidance. During work process description we have noted and recorded these redundancies in naming to maintain consistency with station naming conventions.

- Variability in Specification - We have also encountered variations in work process and information requirements specification across station documents. This is especially so in the specification of information requirements. We are using the current experience of shift staff

with workplace practices to provide clarification of and supplement to the information in station documents.

- Tools - We are still looking for more effective tools to support the project. In particular, we are looking for alternative tools that simplify the use of information on work processes and information flows stored in a database to directly generate graphic model representations.

4.2 Early Insights

Examples of the early insights that we have developed in work process identification and pilot modelling include:

- Information Inflation - There is has been a substantial growth of information that needs to managed by control room staff each shift over the past ten years. Formalization of procedures and operating practices, changes in work practices, and increased demands for recording have all contributed to the information flow that must be managed.

- Secondary Information Burdens - Instances where the information available does not fully meet the needs to accomplish a task can creates work inefficiencies and delays depending on the degree of compensatory activities involved. Compensatory activities typically involve additional effort in information acquisition, conversion, qualification, and organization prior to use. Such instances offer prime opportunities for work process or information support refinement.

- Design Principles - We have begun to formalize some design principles for supporting information flow. For example, bridges should be created between independent systems and applications to allow information to be easily moved in support of task needs, rather than by tedious and error-prone manual transcription.

5. Summary

This paper has outlined the rationale for and initial work to develop a simplified but comprehensive work process and information flow model of CANDU control room operations. We expect to use the completed model to develop insights for how both work processes and information elements may be refined or redefined to offer improved information support to operators for future control room workspace enhancement projects.

8. References

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