Practical Control Centre Retrofit for Refurbishment

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Paper Summary

AECL has a program of evolving our CANDU design through the CANDU 6, CANDU 9 and Advanced CANDU development programs. All of these programs share a common set of design principles in the areas of control centre design and human factors.

The importance of the human's role in supervising and controlling complex systems like nuclear power plants and aircraft has been recognised internationally[1,2,3]. Based on observations and discussions with operations staff at PLGS and other CANDU plants, the human involvement in supervising and controlling CANDU plant operations can be characterised by five high-level statements:

- ***Plant operation is fundamentally goal-based.*** Nuclear power plants are designed to produce electrical energy in a safe and cost-effective manner. The plant control centres play the principal role in providing the information and controls necessary for the operating staff to achieve these two fundamental goals. If challenged, the safety goals of employee safety and protecting the public and the environment from danger due to plant operation shall over-ride the power production goal.
- ***Plant functions to support Operations must be performed by a combination of automated systems and humans.*** The two primary goals of maintaining safety and producing electricity cost-effectively are effected by a large number of inter-related lower-level functions. These functions are accomplished by the actions of both humans and automated systems. In practice, the performance of a specific function is accomplished via a shared division of responsibility between human operators and automated equipment rather than being allocated exclusively to one or the other. The control centres play the principal role of:
  - providing operators with information regarding the state of automated and shared plant functions,
  - alerting operators to changes in the state of plant functions, and
  - providing a direct means for operators to intervene in the plant process where and

[1] Sheridan, T.B.. 1987. 'Task Allocation and Supervisory Control'. In M. Helander (Ed.), Handbook of Human-Computer Interaction (pp. 159-173). New York, New York: Elsevier Science Publishers.
[2] Moray, N.P. 1988. 'Monitoring Behavior and Supervisory Control'. In K.R. Boff, L. Kaufman, and J.P. Thomas (Eds.), Handbook of Perception and Human Performance (volume 2) (pp. 40.1-40.51). Toronto, Ontario: John Wiley & Sons.
[3] Billings, C.E.. (1991). 'Human-Centered Aircraft Automation: A Concept and Guidelines'. National Aeronautics and Space Administration technical memorandum 103885, Ames Research Center, Moffet Field, California.

when required.

- ***Plant operation is supervised by human operators from control centres.*** Human operators are assigned the prime responsibility for all aspects of plant operation (i.e., achievement of safety and production goals). Operators supervise the status of plant goals and effect operational changes from control centres based on approved procedures. Operator communication with plant equipment and processes is effected through interfaces located in these control centres.
- ***Four principal strategies form the basis of operation of the plant processes: normal operation, abnormal operation, upset operation, and emergency operation.*** Each strategy outlines the sets of tasks and functions available for use by operators and the priorities that apply when using them.
- ***Combinations of four secondary strategies (maintenance, testing, fuelling, and commissioning) support each of the principal strategies.*** Each secondary strategy outlines the set of tasks/activities and functions available for use by operators and the priorities that apply when using them. The critical issues involved are the rules for initiating, terminating, completing or suspending each activity (e.g., during an emergency, maintenance activities are terminated) appropriate for each principal strategy and operating region combination.

In parallel to these operationally-centred concepts, AECL has looked closely at both the capital and ongoing operating cost of CANDU stations to improve CANDUs competitiveness with the world-wide competitors. Emphasis on reduction of operating, maintenance, engineering, and construction costs has contributed to changes in the information infrastructure for our CANDU products. Effective strategies combined with efficient information systems can lead to significantly reduced costs and higher capacity factors.

This approach has been used to support the evolution of the design of control centres through the identification of design improvements and enhancements that improve the operational support and cost-effectiveness of the product. These improvements and enhancements are developed through co-operation with existing CANDU stations with many of them implemented/proved in full or part in Canadian CANDU stations or their simulators, or in AECL's CANDU Control Centre evaluation facility to confirm effectiveness. The improvement opportunities were then scrutinised for practicality of implementation resulting a planned evolution of the CANDU products including the CANDU 6 for Qinshan, China, the next CANDU6 sale, the CANDU 9, and future even more advanced CANDUs.

This paper will focus on the practical upgrade (retro-fit) of the CANDU 6 product for Qinshan in China. The current CANDU 6 plant design has evolved slowly over the past two decades based on the design developed in the 1970's for the original CANDU 6 plants at Point Lepreau and Gentilly in Canada , Wolsong in Korea and Embalse in Argentina. AECL made the strategic decision to advance the design of the CANDU 6 to more modern standards while taking great care to maintain the proveness of the product.

The paper summarises the current application and lessons learned in the upgrade of the design of the CANDU 6 control centre for the current project being constructed in China. The paper will present significant CANDU Control Centre features and associated benefits along with lessons learned, including limitations and constraints.