CONTROL ROOM MONITORING OF PROCESS CONDITIONS AND IDENTIFICATION OF IMPROVEMENTS TO DARLINGTON MONITORING DISPLAYS

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ABSTRACT

In supervising CANDU plant operation, Operations staff must routinely monitor plant status using information from several information systems. One key source of plant status information are the CRT displays at console workstations and panel locations. At Darlington, as at most CANDU plants, Operations staff have adopted a reference set of displays for use in monitoring during Full Power Steady State conditions. The display set employed was chosen from the available suite of displays, and operational experience has demonstrated that the current displays could be improved. For Outages, no reference display set has been defined, and for Upset conditions, the current Transient display set does not provide the information needed by operations staff, and consequently is not used.

This paper describes the basis for and findings from a COG project [1] undertaken in 1997 to characterize monitoring practice and develop improvements to control room displays to better support operator monitoring tasks for three key operating states.

BACKGROUND

Role of Monitoring in Plant Operations

CANDU plants are designed and operated with the understanding that the control room operator is ultimately responsible, as the licensed operating authority, for all aspects of plant safety and production. In this role, the control room operator plans, organizes, directs plant operations, and configures and supervises automated systems to achieve operational objectives.

CANDU plants are highly automated. In stable production states, the control system maintains process conditions to established setpoints enabling continuous electricity production with minimal need for operator intervention. During manoeuvres of the plant from one operating state to another, the control system automatically adjusts key process setpoints and continuously adjusts process conditions to stabilize the operating point at the new operating state. In supervising this highly automated system, the control room operator continuously *monitors* selected plant conditions to:

- Confirm that the operating goals and conditions selected are being achieved as expected, and
- Detect a change from normal in key indications that can provide early warning of developing disturbances (e.g., has the trend of a parameter changed).

Areas for Improvement

At Darlington, as at most CANDU plants, Operations staff have adopted a reference set of displays for use during monitoring in Full Power Steady State conditions. The display set employed was chosen from the available suite of displays, and operational experience has demonstrated that the current displays do not support all monitoring needs and thus offer room for improvement.

For Outages, no reference set of monitoring displays had been established. The selection of displays used, varies from operator to operator based on individual experience, preference, and the plant maintenance and configuration state. Definition of a preferred Outage display set was viewed as an important initiative given recent emphasis to improve and formalize operating practices.

For Transients, an operator can select a predefined set of displays for all control room CRTs via a single keyboard selection. This permits rapid access to a reference set of displays for monitoring during a variety of 'situations' associated with transient conditions [2]. The displays assigned to this Transient display set were selected during initial station design prior to commissioning, operational experience with controlled and unplanned plant manoeuvres, and station upset response strategy development. These initial Transient display assignments have not proven useful and require updating.

PROJECT OBJECTIVES

The objectives for the project were to:

- Document current monitoring practice and strategies, and
- Identify potential improvements to monitoring displays and practice for three key operating states (i.e., Full Power Steady State, Outages, and Transients).

A MONITORING STRATEGY

Goal and Setpoint Based Emphasis

Monitoring behaviour is purposeful. At any time, the displays and indications monitored are related to the current operational goals being achieved. As operational goals change, the parameters and values monitored change as well.

Operational goals can be characterized by safety and production components. The primary safety goal is to protect plant staff, the public and the environment from all potential hazards of plant operation. The primary production goal is to produce electricity to meet electrical system demand at lowest total unit energy cost.

To achieve the production goal, a number of setpoints for plant process systems are established. Several automated systems are employed to provide continuous control of process conditions to the established setpoints for production purposes. As long as the production processes are operated to the established setpoints, both safety and production goals will be achieved. Both sets of goals may only become challenged when a process disturbance, equipment failure or operating error occurs. Thus, operators remain confident that both sets of goals are being achieved when:

- The automated production systems operate stably to their established setpoints, and
- Special safety systems remain poised and available to fulfill their function if required to do so.

Types of Parameters Monitored

To confirm that the controlled process systems are performing as intended, operators focus periodic monitoring attention on three types of performance related indications:

- Process Setpoints - current value and trend of process setpoints for major control functions,
- Process Outputs - current value or error and trend of controlled process parameters, and
- Internal Measures - current value and trend of parameters that provide early indications of the internal compensatory response of controlled functions to any disturbance.

For poised systems, operators have high confidence that these systems will be available to perform their intended function as a result of panel and system checks conducted each shift that confirm their availability, and annunciation of system failures. Thus, regular monitoring of these systems is not needed.

Operational Context

The specific parameters to be monitored are dependent on the plant operating state. For example, during Full Power Steady State conditions, the key setpoint, process output and internal measures associated with the six primary controlled functions of the power generation cycle are monitored. These functions are:

- Reactor Power Control (RRS),
- Pressure and Inventory Control (P&IC),
- Steam Generator Level Control (SGLC),
- Steam Generator Pressure Control (SGPC),
- Deaerator Pressure and Level Control (DPLC), and
- Turbomat (i.e., Turbine Control).

During outages, the monitoring emphasis shifts to confirmation of unit safety state, specifically parameters affecting the Guaranteed Shutdown state conditions, reactor power levels, fuel cooling and heat sink status.

Display Location Usage

To support their process monitoring activities, operators use six CRT displays - 4 panel displays and 2 console displays as shown in Figure 1. In each operational context, the displays selected for monitoring are assigned to panel or console locations using the following assignment strategies:

- First, preference is given to assigning the highest priority information to the first console display,
- Second, preference is given to assigning the least frequently monitored information to the second console display allowing this display location to be easily accessed to display information in support of specific operational tasks, in addition to monitoring, and
- The remaining displays selected for monitoring are assigned to panel display locations as best consistent with panel system-based assignments.

IDENTIFICATION OF 'IDEAL' MONITORING PARAMETERS

A set of 'ideal' monitoring parameters were established for each of three key plant operating states (i.e., Full Power Steady State, Outages and Transients). The parameters, preferred presentation form, and display ranges were established based on the key control functions and monitoring emphasis applicable to each operating state. The information defined for monitoring in the Full Power Steady State using this approach is listed in Table 1.

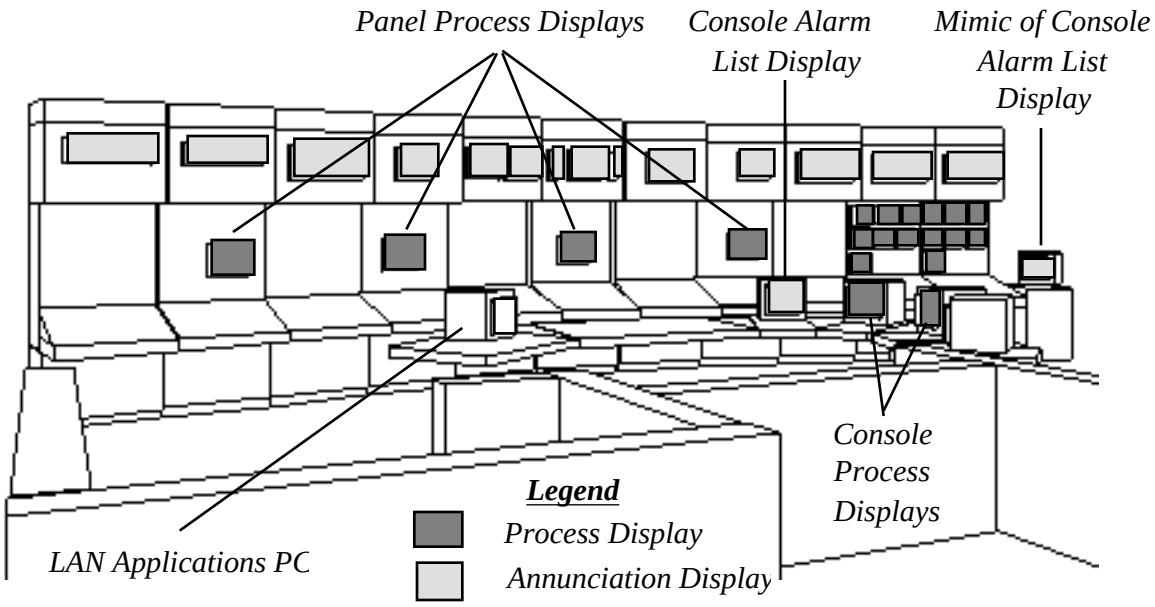

Figure 1: Location of Console and Panel Process Monitoring Displays.

RECOMMENDATIONS FOR IMPROVEMENT

Recommendations for monitoring display improvements were developed by comparing the 'ideal' monitoring parameters with the information content of displays in current use. For the Full Power Steady State and Transients operating states, recommendations for display improvement were developed by introducing changes to the current defined display sets to align the parameter content and organization with the parameters defined for the 'ideal' parameter sets. For the Outage state, a new set of monitoring displays was defined based on the established 'ideal' set of parameters.

The variety of improvement recommendations included:

- *Parameter Substitutions* - Replacement of current display parameters that are not used, with missing parameters relevant to monitoring objectives,
- *Display Organization* - Application of a common ordering of parameters in display sets with using the same formats (e.g., Organization of all trend displays with process setpoint parameters on top, followed by process output parameters in the middle and lastly internal measures of function performance on the bottom of displays),

- *Adjustment of Parameter Ranges* - Customization of parameter display ranges consistent with monitoring objectives (e.g., Narrowing of reactor power display range from full scale, to 95 % FP to 101% FP for monitoring at Full Power Steady State to facilitate disturbance detection), and
- *Definition of New Displays* - Creation of new display formats to better address monitoring and situational task needs (e.g., Definition of a single display for monitoring the current state of all key parameters in outage conditions (see Figure 2). This permits some process monitoring display locations to be used to support specific outage work, thus minimizing display use conflicts between monitoring and other task needs.

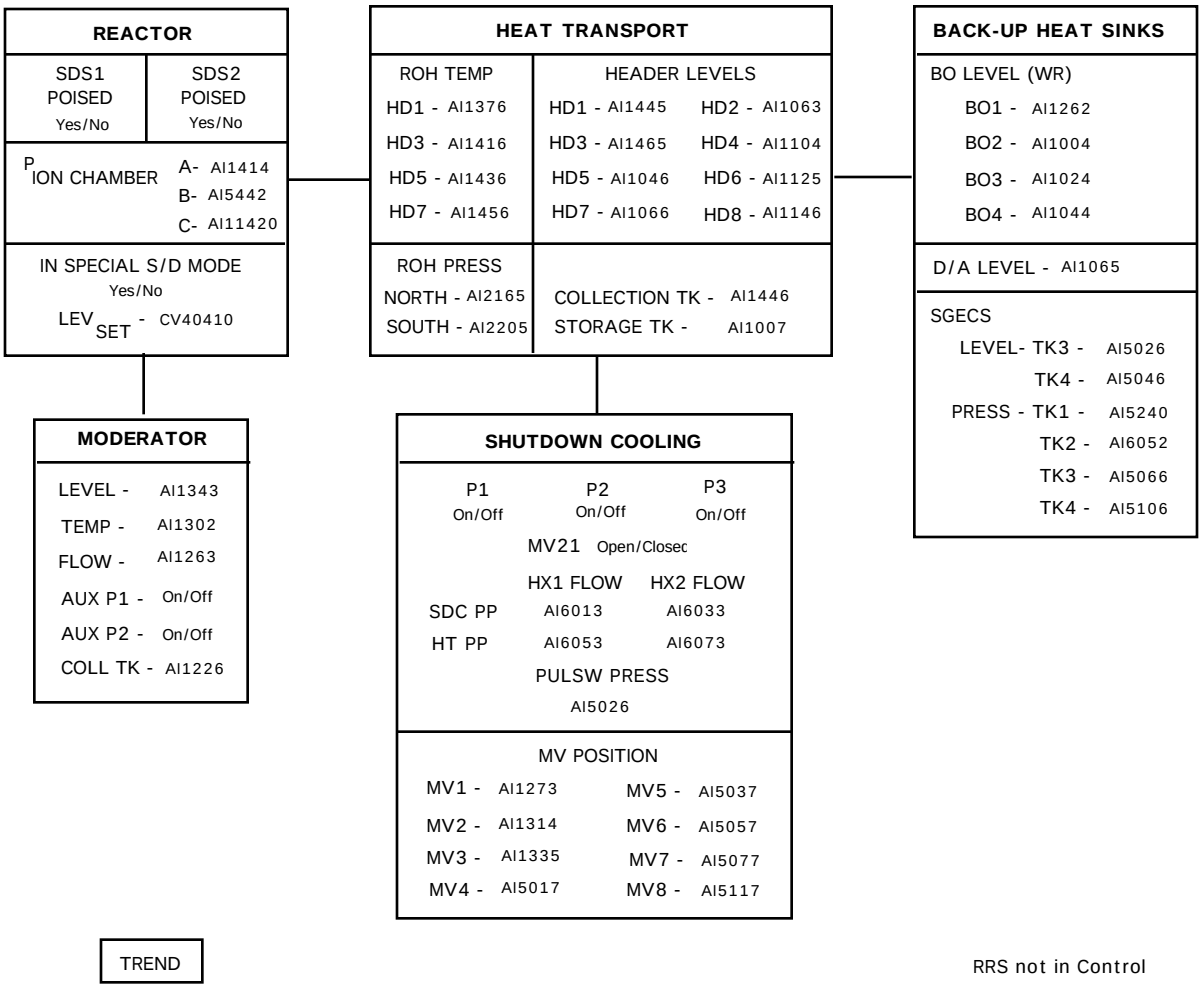

Figure 2: Plant Overview Outages.

IMPLEMENTATION STATUS

The recommendations from this study are being used in the following ways:

- Darlington - Improvement to the parameter assignments and ranges for the Full Power Steady State display set have been incorporated into the DCC software shipment for installation in the 1999 spring unit outages. The improvement suggestions for the Outage and Transient display sets are being considered for future display set improvement.
- AECL - Some of the recommendations for monitoring parameters and parameter ranges have been adopted for overview displays developed for the new CANDU 6/9 control room.

CONCLUSIONS

The priorities and parameters for control room monitoring of process conditions in three key operating states at Darlington have been characterized and recommendations for selecting and improving current control room displays and usage have been established. The findings and recommendations from this study are expected to lead to improved plant monitoring displays to better assist Operations staff in supervising future plant operations.

REFERENCES

1. E. Davey, M. Tonello, D. Rivera and P. McInerny. (1997). Recommended Darlington Displays and Parameters for Unit Monitoring. CANDU Owners Group report COG-97-178. AECL, Chalk River, Ontario.

2. Ackermann, M. and Willson, R. (1989). Man-Machine Interface CRT Display. Darlington GS A Design Description SCI 66300-02, Ontario Hydro, Toronto, Ontario.

Table 1: Ideal Monitored Parameters - Full Power Steady State.

Controlled Function	Monitoring Emphasis	Monitored Parameter/No.	Preferred Form	Range and Units
Reactor Power Control	Performance Objective	Reactor power setpoint (P_{sa})	Trend	95 to 101 % FP
	Performance Output	Reactor power (P_{lin})	Trend	95 to 101 % FP
	Internal Response	Reactor power error (P_{err})	Trend	+/- 1 % FP
		Average zone level	Trend	0 to 100 % Full
		Zone control levels (14)	Bars	0 to 100 % Full
		Shutdown system NOP margins	Bars	0 to 120 % FP
		SSMC - Absence of NOP margin challenges	Bars	-10 to 0 % of Trip Limit
HT Pressure & Inventory Control	Performance Objective			
	Performance Output	Heat transport pressure	Trend	9 to 10 MPa
		Pressurizer level	Trend	6 to 7 m
	Internal Response	Bleed condenser level	Trend	0.5 to 1.5 m
		Bleed condenser pressure	Trend	0.5 to 1.5 MPa
		Heat transport total feed flow	Trend	0 to 15 kg/s
		Heat transport storage tank level	Trend	7 to 8 m
		Heat transport collection tank level	Trend	0.0 to 0.8 m
Steam Generator Level Control	Performance Objective	Boiler level setpoint	Trend	10 to 14 m
		Boiler level control limits (2)	Current Value	m
		Boiler level alarm limits (2)	Current Value	m
	Performance Output	Boiler level (4)	Trend	10 to 14 m
	Internal Response			

Table 1: Ideal Monitored Parameters - Full Power Steady State (Concluded).

Controlled Function	Monitoring Emphasis	Monitored Parameter/No.	Preferred Form	Range and Units
Steam Generator Pressure Control	Performance Objective			
	Performance Output	Boiler pressure	Trend	4900 to 5100 kPa
	Internal Response			
Deaerator Pressure and Level Control	Performance Objective			
	Performance Output	Deaerator level	Trend	2.3 to 2.7 m
	Internal Response	Deaerator total inflow	Trend	1100 to 1350 kg/s
Turbomat	Performance Objective			
	Performance Output	Gross electrical generation	Trend	900 to 950 MWe
	Internal Response			