Establishing Successful Teamwork in Upset Response - Issues and Control Centre Impacts

Eric Davey
Crew Systems Solutions
00 1 613 584 4933, crewsyssol@aol.com

Lee Lane
Darlington Nuclear Division - Ontario Power Generation
00 1 905 839-1151 Ext 3052, lee.lane@opg.com

Abstract

Effective teamwork among control room and shift staff is essential for plant production and safety in all phases of plant operations. During response to unit upsets and emergencies, effective teamwork among control room and responding shift staff is especially critical for operational, public, and environmental safety, investment protection, and minimization of production loss.

In CANDU multi-unit power stations, a common area is used to house the control room resources for all units. With this common control centre arrangement, staff from adjacent units is available to assist in response to upsets or emergencies with any unit. Consequently, the Canadian upset response practice has evolved to draw on the available experience and skills offered by staff from adjacent units.

This paper discusses the Canadian experience with achieving effective teamwork during upset response where responding staff from adjacent units are integrated with the unit team members to achieve a co-ordinated and more capable response capability.

1. INTRODUCTION

Nuclear station production is directed and supervised by teams of operating personnel. While many plant safety and production functions are highly automated in current generation CANDU plants, it is shift operating personnel that establish the operating configuration, plan and effect operating actions, monitor operations, conduct routine inspections, maintain equipment operating capabilities, and detect and respond to process disburbances and equipment failures. The effective performance of these tasks is highly dependent on individual human performance and group teamwork behaviours.

The formation, development and maintenance of shift team capabilities is an on-going process. Following recruitment, the development of individual shift operating staff can span several years. Once fully qualified, operating staff are assigned to a specific shift team and begin a period of regular shift work and refresher training with the team members. This combination of regular operating work and periodic re-training provides an environment where team support behaviours can be practiced and effectiveness continually honed across the range of station operating conditions.

In, Canada, five of the seven CANDU stations have four individual nuclear units. Operation of these multi-unit stations is directed and supervised from a common central control room where the controls and information systems

for each unit and common station services are manned by individual shift teams. This centralized design affords flexibility in resourcing control room duties, as staff can be shared among individual unit shift teams to accommodate workload differences and temporary changes in unit shift team member availability.

Operational experience has shown that unit and station upsets can present significant operational challenges to control room teams and supporting plant staff. While many upset conditions have been pre-determined through safety analysis, and the appropriate responses characterized, proceduralized and practiced; a number of factors can often complicate situational understanding, response planning, and the timeliness and effectiveness of the shift team actions. Examples of such factors can include unit configuration and maintenance status, the occurrence of secondary failures, situational uncertainty, goal conflicts, response resource constraints, and even communication with the 'outside world'.

To maximize response resources available during upsets, staff from non-upset units may be temporarly re-assigned to assist the shift team of an upset unit. In such situations, a number of teaming changes occur across the control room, as some staff on non-upset units transfer their regular duties and pickup new assignments in becoming members of the response team on upset units. These changes in staffing assignment can substantially alter individual team composition, responsibilities, supervisory and co-ordination relationships, and communication and reporting needs resulting in changes to individual team capabilities, experience level, cohesion, and subsequent effectiveness. Successfully managing these team changes and rapidly reforming individual unit teams has two objectives:

- The effective addition of response resources and capabilities to assist in stabilizaton and recovery of upset units, and
- Continued safe operation of non-upset units with reduced shift team resources.

2. BACKGROUND

2.1 Staffing Model and Normal Duties

The operating shift staff at CANDU multi-unit stations comprises the following duty positions and personnel numbers:

- 2 Shift Supervisors (SS) - licensed,
- 5 to 8 Authorized Nuclear Operators (ANO) - licensed,
- 4 Supervised Control Panel Operators (SCPO),
- 4-6 Field Senior Nuclear Operators (SNO),
- 2 Common Services Panel Operators (CSPO), and
- 18 to 22 Field Nuclear Operators (NO).

During weekly shifts when on-line fuelling and/or fuel handing maintenance occurs, the following additional operating staff are present:

- 1 Senior/Supervising Fuel Handling Operator (SFHO),

- 2 Fuel Handling Console/Panel Operators (FHCO), and
- 4 Fuel Handling Field Operators (FHFO).

Each shift also contains a number of non-operating staff comprising mechanical, electrical, and instrumentation maintainers; chemical technicians; and stores, work control, and administrative clerks.

Overall station operation is overseen by the two shift supervisors (SSs). One supervisor is designated the Shift Station Manager (SM) with overall responsibility for station operations and in particular oversight of station activities outside of individual unit operations. The second supervisor is designated the Control Room Shift Supervisor (CRSS) with responsibility for oversight of all operating actions in support of individual unit production and safety.

Authorized Nuclear Operators (ANO) are assigned full responsibility and authority to control all aspects of individual reactor unit operation within administrative limits. ANOs direct and supervise the duties of all other shift team members assigned to their units, and are the only shift staff authorized to undertake operating actions via control room unit controls.

The controls area for each unit is normally staffed by three team members: one or two ANO's, a Supervised Control Panel Operator (SCPO), and periodically a Senior Field Nuclear Operator (SNO). SCPOs assist ANOs with unit monitoring and conduct of control room equipment tests. SNOs assist ANOs with planning, specifying, tracking and recording of field operating actions in support of ongoing unit production and maintenance.

2.2 Control Room Layout

The five Canadian multi-unit stations exhibit three types of control room layout:

- Pickering - The control room layout is based on a square format with unit controls and consoles centred in each room corner. Fuelling controls are located in a central console hub to facilitate communication with unit operators. Common services are positioned near the mid-points of walls between individual unit controls.
- Bruce - The control room layout is based on a rectangular design with pairs of unit controls and consoles positioned along the two long sides of the room. Again fuelling controls are located in a central console hub, and common services are located along one of the two shorter room walls.
- Darlington - The control room layout is based on a narrow rectangular room design to accommodate seismic and civil structural needs. Unit consoles and controls are positioned in a linear fashion along one of the two long room walls. Fuel handling and common service controls and consoles are located along the opposite long wall with common services in the middle and fuel handling operating consoles and panels sited at either end.

3. RESPONSE TO UPSETS

3.1 Response Strategy

CANDU plants employ a heavily formalized and proceduralized response to unit upsets. Upsets are declared when any one of the following five conditions occurs:

- Power changes - An unplanned power change of > 10% or a forced reduction to < 2% full power (FP),

- Challenge to fuel cooling - A subcooling margin of < 20°C when reactor power is > 2% FP,
- Loss of support systems - Disruption in supply of electrical power, instrument air, cooling, and
- Radioactivity release - Airborne or liquid effluent releases beyond confinement barriers, or
- Uncertain situation - Any situation where the certainty of unit safety comes in doubt as determined by the unit ANO or shift supervisor.

When an upset is declared, the unit ANO and CRSS apply the procedures in the Abnormal Incidents Manual (AIM) to guide staff response to the upset. The ANO AIM procedures consist of a single universal procedure for initial upset response and appropriate event procedure selection, and a suite of event-based response procedures which mesh with and are supported with normal system-based operating procedures. The CRSS AIM procedures consist of a procedure for independently monitoring unit safety state, and priority actions for redirecting ANO response to restore safe conditions when the acceptable values of Critical Safety Parameters (CSP) are challenged. CANDU utilities utilize both event and symptom based procedural response, and procedure entry may be direct, based on events occurring (e.g., turbine or reactor trip), or based on annunciation response procedures, and/or parameter trends.

The overall control room actions centre on the following sequence of actions:

- Confirmation of the effectiveness of safety system actions, if demanded,
- Confirmation of the stabilization of major plant processes and services by automated control actions,
- Selection and application of appropriate event-based procedural actions, to further supplement automation responses to the upset or to effect operator intervention where the automated response is less effective than required,
- Upset cause diagnosis and correction, and
- Preparation of the unit for restart and return to normal production service.

3.2 Changes in Staff Duties

When a single unit upset is declared (i.e., a paging system general announcement), a number of shift crew duties change. Key changes in duty assignments include:

- SSs - Transfer of control room unit oversight responsibilities for non-upset units from the Control Room Shift Supervisor to the Shift Manager, effectively focusing the shift supervisor control room oversight presense.
- ANOs - On non-upset units, placement of the unit in 'quiet mode' to minimize upset potential, and turnover of unit supervision and operating responsibility to a supervising ANO per non-upset unit, permitting the remaining ANOs to assist the upset unit.
- SCPOs - On non-upset units, wrapup of current duties, and devotion of full attention to unit monitoring in support of 'quiet mode' operation.

- SCPOs - On the upset unit, wrapup of current duties, and initiation of continuous Critical Safety Parameter monitoring to support shift supervisor independent safety oversight of the upset response.

- Upset unit ANO - Assumes the 'lead' role in response, and prepares to accept assistance and effectively apply responding ANOs from non-upset units. This will involve a partitioning of normal duties, for example, responding ANOs initially assist with control panel monitoring and actions during plant stablization, and then may be subsequently re-assigned to annunciation log reviews, repairs and recovery work planning, work permit preparation and authorization, co-ordination of field actions, or providing temporary shift relief to upset unit staff.

Other staff on non-upset units, suspend or continue normal duties consistent with 'quiet mode' operating limitations. Other staff on upset units, suspend current work in a safe state and report to the control room for re-assignment to unit response tasks as directed by the unit or assisting ANOs.

3.3 Team Transitions

In undertaking the shift in duties from normal operating assignments to upset response tasks, a number of transitions in individual teaming arrangements occur. These transitions are characterized by the conduct of turnovers of information on operating status and duties between staff on both upset and non-upset units. These transitions mark the partial disassembly and down-sizing of teams associated with non-upset units and the re-forming of larger teams for response on upset units and must be conducted fairly rapidly to free additional operating resources to assist with upset unit response in a timely manner. At the end of the response to an upset, there is a corresponding transition back to normal unit staffing levels and duty responsibilities.

4. CANDU TEAMWORK EXPERIENCE

Station operational and training experience has highlighted specific teamwork challenges and issues, and led to the adoption and development of enhanced response practices and capabilities. Key teamwork related experience includes:

- Initial Turnover Coordination - The timely initiation and completion of turnovers on both non-upset and upset units to facilitate the redistribution of shift staff can be delayed. Ongoing unit tests and work, constraints associated with unit conditon, or the temporary unavailability of staff on breaks can delay or disrupt turnover coordination. Consequently, shift staff must be trained to accommodate flexibility in turnover coordination outcomes.

- Upset Team Augmentation - With uncertainty in initial turnover coordination, the arrival of assisting staff to an upset unit can be variable and staggered. This can complicate response planning and duties re-assignment by the lead ANO on upset units, and require repeating of communications and actions necessary to integrate new staff into the response team as assisting staff become available. The current initiative to staff shifts two ANOs per unit, will substantially simplify upset team augmentation as assisting staff will be available sooner and likely arrive as a single group, In meeting this staffing objective, a significant challenge exists in training and qualifying the additional ANOs. .

- Early Availability of Supervisory Support - CANDU units have the capability to recover from certain types of unplanned power reductions to 60% FP within the first twenty minutes of upset initiation to avoid a two-

day forced poison outage. In such cases, authorization to raise power must be granted by a shift supervisor. Formerly, the work locations for both supervisors were outside the control room, and this reduced their control room presence and ongoing awareness of unit conditions. In responding to upsets, supervisors must first develop an awareness of unit conditions prior to decision makng. In developing unit understanding and awareness under upset conditions, there is a risk that supervisory staff can focus attention in one area to the detriment of supervisory support in other areas. For example, initial supervisory attention to understanding equipment alarm response in one area, have precluded timely authorization of ANO recovery actions on recoverable units. The recent relocation of the normal workplace of one supervisor to a more accessable control room location and simulator training emphasis on avoidance of focussing attention exclusively in one area to the detriment of support to all units is expected to improve supervisory support to ANOs early in upset response.

- Understanding Unit Status Awareness - To successfully plan and respond to plant upsets, team members must be aware of unit status, configuration of systems, idiosyncrasies of specific equipment, and equipment maintenance status. This information can be distributed among a number of sources resulting in delays in response planning and implementation. To simplify upset response and other operating needs, operations staff have created unit logs organized by equipment indexes. These logs are maintained by shift staff and serve as an easily searchable record to find information on the behaviour idiosyncrasies, current configuration and service status of specific equipment.

- Maintaining Common Situational Awareness - Current generation plants are designed to be supervised and controlled by a single operator from a single console postion. In upset response, assisting ANOs may be working at panel locations or removed from the central console position. In the absence of a central unit status overview display viewable from all working positions, the response team rely heavily on verbal communication to exchange and share relevant information. In addition, the lead ANO may initiate periodic meetings of the response team to ensure all team members are fully conversant with current unit issues, status and planned action alternatives. This dependence on verbal commuication, is time consuming, requires redundant messaging, and is prone to mis-interpretation or being missed when staff duties are attention intensive.

- Co-ordination of Actions - In situations where multiple team members operate on the plant in parallel, staff must be encouraged to think about the impacts of their operating actions beyond their local needs. Even simple actions to change display views, or acknowledge alarm screens, can result in disruption or loss of information to other team members. Extra effort is required to ensure actions are adequately coordinated.

- Team Direction and Decision Making - Supervisory and ANO staff are selected and developed to promote strong leadership capabilities (e.g., comprehensive technical knowledge, active listening and questioning, independence, and decisiveness). In upset response, augmentation of teams with additional leaders may create distractful conflicts and delay response. Training in leadership-followership properties, dynamics, and role exchanges has helped supervisory and ANO staff better understand and adjust to teaming roles in upset response.

- Conflict Resolution - In upset situations, it is common to experience situations where conflicts in response objectives, priorities, procedures, or methods arise. In many instances, these conflicts can be effectively resolved via team consensus or leadership decisions. In situations where the merits of competing options have validity, we have found it benefical for staff to accept differing perspectives and work to incorporate and implement both options rather than spend too much effort choosing a single preferred option.

- Error Reduction Behaviours - CANDU utilities have universally adopted human performance behaviours advocated by the Institute for Nuclear Operations (INPO) and World Association of Nuclear Operators (WANO). These workplace behaviours (e.g., pre-job briefings, three way communication) are intended to reduce the incidence of indivdual and team errors, promote timely error identification and recovery when they occur, and assure team cohesion and co-ordincation during the conduct of work. Initially introduced into station operations as a human performance initiative, support for these behaviours has been integrated into station operating procedures.

- Training Qualification - The authorization of staff in licensed duty positions involves testing upset response knowledge and skills in simulator evaluations. The training organization has implemented 'team' training and 'team' testing scenarios, that allow for assessment of both individual and team response behaviours in a number of areas, for example, communications, oversight, independence, and conflict resolution. The importance of both simulator fidelity, and the fidelity of training and testing evaluations, are critical to ensuring that staff capabilities are assessed in conditions that closely resemble actual plant upset and team response conditions, and eventualities.

5. CONTROL CENTRE RESOURCE IMPACTS

Station upset response and the resulting team support needs create additional and new demands on control centre resources, both human and physical. Some important resource aspects that impact person-to- person and person-to-automation teamwork include:

- Additional Workspace - Operating situations where a greater number of staff than normal is required to work in the unit control area increases workspace demands and increases the potential for congestion, sources of disturbance, and distraction. Additional space to accommodate multiple team member discussions, pre-job briefings, and layout and review of documents for several unit systems should be supported. This can sometimes be accommodated by redeployment of unit work areas or temporary re-assignment of work areas in adjacent units, but both normal and upset operations must be considered in design.

  As nuclear vendors look to more compact console based control rooms for new plants and retrofit of old plants, consideration should be given to how the workspace needs of situations with increased staffing (e.g., upset response, outages, commissioning) can be effectively accommodated. Further, communication requirements, traffic flow patterns and ergonomics must also be considered for both normal and upset operations.

- Visibility of Unit Status Information - In current generation stations there is no concise representation of plant context in most operational (i.e., Full power operation versus low power states). In most cases, operating staff must develop and maintain an understanding of unit context and configuraton awareness based on the monitoring and synthesis of information from low-level panel and computer display indications in multiple locations. Equally important is the visibility of information concerning configuration and maintenance status. Future control room improvements should address improved options for common presentation of this information to better support both normal and upset operations,

- Information Access Bottlenecks - For the past ten years, utilities have been developing administrative computer-based applications for control room and work control deployment to simplify work planning, organization, and oversight, and equipment status tracking. In some cases, these applications are currently

available in one console location, and become in demand in situations where the operating team has more than a single user. The capability to add additional information workstations or display both plant status and configuration information on large status displays to support multiple users when operations create more user demands should be considered in future plant designs. It is important to ensure that the workspace is variable enough to support changes in Information Technology (IT). The ability to operate the plant safely in the absence of these IT systems must be thoroughly considered.

- Awareness of State Change - Current generation annunciation systems are incapable of serving the 'change' awareness information needs of upset response teams. This is an aspect of human-information automation where automation team support remains deficient. Consequently, the formalized response to upsets has been structured with minimal dependence on annunciation information. Exploration of alternative methods of conveying information on plant changes or equipment status may prove more beneficial than trying to further improve existing annunciation systems based on alarm list analysis and presentation. To be effective, future annunciation systems need to consider unit changes of state, as well as the 'information overload' that may face the operating staff.

- Duty Dedicated Work Areas and Resources - Until recently in legacy designs, shift supervisors had no assigned control room work area so that they were dependent on the use of the information workspaces and displays of other shift staff for workplace support. Some plants have created a central workspace, and others are developing dedicated work areas as part of each unit control area for supervisor use. A follow-on step will be the development of displays to support supervisory tasks.

- Access to External Information Sources - Current control rooms are not designed to offer ready access to news information from outside the station. Awareness of changing weather, traffic, neighbouring, and regional events can assist staff in making prudent response decisions and formulating action plans. This introduced a challenge during the August 2004 loss of electrical grid event in the north-eastern North American grid system.

6. CONCLUSION

This paper has outlined the Canadian experience with achieving effective control room teamwork during response to upsets in CANDU multi-unit stations. Canadian utilities are continuing to further refine teamwork capabilities, work practices, and supporting control room resources and work areas based on both local and international peer experience.

7. ACKNOWLEDGMENT

The authors would like to acknowledge the contributions and support of operating and training colleagues at Bruce Power and Ontario Power Generation. The insights, observations, and experience offered by these colleagues have helped the authors summarize the teamwork issues and experience associated with multi-unit station upset response practice reported in this paper.

8. REFERENCES

None.