Utilizing the SACADA System to Collect Simulator Training Data to Inform Human Reliability Analyses

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ABSTRACT

Lack of appropriate human performance data for the development of human reliability analysis (HRA) methods has been identified as a key issue contributing to the method-to-method variability among the HRA methods. The United States Nuclear Regulatory Commission (NRC) worked with domain experts to develop the Scenario Authoring, Characterization, and Debriefing Application (SACADA) system to collect nuclear power plants' licensed operator simulator training and examination data to inform HRA.

In the past two decades, significant improvements in understanding and modelling human performance in HRA have affected the perspectives of the types of data to be collected for HRA. A significant change is that human performance is strongly dependent on the context of the tasks to be performed. To incorporate this understanding, the SACADA data taxonomy collects the context and actual performance information of the training objective elements (TOEs) in nuclear plant operator simulator training. This provides a framework consistent with HRA to use context to estimate human error probabilities. It is recognized that measuring crew performance is equally important as improving operator training. SACADA is designed to support the nuclear trainers in capturing this important information that is used to identify training weaknesses and drive continuous improvement.

This paper discusses the SACADA taxonomy, the SACADA system's functions, and the supporting software design to enable the SACADA system to be practically implemented in the nuclear power plants' operator simulator training program to collect data for tracking operator performance and HRA analysis.

Key Words: SACADA; Human reliability analysis; HRA database; Operator training

1 INTRODUCTION

Lack of appropriate human performance data for the development of human reliability analysis (HRA) methods has been identified as a key issue contributing to the method-to-method variability among the HRA methods [1], [2]. The United States Nuclear Regulatory Commission (NRC), working with domain experts, developed the Scenario Authoring, Characterization, and Debriefing Application (SACADA) to address this issue.

SACADA's purpose is to provide a means to collect human reliability data with sufficient contextual information, both quantitative and qualitative, for HRA analysts to use as reference points for their human error probability (HEP) estimates [1]. SACADA was developed as a tool that can be implemented in the operator training program of nuclear power plants (NPP) to collect performance data during operator simulator trainings. SACADA provides a user interface for NPPs to record performance data and generate reports that can be used to track and trend performance data in order to help improve operator performance. Use of SACADA at the South Texas Project Nuclear Operating Company (STP) for more than three years has shown very positive experience for STP's operator simulator trainings. The data collected is then available for not only informing HRA but also improving operator simulator training.

This paper discusses the SACADA taxonomy, the SACADA functions and user interface design that enables the SACADA system to be used as a long-term data collection program that can both support operating training programs and inform human reliability and human performance analysis.

2 TAXONOMY

SACADA's data structure includes three hierarchical levels: scenario, malfunction, and training objective element (TOE). An operating crew is trained on a scenario in a training session. Each scenario contains a few system malfunctions or situations. The operators are trained to respond to these malfunctions or situations. Malfunction refers to an abnormal state of the plant that needs operators' actions to restore the plant back to a normal and safe state. A leaky valve, a broken pipe, and a pump failure are examples of a malfunction. Situations refer to changes in the plant status during a normal operation, e.g., increase reactor power. There are certain things that the operators need to do to respond to each malfunction and situation. These are called TOEs, which generally include detecting the need to respond, understanding the situation or the issues, deciding on a response plan (typically guided by operating procedures), and perform actions in a teamwork environment to drive the plant to the desired state. In SACADA, each TOE is a data unit that contains three types of information: general information, context, and performance results.

2.1 General Information

General information includes the crew composition (i.e., the number of operators and their positions), individual operator's experience level, the TOE description, and the TOE importance. The TOE importance is classified into four levels based on their significance to system safety.

2.2 Context

In the past two decades, significant improvements in understanding and modelling human performance in HRA have affected the perspectives of the types of information to be collected for HRA. A significant understanding is that human performance is strongly dependent on the context of performing the tasks, especially the context that affects human cognition. The same task performed in different context could have significant difference in reliability. To incorporate this understanding, the SACADA system collects context information relevant to the simulation of main control room activities. In SACADA, the context is characterized by a set of situational factors (SFs) [3]. The SFs are grouped based on their effects on the following cognitive functions [1],[3]: monitoring and detecting information, understanding the situation, making decisions and planning responses, performing actions, and communication & coordination. Examples of SFs are workload, time criticality, statuses of alarm boards, familiarity, and location and guidance.

2.3 Performance Results

The performance results include the response time and performance analysis. The SACADA software provides functions for users to specify the start time (e.g., a malfunction actuated) and the end time (e.g., a certain action is performed) to record the time information. Response time can provide clues to human performance, especially when the crews are taking unusually long or short times to accomplish tasks.

The performance analysis is each crew's performance to each TOE. SACADA collects the following information [1]:

- Overall performance rating: A four level system that includes outstanding performance (SAT+), satisfactory performance (SAT), satisfactory performance but there is performance deficiency (SATΔ), and unsatisfactory performance (UNSAT).
- If a TOE's performance rating is UNSAT or SATΔ:
    - Operator fundamental weakness: This is the five operator fundamentals specified by the Institute of Nuclear Power Operations (INPO). Because industry has used INPO's classification system SACADA provides this to link a performance deficiency to an INPO's operator fundamentals even though the SACADA does not collect detail performance information based on the INPO's classification.
- If a TOE's performance rating is UNSAT or SATΔ and the TOE's importance is at the top two levels additional information is collected. If the TOE's importance is not at the top two levels then the user can decide whether or not to collect the following information:
    - Performance problem type: This is a classification of the performance deficiencies based on the following macrocognitive functions: Monitoring/detecting, understanding, response planning, manipulation, communication, teamwork, and supervision. Because a TOE could have more than one performance deficiency (e.g., an operator mistake not detected by supervisor) a TOE can have more than one performance problem type.
    - Performance problem sub-type: Sub-types are pre-specified for the data enterers to choose from. For example, "not detecting a key alarm" and "late in detecting a key alarm" are two sub-types of the monitor/detecting performance problem type.
    - Causes of the performance problem: For each type and sub-type, a set of causes are pre-specified for the data enterers to choose the most appropriate causes for the performance problem.
    - Recovery: The performance problem may be identified by the individual or the other crew members before having an irreversible impact on the event. The recovery information documents how the performance problem is recovered.
    - End Result: The effects of the performance problem on the scenario by seeing the crew as a whole.
    - Remediation: Remediation specifies whether and what actions should be taken by the plant to prevent the reoccurrence of the performance problem. This is used for training purposes by the plants and is not collected for HRA analysis.

The taxonomy used to collect the performance results is structured to stimulate the crews to focus more on their performance deficiencies by providing cues for the crews to recognize them and to promote positive discussion on how to mitigate them in the future. This provides a significant benefit to improving training effectiveness. The software is designed to allow users to quickly collect performance data using checkboxes and lists rather than significant amounts of manual typing.

3 SOFTWARE USER INTERFACE DESIGN

The purpose of SACADA is to be a tool to collect human performance data. To be successful, SACADA needs utilities to enter performance data and the software is designed to benefit the operations training group and to encourage NPPs to utilize SACADA in their training program. The software supports operating crew performance by tracking and trending crew performance. This information can be used to improve simulator training or provide focus for operating crews on areas for improvement. There are several reporting features built into the software that reduce the workload for trainers. Examples of the reports include exports to crew notebooks and end-of-cycle reports.

Time is a limited commodity during the debrief session after a crew simulator training session. SACADA is designed to provide an interface for the crews to enter their performance information in a quick and efficient manner.

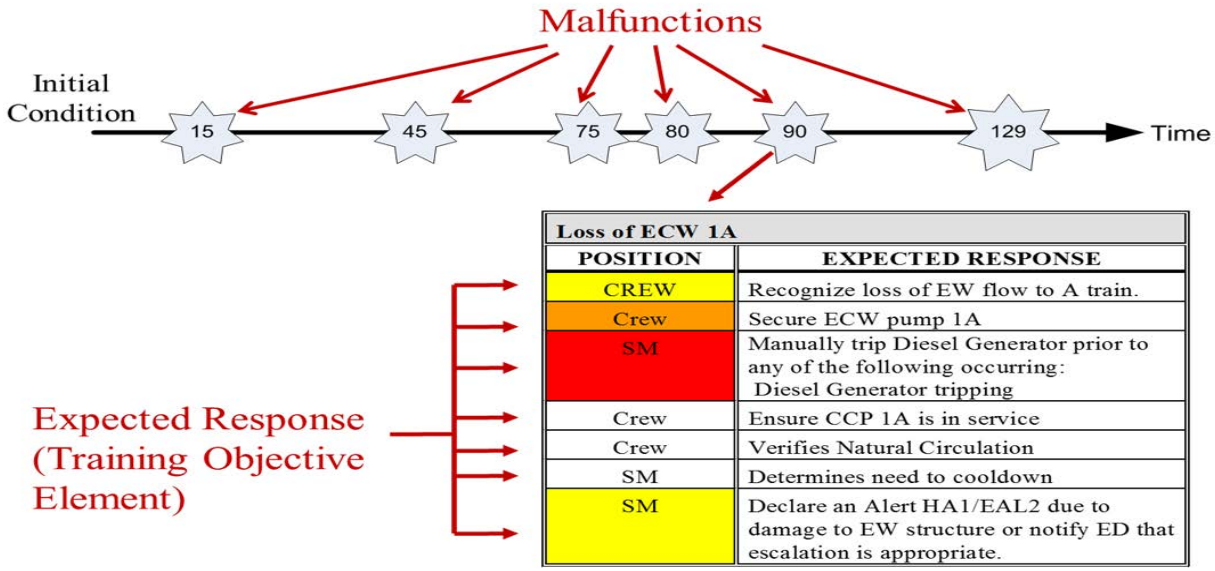
SACADA software has the following main functions to facilitate data collection:

- Scenario Authoring
- Characterization
- Debrief

3.1 Scenario Authoring

Scenario authoring and characterization are performed by the operations trainers before the simulator training session. Scenario authors can create new scenarios, reuse and update scenarios, and share scenarios with other plants. SACADA also allows users to copy only specific parts of other scenarios (malfunctions and elements) and add them to new scenarios. This ability to share and reuse portions of previous scenarios speeds up the process as a NPP's library grows within SACADA. Authors can also specify which malfunctions and TOEs that timing data should be collected on.

Figure 1 provides an example of the breakdown of a scenario's structure:



Loss of ECW 1A	
POSITION	**EXPECTED RESPONSE**
CREW	Recognize loss of EW flow to A train.
Crew	Secure ECW pump 1A
SM	Manually trip Diesel Generator prior to any of the following occurring: Diesel Generator tripping
Crew	Ensure CCP 1A is in service
Crew	Verifies Natural Circulation
SM	Determines need to cooldown
SM	Declare an Alert HA1/EAL2 due to damage to EW structure or notify ED that escalation is appropriate.

Figure 1. Example Scenario Structure

SACADA's interfaces presents the scenario is the same method as shown in Figure 1. A scenario is composes of one or more malfunctions, and each malfunction has one or more TOEs. This structure is just

an expansion on how scenarios appear in most simulator software used by the NPPs. Figure 2 provides a sample of how the scenario appears during the authoring of a scenario in SACADA, the color coding indicates each TOEs importance:

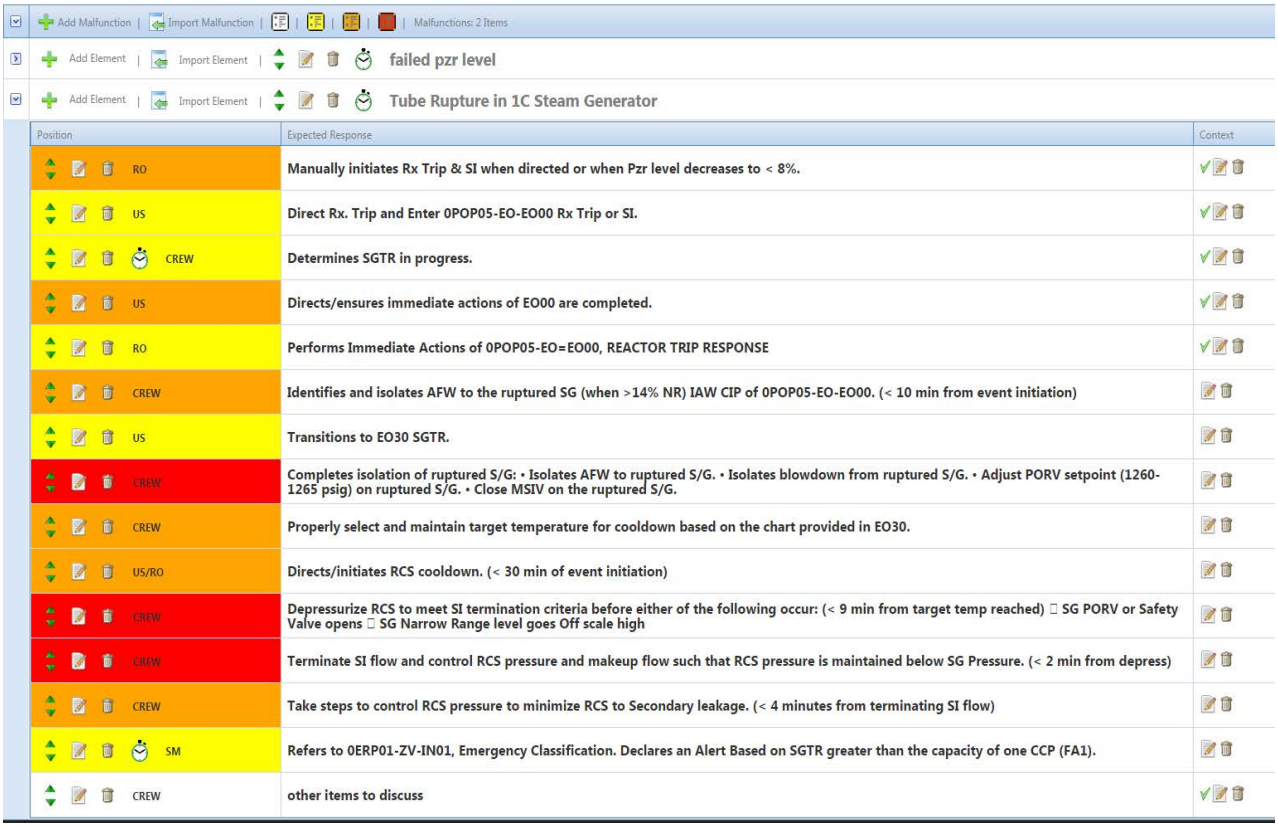


Figure 2. Sample Screen of SACADA Authoring

3.2 Characterization

Characterization is the process of determining the level of difficulty the crew is expected to encounter in performing the TOEs. The context is characterized by situational factors and then supplemented by a brief pre-specified narrative dialog that gathers more detailed information needed for the context as seen in Figure 3. This approach not only reduces data entry efforts for practical implementation in operator simulator training, but also has a few significant advantages, including:

- Providing a basis for evaluating crew performance variation;
- Enabling assessment of the context's effects on performance;
- Standardized information; and
- Providing a basis for informing context-based Human Error Probabilities (HEPs).

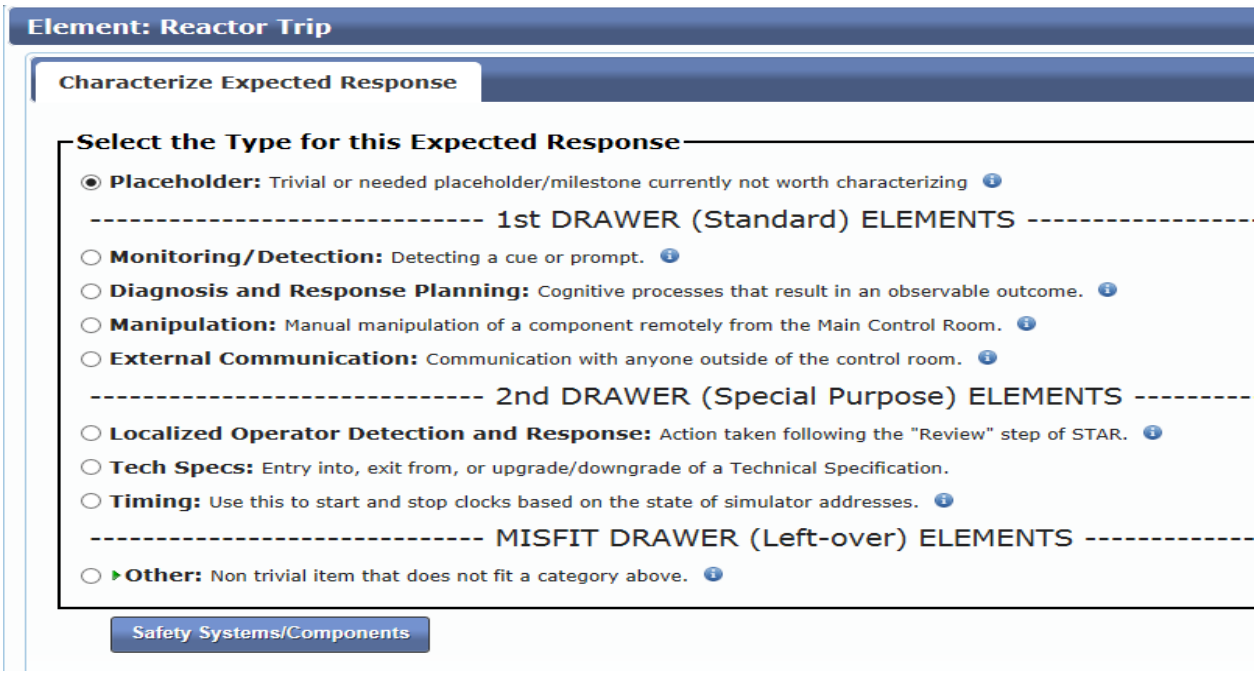


Figure 3. Sample Screen of SACADA Characterization

3.3 Debrief

The Debrief functionality of SACADA is typically handled by the crews themselves shortly after a simulation. This provides a retrospective analysis and it is seen that, in general, crews are more critical of their own actions. An observer can use the debrief screen during the training session to collect the timing data during the simulator observation. A mobile tool is also available for an observer record comments and timing data. This tool allows for offline collection of data that can be synced back to the scenario in SACADA.

Figure 4 shows a sample of a scenario debrief screen after a debrief session:

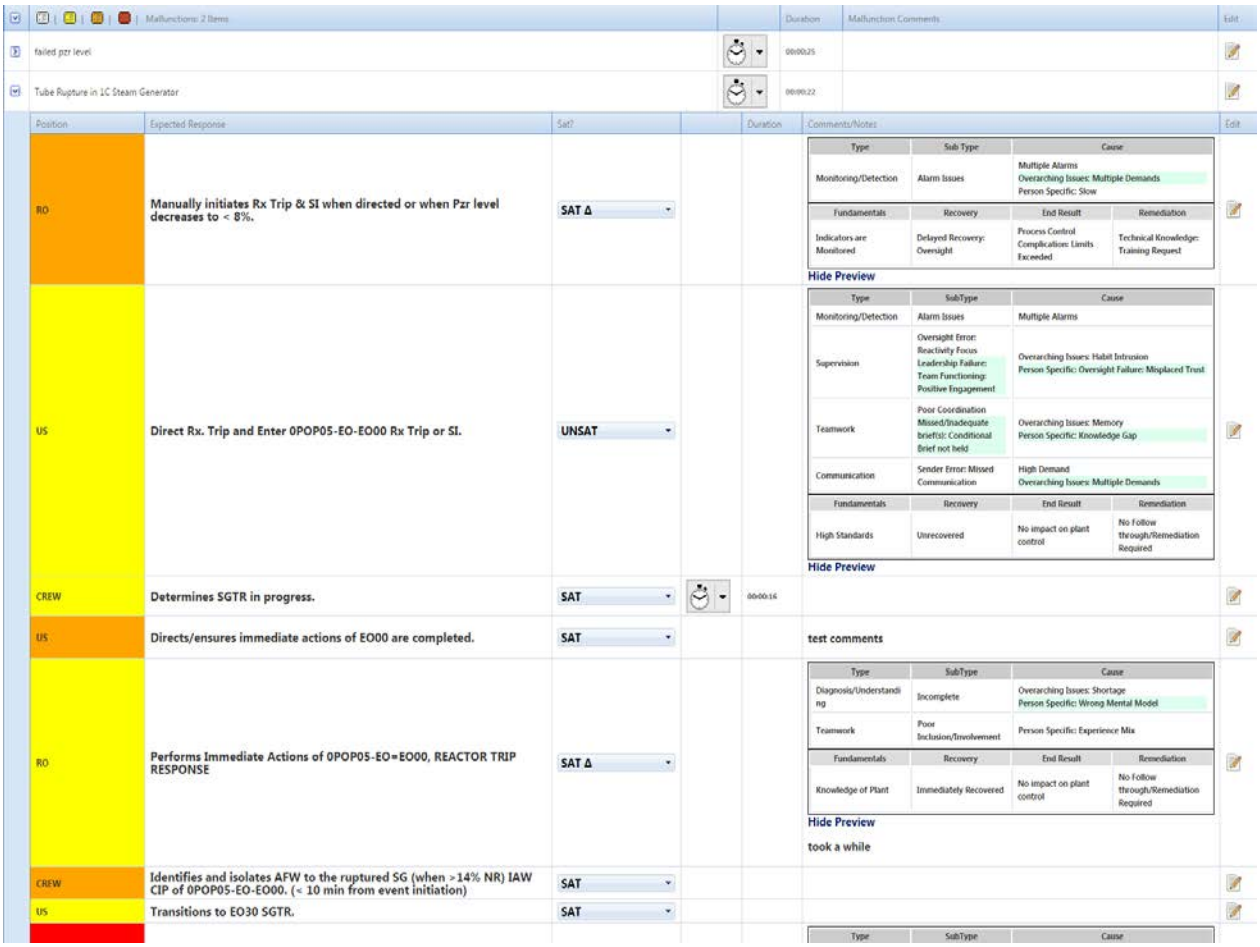


Figure 4. Sample Screen of SACADA Debrief

During the debrief, the crew evaluates each malfunction and TOE against the expected response. The performance is evaluated as either SAT+, SAT, SATΔ or UNSAT as described earlier. If the performance was judged to be SATΔ or UNSAT, additional information is collected to record the type of performance deficiency, the specifics of the deficiency, the causes of the performance deficiency, the recovery, the effects on the scenario and the required remediation. The SACADA application guides the crew through various possible causes for performance problems to maintain consistency. The dialog used to guide the crew through the performance review is designed to save time by allowing the crews to choose from options instead of having to type out each detail. The crews enter data following the pre-specified dialog based on the taxonomy described in the previous section. The dialog allows the crews to choose the most common reasons for their performance deficiency if applicable. Use of this taxonomy provides cues to the crew to help stimulate discussion into the underlying causes of the performance issue. Various reporting features built into SACADA support the tracking, trending and dissemination of operator performance data saving time for operations training staff.

Figure 5 shows an example of the dialog used to collect the performance results:

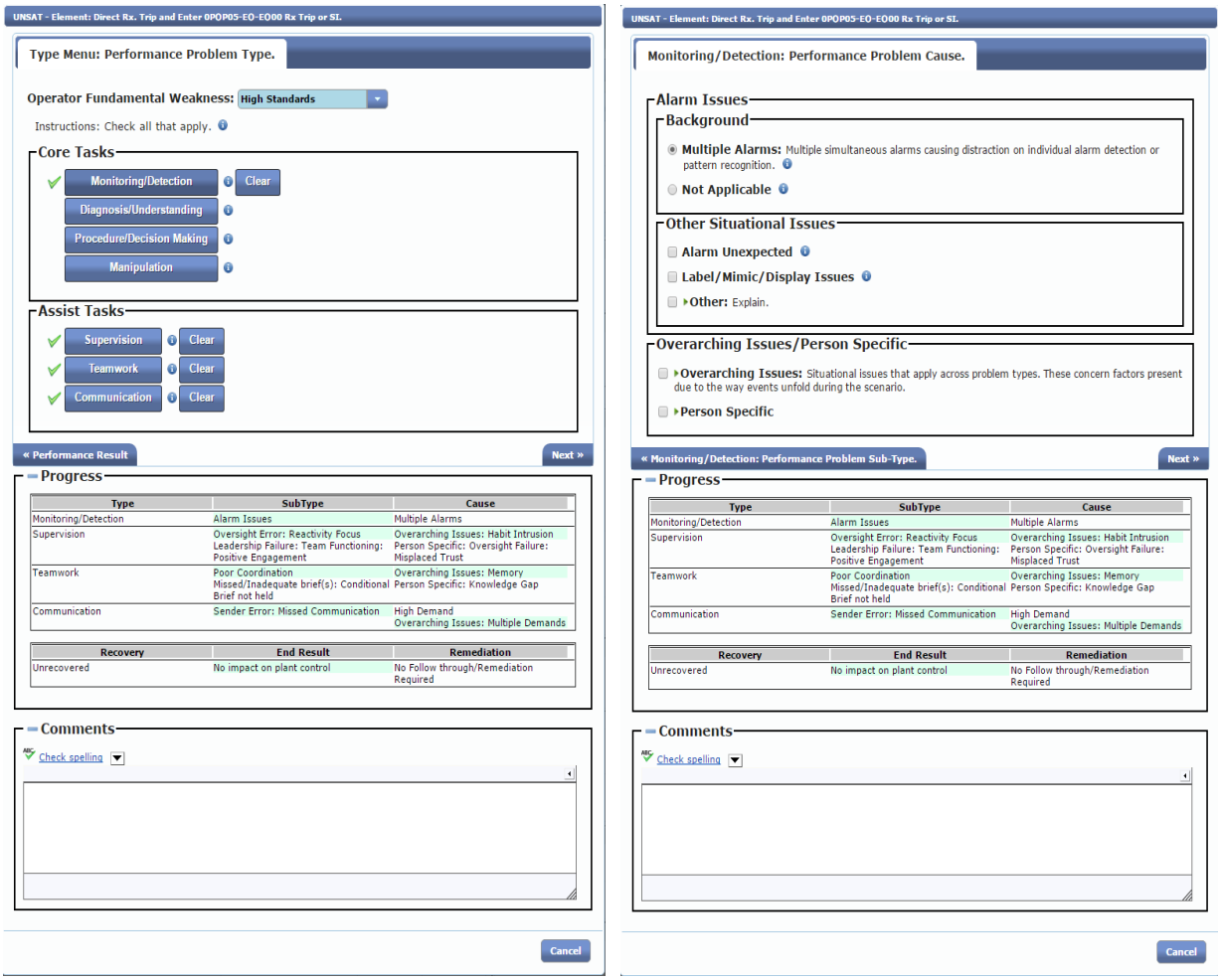


Figure 5. Sample Screen of SACADA Debrief Dialog

4 CONCLUSIONS

SACADA is a tool that provides operations trainers and crews with a quick and convenient way of capturing simulator performance information. SACADA's user interface design provides a method that allows the collection of information in a standard format. The user interface is also designed to decrease the amount of time needed to collect the performance results during the simulator training debrief.

The South Texas Project Nuclear Operating Company has had a very positive experience in using SACADA in its operator simulator training since 2012. The data have been used by the utility to support crew performance improvement as well as improving the training program. Reporting features built into the software application save time and have replaced many manually generated reports.

As more NPPs use SACADA, more data will be available for analysis. All users of the software, regardless of language or culture differences, enter their information following the same dialogs and therefor the data are gathered and stored into the same classifications and will be able to be aggregated based on similar context thus maximizing data usability. The amount of data will continue to grow and will be able to be used in support of operator training programs, informing different functional elements of conventional HRA methods, and providing a basis for context-driven HEP estimates [1]. Although verification is still being done on how the data will inform HEP estimates, current experience indicates that the data will support HEP estimates with stronger data basis.

5 ACKNOWLEDGMENTS

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6 REFERENCES

1. Y. J. Chang, D. Bley, L Criscione, B. Kirwan, A. Mosleh, T. Madary, R. Nowell, R. Richards, E. M. Roth, S. Sieden, A. Zoulis, "The SACADA Database for Human Reliability and Human Performance," *Reliability Engineering & System Safety,* **Volume 125**, pp.117-133 (2014).
2. H. Liao, K. Groth, S. Steven-Adams, "Challenges in Leveraging Existing Human Performance Data for Quantifying the IDHEAS HRA Method," *Reliability Engineering & System Safety,* **Volume 144**, pp.159-169 (2015).
3. E. M. Roth, A. Mosleh, Y. J. Chang, R. Richards, D. Bley, S. Shen, A. Zoulis, "Model-based Framework for Characterizing Contextual Factors for HRA Applications," *Proceedings of the 11th International Conference on Probabilistic Safety Assessment and Management (PSAM-11),* Helsinki, Finland, June 25-29 (2012).