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# Light Water Reactor Sustainability Program

Report for 2.2.1 Task 5: Develop and Document a State-Based Alarm System for a Nuclear Power Plant Control Room Using Machine Learning

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Report for 2.2.1 Task 5.a Develop and document a state-based alarm system for a nuclear power plant control room using machine learning



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### 1. Background

Institutt for Energiteknikk (IFE) operates the Organization for Economic Co-operation and Development OECD Halden Reactor Project. The organization has extensive experience from more than 20 years of research in human system interface (HSI) design and the operation of nuclear power plant research simulators in the Halden Man-Machine Laboratory (HAMMLAB).

HAMMLAB serves two main purposes. These are the study of human behavior in interaction with complex process systems and the development, testing, and evaluation of prototype control centers and their individual systems. The aim of HAMMLAB is to expand the knowledge of human performance in complex process environments in order to adapt new technology to the needs of the human operator. By studying operator performance in HAMMLAB and integrating the knowledge gained into new designs, operational safety, reliability, efficiency, and productivity can be improved.

IFE also provides new and innovative technology to customers in the form of operational task-based displays, large screen displays, innovative eye-tracking programs, and innovative performance testing methods. IFE also provides expert support in both nuclear power plant operations and setting up and running operations-based experiments and workshops.

#### 2. Introduction

Idaho National Laboratory (INL) has contracted IFE to support human factors research and the development of leading-edge technology to support control room operators as the U.S. fleet undergoes the modernization and digitalization of legacy plants and control rooms. As the nuclear industry starts to shift to more digital controls and systems, these upgrades provide more information to the main control room in the form of digital signals and values. Also, vendors provided an increase in the number of alarm points. New digital control rooms shift from main control boards to soft controls and from alarm panels to a single display. This change to a single display has created an alarm waterfall problem, a situation in which the addition of new alarm points causes an overload of information to the operator during either a plant disturbance or other than normal full power operations. IFE's goal is to find a workable solution to assist operators in both handling and understanding incoming alarms during emergency situations under these waterfall conditions.

# 3. Current Design

In legacy control rooms, operators might have 20 to 30 alarms to deal with on multiple control boards throughout the control room during a reactor trip. The new digital alarm system in the upgraded control room will display between 150 and 200 alarm points on a single screen. This overload of information prevents the operators from quickly identifying abnormal alarms, without having to scroll through the alarm list looking for abnormalities. One way to tackle this problem would be to create a state-based alarm system that would recognize plant states, identify alarms that are expected in those states, and suppress expected alarms from the alarm screen so that unexpected alarms would be displayed, prioritized, and easily identified by the operators. This can be done today, but the process is labor intensive in that an operator or training instructor would be required to run scenarios and log those alarms that need to be suppressed. The hope is that machine learning (ML) can provide an alternative, less labor-intensive solution.

### 4. Machine Learning for Unexpected Alarm Detection

The creation of traditional state-based alarm systems requires operators or trainers to manually specify the state conditions for the reactor at each state. This process differs in that, instead of trying to manually define these states, data is collected and ML is used to learn the state conditions automatically. The research described in this report is a continuation of the research performed last year where supervised learning and semi-supervised anomaly detection was used to establish that ML could, as a proof-of-concept, be used to develop state-based alarm solutions (Langstrand, Nguyen, and McDonald, 2019). Based on the results of the testing performed last year where anomaly detection on simple scenarios performed well enough to demonstrate the feasibility of this ML approach, this year's research was focused on this technique.

Anomaly detection is useful when accessible data contains predominantly positive or negative samples. In this case, the aim is to model the nominal behavior of the reactor and detect any unusual behavior in new data. This approach can also be called semi-supervised learning because only one class or type of data is used during the training of the model.

#### 5. Scope

The core deliverable is a report on the use of ML to create a state-based alarm system as compared to a human subject-matter expert (SME) state-based alarm system. Due to a COVID-19 outbreak during the early part of 2020 and issues with access to the simulator used by the initial SME, we were forced to adapt the initial plan to a modified process. The project used the generic pressurized-water reactor (gPWR) simulator found in both INL's Human System Simulation Laboratory (HSSL) and IFE's HAMMLAB in Halden, Norway. We will be able to compare IFE research results to the gPWR simulator results in HSSL. The results contained in this report are easily repeated in the HSSL using the same initial conditions and running through the same procedures.

The whole process, from collecting data to training and deploying a ML system, will be covered in this report, as will lessons learned.

#### 6. Data Collection

In order to train ML models, we first need to collect meaningful data that capture the nominal behavior of the gPWR. We chose a number of simple scenarios, including reactor startup from zero power, low power plant shutdown with manual turbine and reactor trips, and plant cooldown and depressurization. Once the nominal behavior of the gPWR was validated, we used more complex scenarios to further test the feasibility of the ML approach. Those scenarios included: manual reactor trip and manual safety injections, and reactor at full power with reactor trip, including safety injection due to malfunctions. Choosing these scenarios allowed us to focus on testing and iterating our ML models on a simpler problem, rather than initially spending an inordinate time on scenarios and complex combinations. Initially, we believed that we would need to create a data collection tool for this project; however, it turned out that we could repurpose an IFE-developed tool.

#### 6.1. Data Collection Tool

To collect data from the gPWR, the IFE's data collection tool was used. It is a tool developed by IFE that allows the collection of synchronized sound, video, simulator signals, and simulator events as well as having the ability to replay collected data. Only data relevant for

the modeling of nominal reactor behavior were collected such as: process signals, alarm signals, and process events. In total, we ran the simulator 20 times with scenarios of various lengths and complexities.

#### 6.2. Scenario Descriptions

#### 6.2.1 Scenario 1

The initial condition (IC) on the gPWR is IC 112 "Ready to remove RHR during heat-up." The controlling procedure is GP-002, Section 5.0, Step 55. This plant state is a normal condition during start-up activities after a refueling outage. The initial reactor coolant system (RCS) temperature is 342°F and 312 psig. The crew has secured the B Train of the residual heat removal (RHR) system and is ready to secure the RHR A Train and continue heating up the plant to greater than 350°F. There were 55 initial alarms at the start of this IC, as shown in Figure 6. This scenario was identified as a bad candidate for this ML project due to the time between different component operations. Also, there were few changes to the plant and no significant changes to the alarm display. This scenario is still relevant with the use of ML to identify the expected alarms, but, for this project, we were looking for more changes in the alarms, both clearing and activating, so we could identify if the ML was able to identify unexpected alarms.

#### 6.2.2 Scenario 2

The IC on the gPWR is IC 16 "Reactor start-up Shut-down Banks out." The controlling procedure is GP-004, Section 5.0, Step 30. An estimated critical condition of 95 steps on Control Bank D has been calculated. The crew is ready to start withdrawing the rod in accordance with the procedure until the reactor has reached criticality. This state-based condition is common after every reactor trip or outage. This is the normal startup procedure and process. There are 30 initial alarms at the start of this IC, as shown in Figure 7. This scenario was also identified as a poor candidate for this ML project due to the time that is required to start up the reactor and the lack of changes to the alarm display. ML could still be used to identify both expected and unexpected alarms. We chose not to continue with this based on time constraints.

#### 6.2.3 Scenario 3

The IC on the gPWR is IC 5 "Ready to trip the turbine during Shutdown." The controlling procedure is GP-006, Section 5.2, Step 34. This scenario is a normal shutdown from 8% reactor power followed by a turbine trip and then, when reactor power is less than 3%, a manual reactor trip is initiated. The crew will then continue a cooldown to 520°F and depressurization to 1,900 psig. There are 11 initial alarms, see Figure 8, at the start of this IC. The crew has reduced the reactor power to 8% and are ready to trip the turbine. Per the procedure, when the crew is ready, they trip the turbine manually and continue with the procedure. After the turbine has been tripped, there will be 23 alarms in the alarm summary, shown in Figure 9. Once reactor power has decreased to less than 3%, the crew is directed by the procedure to trip the reactor. After the reactor trip, there are 29 alarms in the alarm summary, as shown in Figure 10. The crew then transitions to GP-007 "Normal Plant Cooldown." This procedure is used to cooldown the RCS to 520°F and reduce the RCS pressure to 1,900 psig. The crew will follow this procedure until they have reached the previously desired plant conditions and then the scenario is stopped. The final alarm list contains 40 alarms, as shown in Figure 11. This scenario is easily replicated with near identical results, and is a good scenario to work with the ML. The scenario lasted

approximately between 40 to 60 minutes, depending on the rate of cooldown, and the number of alarms increased from 11 to 40.

#### 6.2.4 Scenario 4

The IC on the gPWR is IC 1 "Middle of Life, 100% reactor power Xenon is at equilibrium." The controlling procedure is GP-005, Step 143. This scenario is an abnormal situation with an inadvertent reactor trip and inadvertent safety injection. There are five initial alarms at the start of this IC, as shown in Figure 12. An inadvertent trip will be initiated, followed by an inadvertent safety injection. This scenario was created to see if ML could handle the large volume of alarms created by the reactor trip and safety injection. There are 105 alarms displayed on the alarm screen, as seen in Figures 13.1–13.3. By using an inadvertent trip and safety injection. This will provide a good base condition so that, when there are significant reasons, the unexpected alarms will stand out and give the control room staff a better understanding for the cause of the trip or safety injection.

### 6.3. Final Scenarios with Faults

#### 6.3.1 Scenario 3

Scenario 3 was conducted using the ML program connected to the gPWR simulator. The scenario was conducted as described in Section 6.2.3. Figures 14, 15, 16, and 17 show the results of the four stages: initial, after turbine trip, after reactor trip, and after cooldown. Figure 18 shows the results after faults FT-494C (XMT), and FT-494C Steam Generator C Component Steam Flow, Channel III final severity 0.00, and CFW16A Main Feedwater Pump #1 Trip is inserted. ML identified the expected alarms in the initial condition and in the turbine trip phase of the scenario. When the reactor was tripped, the ML identified all alarms as expected except one, the "Reactor Trip Manual." This alarm was later identified as an expected alarm, as the crew proceeded with the cooldown and depressurization of the RCS. While the crew continued with the cooldown and depressurization, nine additional alarms were received, which ML identified as three expected alarms and six unexpected alarms; however, all received alarms were expected. When the faults were inserted into Scenario 3, there were three additional alarms associated with the faults. The ML correctly identified that these alarms were not expected. A fault was inserted to see if the ML could handle a sudden influx of alarms and not change the state/condition selected, in this case a normal reactor shutdown and cooldown. We inserted fault MSS01B Steam Line Break Inside Containment (SG#2). Figures 19.1 and 19.2 show the results of this induced fault. The results were that the ML maintained the state/condition and identified almost all new alarms as unexpected while maintaining the previously identified alarms from earlier in the scenario. There were 41 initial alarms prior to the insertion of the final fault, then, after the fault, there were 89 alarms. One of the new alarms was identified as expected because it was identified earlier in the scenario and continued to be expected in the selected state/condition. The ML identified 46 additional alarms as unexpected for the state/condition.

#### 6.3.2 Scenario 4

Scenario 4 was conducted using the ML program connected to the gPWR simulator. The initial condition is IC 1, and the condition/state is a 100% power inadvertent reactor trip with a safety injection. The fault installed is the RCS18B RCS18 Small CL LOCA B Loop 100% = 4.5-inch-diameter break. The final severity was set to 25% with a ramp time of 5 minutes and a delay of 2 minutes. The severity and ramp time were selected based on the desire for the

leak to be large enough to cause a reactor trip and safety injection but small enough to allow time for the plant to respond to changes. The ramp time allows the pressurizer and charging system a chance to respond to changes in the RCS/pressurizer's pressure and level. These are not expected alarms in the initial scenario, so the goal is to see if the ML can identify these initial changes as unexpected. The next step is to see if ML can then separate a normal reactor trip and safety injection and identify the alarms that were unexpected. The goal here is to have those alarms that are unexpected to standout so the operator can easily determine the cause of the reactor trip and safety injection. Figures 20.1–20.3 show the results of the ML response to the fault. The scenario starts with a radiation monitor alarm that is not expected in this state/condition. Before the reactor trip at 05:55, there are some expected alarms and unexpected alarms. The unexpected alarms would help the crew focus on the pressurizer. Once the reactor trip has occurred at 06:10, there is a safety injection due to low pressurizer pressure. This is not expected in the selected state/condition. Of the first 50 alarms that are received, seven are unexpected in the selected state/condition. These 7 unexpected alarms show the cause of the both the reactor trip and the safety injection. In alarms 51–77, there are three unexpected alarms, which show a problem inside the containment building as the relative humidity is rising. Alarms 78–105 show an additional 26 alarms that are unexpected and continue to point to a problem with the RCS in the containment building. There are 36 unexpected alarms in this scenario. To a crew, reducing the number of meaningful or unexpected alarms from 105 to 36 would ease the burden of diagnosing the event and ensure that they take the proper actions in the emergency procedures.

#### 6.4. Data Description

The data collected by the IFE data collection tool are received in multiple files, so only the active directory monitor files used will be covered here:

- valueInfo.txt: describes the content of the binary file containing all the simulator process signals. This binary file assigns every process signal a unique identifier, lists the valid ranges for that signal, its engineering units, and also includes a short description.
- values.dat: contains all the process signals collected during a simulator run in binary format.
- processEvents.txt: contains all the process events with timestamps and identifications (IDs), for instance lamps turning on, valves opening or closing, and alarms on, and an operator can easily identify the cause for the reactor trip and safety injection. The unexpected alarms can provide a quick insight into the cause of the abnormal condition during the simulator run.

#### 6.5. Deliverable 1: Data Preprocessing Script

Before using the collected data to train the ML models, the data was preprocessed into a format that could be used by the ML models. The binary files containing the collected process signals were parsed into a csv and further packed into pickles, which allows for a quicker loading of the data. See Figure 1 for an image with graphs of some of the process signals collected during this step.

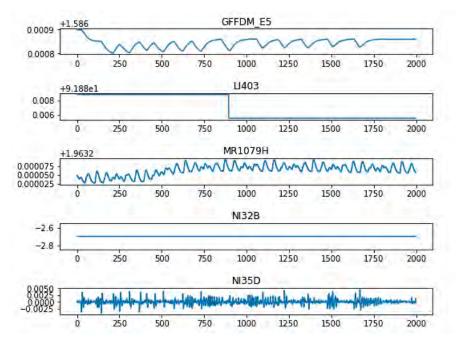


Figure 1. A selection of process signals used to train the ML systems.

The alarm signals were extracted from the process events file, using the timestamps, signal IDs, and alarm states to convert the events into continuous signals. The timestamps of both data sources were used to synchronize process signals with alarm signals.

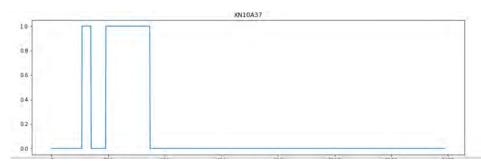


Figure 2. An example of an alarm signal that was created using the process events where a value of 0 represents the alarm off and a value of 1 represents the alarm on.

Both data sources were loaded as data frames into a Python notebook script. In total, there are 655 process signals and 751 alarm signals. Finally, the signals required normalization in order to make the ML training more effective and reduce the amount of time required to train a model. Without this step, the training would require more time and might even fail to converge on a good solution. An attempt to use the specified ranges from the file describing the ranges of each signal to normalize the values failed; however, it failed because some of the signals had incorrect ranges specified. As a result, min-max scaling was performed on the available data in order to have data within a valid, normalized range. Ideally, the predetermined ranges would have been used to normalize the input data because the ranges cover all possible values that the signals can have. In this way, even if the full range is not represented in the training data, the model would have access to the full range when working on unseen data.

Because the written script relied on data collected by the IFE-developed data collection tool, it would be difficult for INL to directly utilize the script without having Viewer access.

However, one option could be to extend the real-time tool to also have data collection capabilities, which would allow INL to collect data.

### 6.6. Machine Learning Modeling

With the data preprocessed and normalized, it was possible to begin ML modeling using the collected data. The data was split at the scenario level so that a model could be trained and tested for each scenario. The resulting datasets were highly imbalanced in terms of having 755 potential possible alarm signals, but only a fraction of these signals were ever in an on state. To mitigate the class imbalance problem, the root-mean-square error was used as the loss function during training. It is more effective than the mean-square-error in penalizing prediction errors in unbalanced datasets. Otherwise, the model might predict that all alarms are in an off state and still achieve a high accuracy. The dataset was then split into batches with a sequence length of 120 samples. The order of the batches was randomized before splitting the batches into training, validation and testing sets. As the training process ran, the batches were sampled at a random starting point to collect sequences of the desired time frame, which in this case was set to 30 samples. When pulling data from the simulator, it has a frequency of about three samples per second. Meaning that the model was trained to take an input sequence of 10 seconds and predict the expected alarm states from that.

Once models trained on the individual scenarios performed well, a combined scenario model was trained, utilizing data from both scenarios. Real-time testing was performed to determine how well the models filtered expected alarms and highlighted anomalous alarms. During testing, the operating procedures defining the scenario were followed and showed that the models could filter many expected signals. Additionally, anomalies were introduced during the scenarios, and the models were able to highlight these without filtering any by accident.

# 6.7. Tools and Frameworks

To handle the data preprocessing and preparation as well as ML, Python was used with frameworks, such as Pandas, Numpy, and Keras. Keras is a widely used ML framework that provides a higher-level, easier-to-use API for modeling. Keras also supports multiple popular ML libraries, such as Theano, CNTK, and Tensorflow. Tensorflow was selected for these tests. Tensorflow is a popular open-source ML library, developed by Google.

#### 6.8. Modeling

Long short-term memory (LSTM) layers were used during modeling, as they have been shown to be effective in processing sequential data. This layer type also performed better than fully connected or convolutional layers, which were tested during last year's project. An autoencoder-type architecture was used where the initial layer is large, then shrunk in size (encoded), and then expanded back to the original size (decoded) in the last layer. This means that the large number of signals coming into the network will be encoded into a smaller dimension and then recreated from the encoding in the later layers. See Figure 3 below for an overview of the final model architecture used.

Layer (type)	Output Shape	Param #
input (InputLayer)	[(None, None, 655)]	0
lstm (LSTM)	(None, None, 1024)	6881280
lstm_1 (LSTM)	(None, None, 512)	3147776
lstm_2 (LSTM)	(None, None, 512)	2099200
lstm_3 (LSTM)	(None, 1024)	6295552
output (Dense)	(None, 751)	769775
Total params: 19,193,583 Trainable params: 19,193,583 Non-trainable params: 0		

Figure 3. The architecture of the final LSTM model used during the evaluation of the testing scenarios.

Once trained, the model is used as follows. The 655 process signals are entered into the network, and the network predicts the expected state of the 751 alarm signals. The resulting output of the model is then subtracted from the current alarm state. A difference close to zero means that the signal is expected. If it is bigger than some defined threshold, it is treated as unexpected. This threshold was set to 0.8 during the real-time testing.

#### 6.9. Results

There were a series of test runs to see how the ML would respond to the two identified scenarios. The results are seen in Figures 21–27. These test runs were conducted using the gPWR in HAMMLAB.

Once the desired state/condition has been identified, a scenario can be created around that state. The scenario creation process usually takes 4 hours to set up and test the scenario for the first time and determine if it will be stable and work for the desired time. Once the scenario has been defined, it will need to be run and the data captured using IFE's data collection tool. The scenarios vary in length, as Scenario 3 was 90 minutes whereas Scenario 4 lasted between 10 and 15 minutes. During testing, we shifted back and forth between scenarios to verify that the ML could quickly identify the desired state and expected initial alarms. The ML never had any problems identifying the initial set of alarms, and the results show the success in the final scenario runs.

# 6.10. Deliverable 2: Trained Machine Learning Models

As part of the tool described in the next section, some of the trained ML models have been included for testing purposes. There are some steps required to go from a newly trained model to one that can be deployed and used in an application:

- First, the model must be exported, either to two files, with one describing the model architecture and one containing the model weight, or to one file containing both the architecture and the weights.
- Second, the model must be converted from a Keras model (.h5) to a frozen Tensorflow model (.pb).

 During this step, it is important to find the name of the input and output layers of the model, as these will be required when deploying the model for inferencing later.

#### 6.11. Deliverable 3: Simulator and Machine Learning Interface Tool

To connect trained models to the simulator so that the model can receive live data and perform alarm filtering, a tool in C# was developed that uses ProcSee to communicate with the simulator (see Figure 4). ProcSee uses a publication and subscription model that allows it to subscribe to the process signals of interest and receive messages containing the value of these signals approximately three times per second. Using the publication module, the output of the ML model is published to update an alarm display made for the testing the alarm system.

🖳 Simul	ator ML inference tool			E E	
File	Model autoencoder_100_rt	Threshold 0.5	*	luna	<ul> <li>Connect</li> </ul>

Figure 4. A snippet of the simple tool created to communicate between the simulator and ML models.

The tool allows the user to select the ML model to load and the simulator with which to connect. To load a model, a json file with the same filename as the ML model file must also be provided. The json file must contain these values:

- "friendly\_model\_name": the name used when displaying the model option in the dropdown box.
- "input\_name": the name of the input layer of the frozen ML model.
- "output\_name": the name of the output layer of the frozen ML model.
- "nmb\_input\_signals": the number of signals input to the ML model. This number is used when preparing the input data structure used when inferencing with the ML model. Note that this number must match the number of inputs in the input layer of the model used.
- "input\_sequence\_length": the length of the input sequence used when running a model inference. If the value is greater than 1, it will use a time window of that size when running model inference. Note that this number must match the sequence length used during the training of the model.

- "only\_process\_in": a Boolean value to determine if only process signals are used as input or both process and alarm signals.
- "scenario": the name of the scenario the model was trained on. This is used to load the corresponding min-max scaling data required to normalize the process signals received from the simulator.

Once loaded, the data received from the simulator signal subscription are used to run inference with the loaded ML model. The output produced by the model is then compared to the original alarm states received from the simulator. If there are discrepancies, they are considered unexpected and flagged as such. In addition, it is possible to change the threshold value used when processing the output of the ML model during runtime.

After all the signals have been processed, a message is constructed and sent to the simulator with a list of the alarms that have changed state and their new state, as predicted by the ML model. Once received, this message updates the alarm display mentioned earlier (see Figure). The display was created to facilitate comparison between the alarm lists. The tool will be made available to INL; however, modifications might be necessary to connect to INL's simulator. ProcSee is available for use at INL as well. Minor modifications might be necessary to communicate with INL's gPWR simulator.

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		Doc Doc				00:03:18.680	L-XSB2C08	H250 5W-573 (RED	LAMP)	OFF	
		Doc				00:03:19.000	L-XSB2C08	H250 SW-573 (RED		ON	
						00:03:19.640	L=XSB2C08	H250 SW-573 (RED		DFF	
						00:03:20.000	L-XSB2C08	H250 SW-573 (RED		DN	
						00:03:52.200	L+X582018	CNDSER HD-325 (R		DN	
		Doc Doc				00:04:15.600	HD-325	46 Heater To Con		INTERNI.	
		Dac				00:04:13.500	L-XSE2D18	CNDSER HD-325 (R		OFF	
		Dati Dati				00:04:53.640 00:04:53.640	XN18A28 XN20A15	TURBINE TRIP AUTO TURBINE AUTO STO		ACTIVE	
		(Davi)				00:04:53.840	TV-1	Throttle Valve 1		ACTIVE INTERN.	
		Daci				00:04:53.840	TV-Z	Throttle Valve 2		INTERN.	
		1000				00:04:53,840	TV-3	Throttle Valve 3		INTERN	
						00:04:53,840	TV-4	Throttle Valve 4		INTERM.	
						00:04:55,840	GV-1	Governor Valve 1		INTERN.	
						00:04:53.840	GV-2	Governor Valve 2		INTERN.	
						00:04:53.840	GV-3	Governor Valve 3		INTERM.	
						00:04:53.840	DEHAL	Turbine trip		ON	
						00:04:53.840	L-XSB3C07	28 NRV ES-110 (G	REEN LANP)	ON	
						00:04:53.840	L-XSB3C05	3B NRV ES-81 (GR		DN	
						00:04:53.840	L-XSB3C03	48 NRV ES-18 (GR		ON	
						00:04:53.840	L-XSB3C01	SE NRV ES-2 (GRE		ON	

Figure 5. A screenshot of the operator display, showing both alarm lists side by side for easy comparison. The list on the left contains the original alarm list while the right list shows the ML-filtered alarm list.

The display developed for showing the alarm lists is very simple and was used only to test the ML model's filtering capability. This does not mean that this display is the best way to visualize the results of the ML system.

### 6.12. Conclusions

6.13.

The use of ML in the attempt to create a state-based and condition-based alarm system showed good promise. The initial tests and trials had mixed results that were dependent on which ML program was used. The ability to collect the data and train the ML program was simple and straightforward. The ability of an operator or training instructor to create the "scenarios" and identify the various states is a straightforward task. The time to set up and run the different scenarios varied from 60 and 90 minutes for Scenario 3 to 5 minutes for Scenario 4. The training of the ML program was a relatively quick process and could be done in 10 to 15 minutes for each state and further improved with increased training times. The results for Scenario 3 were positive but still had six expected alarms unidentified by ML. Additionally, ML maintained its requested state in Scenario 3 when a large steam break inside the containment building was initiated. Scenario 4 was successful in identifying expected alarms and providing the operator with information on unexpected alarms that would support future troubleshooting on the cause of the reactor trip and safety injection based on the unexpected alarms.

The research conducted under this project provided insight into the ability to use ML as a method of creating a state-based alarm system. The project showed strong positive results in the higher volume of alarms in Scenario 4. Research needs to continue to find the best ML system and most efficient method of training the ML. Including the investigation of new emerging state-of-the-art ML architectures, such as the Transformer model, which has shown great results on the processing of sequential data.

0.13.	Appreviations
AMS	alarm management/filtration system
CCW	component cooling water
CNN	convolutional neural network
DNN	deep neural network
gPWR	generic pressurized water reactor
HAMMLAB	Halden Man-Machine Laboratory
HSI	human system interface
HSSL	Human System Simulation Laboratory
IC	initial condition
IFE	Institutt for Energiteknikk
INL	Idaho National Laboratory
LSTM	long short-term memory
ML	machine learning
RCNN	recurrent convolutional neural network
RCS	reactor coolant system
RHR	residual heat removal

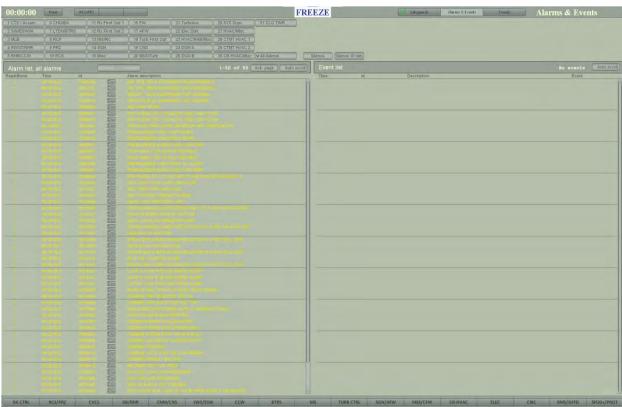
Abbreviations

RNN recurrent neural network

SME subject-matter expert

#### 6.14. References

Langstrand, J.P., Nguyen, H., and McDonald, R. (2019). Report for 2.2.1 Task 5: Develop and Document a State-Based Alarm System for a Nuclear Power Plant Control Room Using Machine Learning, INL/EXT-19-55368. Idaho Falls: Idaho National Laboratory.



### 6.15. Figures Section

Figure 6. Initial alarm display for Scenario 1, 55 alarms.

00:00:00	Print	CS/PR2				FREEZE	Sateguardi	Alarms & Events	tronets	Alarms & Events	
	6 CHG/BA	11 Rx First Out 1	16 FW	26 SYS Supy	31 CLG TWR						
3 MLB				ac 28 CTMT HVAC 1							
					V All Alarms	Silence Silence 10 min.					
						Event list					
Repetitions T	Fime Id	100	Alarm description			Time Io	Description			Eyent	
		VISBOS Doci I				1					
		VIJCOS Doc									
		NS3C07 Doc									
		N13802 ESS N13804 ESS N13804 ESS N13807 ESS									
		113007 Doc									
		VILAGO (LOC)									
		NS4ASB Doc									
		NS4A58 (Dob)									
		NAAR 028 NRAAS 026 NRAAS 026 NRAAS 020 NRAAS 020									
		119A22 Doc									
		NIGA24 Doc									
		N20A03 (Doc)									
		N20A10 Doc									
		V20A15 (Doc)									
		120A18 (Doc)									
		V20A24 Doc I									
		V22A06 (Doc)									
		N22A26 Doc									
		V23M0Z (Doc									
		N23905 Doc 1									
		V23M02 Dec V23R05 Dec V23R05 Dec V23R04 Dec V23R04 Dec									
		V23T05 (Dec)									
						U.					

Figure 7. Initial alarm display for Scenario 2, 30 alarms.

00:00:00	Print	PCS/PRE					FREEZE	mateguardi	Alarms & Events	fronts.	Alarms & Events	
1 CTS / Accum 2 SW/ESW/A 3 MLB 4 RWST/RHR 5 RHR/CCW	6 CHG/BA 7 LTD///BTRS 8 RCP 9 FRZ 10 RCS	11 Rx First Out 1 12 Rv First Out 2 13 NI6/RC 14 SON 15 Milec		21 Turb/Aux 22 Elec Dist 23 HVAC/RAB/Misc 24 DGN A 25 DGN B	26 SYS Supy 27 HVAC/Mise 28 CTMT HVAC 1 29 CTMT HVAC 2 30 CR HVAC/Mise	31 CLG TWR	Silence  Silence 10 min.					
Alarm list, all						Ack page Auto					No events	Auto sc
		d	Alarm description		1-11 01 11	Ack babs IL Auto	Time Id	Description			Event	HEND SEA
			SOURCE MANUEL LO SOURCE MANUEL LO PONDE RANGE LOW CHOST PAURE RANGE LOW CHOST PAURE RANGE LOW CHOST PAURE RANGE LOW CHOST PAURE RANGE RANGE BAR AND AND AND AND AND AND AND SOURCE AND AND AND AND AND AND AND AND AND AND AND AND AND AND AND AND AND AND AND AND AND AND AND AND AND AND AND AND AND AND AND AND AND AND AND									

Figure 8. Initial alarm display for Scenario 3, 11 alarms.

0:08:53	Print	MM/CBS							Tatosuarda	Alarms & Events	Taxando.	Alarms & Even	ats
	6 CHG/8A	H Rx Pirst Out 1		21 Turb/Aux	26 SYS Supv	31 ELG TWR							
		12 Rx First Out 2			27 HVAG/Misc								
LO	BRCP	10 NIS/RC			Milec 28 CTMT HVAC 1								
			IN CND										
HR/CCW	10 RCS		( 20 MSS/Turb	25 DGN B	30 CR HVAC/Misc	V Alt Alarma		min.					
larm list, all			1		1-23 of 23	Ack. pape VAuto scre							
etillions 7	Time In	1	Alarm description				Time	Id	Description			Event	_
		transition (Date)					00:03:04.600	L-X582008	H250 SW-573 (			ON	
		Inchine Doc					00:03:04.920	L-XS82c08	H250 SH-573 (			OFF	
		Doci					00:03:05,600	L-1382008	H250 5H-573 1			ON	
		1000 Eco					00:03:05,920	L-XSB2C08	H2S0 SW-573 (			DEF	
		Deci					00:03:06,560	L-1/58/2008	H250 SW-573			DN	
		Dec					00:03:06.840	L-X582008	H250 SW=\$73			OFF	
		Dail					00:03:07,450 00:03:07,800	L-X582008	HZSD SW-573 ( HZSD SW-573 )			ON OFF	
		Inclass (Dec)					00:03:08.480	L-X582C08	H250 Sk-573 1			OFF	
		Dec Dec					00:03:08.480	L-3582008	H250 SW-573 4			OFF.	
	An extension	(Sed)					00:03:09.400	L=X5B2C08	H250 SIN-573			ON	
		(Doc)					00:03:09.720	L-X582008	H250 SW-573 (			OFF	
		Des					00:03:10.400	L-1/582C08	H250 SW-573 (			ON	
		(Dec)					00:03:10.720	L-3582008	H250 3W-573			OFF	
		Doci					00:03:11.320	L-1582008	HZSO SW-573			DN	
		(50C)					00:05:11.640	L-XS82008	H250 SW-573 1	RED LANP)		OFF	
		(Doc)					00:03:12,320	L=X582008	H250 SW-573 1	RED LAMP)		ON	
		Daci					00:03:12.920	L-1382c08	H250 SW-573			OFF	
		(Dok)					00:03:15.240	L-3562008	H250 50-573 1			ON	
		Interest (Doc)					00:03:13.880	L-XSB2C08	H2SO 516-573 1			OFF	
		Dot					00:03:14.200	L-X582008	H250 SW-573 4			ON	
							00:03:14.840	L-X582008	H250 SW+573 (			OFF	
		Doc)					00:03:15.200 00:03:15.800	L-X582008	H250 SW-573			ON	
							00:03:16.120	L=X582C08	H250 SW-573 4			ON	
							00:03:16.720	L-1582008	H250 51-573 (			OFF	
							00:03:17.120	L-XSB2C08	H250 SW-573 (			ON	
							00:03:17-720	L=\\582008	H250 5(v=573 (			DFF	
							00:03:18.080	L-MS82008	H250 SW-573			ON	
							00:03:18.680	L-3582008	H250 SW-573 (			OFF	
							00:03:19.000	L-X582c08	HZSO 5W-573 (			ON	
							00:03:19.640	L-XSB2C08	H250 SIN-573			OFF	
							00:03:20.000	L=X582C08	H250 5W-573			ON	
							00:03:52.200	L-X582018	CNDSER HD-325			ON	
							00:04:15,600	HD-325	48 Heater To			INTERM,	
							00:04:13,600	L-%582018	CNDSER HD-325			OFF	
							00:04:53.840	XN18A28 XN20A15		AUTO STOP OIL TR		ACTIVE	
							00:04:53.840 00:04:53.840	TV-1	TURBINE AUTO	STOP OIL LOW PRE		ACTIVE INTERM.	
							00104:53.840	TV-2	Throttle Valv			INTERN.	
							00:04:53.840	TV-3	Throttle val			INTERM.	
							60:04:53.840	TV-4	Throttle Val			INTERM.	
							00:04:53.840	6V-1	Governor Valu			INTERM.	
							00:04:53.840	GV-2	Governor Val			INTERM.	
							00:04:53.840	GV-3	Governor vals			INTERM.	
							00:04:53,840	DEHAL	Turbine trip			DN	
							00:04:53.840	L-X583C07	28 NRV ES-110	(GREEN LAMP)		ON	
							00:04:53.840	L-XSB3C05	3B NRV ES-81			ON	
							00:04:53.840	L-KSB3C03	4E NRV ES-18			ON	
							00:04:53.840	L-XSB3C01	SE NRV ES-2	GREEN LAMP)		ON	
	RCS/PRZ	CVCS S	IS/RHR CN										SEGDS

Figure 9. Scenario 3 after a turbine trip, an additional 12 alarms for a total of 23.

0:12:20	Print	MA/CHS ]							Tatezuarda	Alarms & Events	frends	Alarms & Eve	nts
	5 CHG/BA	11 Rx Pirst Out 1	16 EW		26 SYS Supv	31 CLG TWR							
		12 Rx First Out 2			27 HVAC/Mac								
4.8	8 RCP	13 NIS/RC				÷.							
RWST/RHR	8 PRZ	14 SUN	ID CND	ZA DGN A	29 CTMT HVAC 2	4							
RHR/CCW	10 RCS	15 Misc	1 20 MSS/Turb	25 DGN B	30 CR HVAC/Misc	V Alt Alarma	Silence Silence 10	min.					
						Ack. page VAuto scr							
etillons 7	Time Id	the second se	Atarm description				Time	ld	Description			Event	
		Dasi					00:03:04.600	L-X582C08	H250 SW-573 (F			ON	
		Intrine (Doc)					00:03:04.920	L-XSB2c08	H250 SW-573 (F			OFF	
		in the second					00:03:05,600	L-X382008	H290 51-573 (			ON	
		Dec Dec					00:03:05,920 00:03:06.560	L-X582008 L-X582008	H250 SW-573 (F H250 SW-573 (F			DEF	
		(Dec)					00103106.840	L-X5B2C08	H250 51-573 (F			OFF	
		(Doc)					00:03:07,480	L-3582008	HZSO 5W-573 (F			ON	
		(FIAR)					00:03:07,800	L-XSB2C08	HZSO 5W-573 (F			OFF	
		(Dac)					00:03:08.480	1-XS82C08	H250 SIN-573 (F			ON	
		Eac Dec					00:03:05.800	L-xSB2c08	H250 SW-573 (F			OFF	
		000					00:03:09.400	L-XSB2C08	H250 51-573 (F			ON	
		Dac					00:03:09.720	L-X582C08	H250 SW-573 (F	RED LAMP)		OFF	
		(Doc)					00:03:10.400	L-MSB2C08	H250 SW-573 (#			ON	
		(Dec)					00:03:10.720	L-XS82c08	H250 5W-573 (F			OFF	
							00:03:11.320	L-X582008	HZSO SW-573 (#			DN	
		Dod					00:03:11.640	L-XS82C08	H250 SW-573 (P			OFF	
		Dor					00:03:12,320	L-XSB2C08	H250 SW-573 (F			ON	
		Dec Dec					00:03:12.920	L-X582C08	H250 SIN-573 (F			OFF	
		(Doc)					00:03:13.240 00:03:13.880	L-X582C08	H250 5W-573 (F			ON	
		(Doc)					00:03:14.200	L=X582C08	H250 SW-573 (F			ON	
		Dec					00:03:14.840	L-X582C08	H250 SW=573 (F			OFF	
		Dac					00:03:15.200	L-X582005	H250 5W-573 (F			ON	
		(Dac)					00:03:15,800	L-1582008	H250 SW-573 (F			OFF	
		(Doc					00:03:16.120	L=x582C08	H250 SW-573 (#			ON	
		Dec					00:03:16.720	L-1582c08	H250 51-573 (F			OFF	
		Doc					00:03:17.120	L+%582C08	W250 SW-573 (F			ON	
		Dec					00:03:17-720	L=NS82c08	H250 SW-573 (F			OFF	
		Ear					00:03:15.030	L-kse2c08	H250 SW-573 (F			ON	
							00103:18.680	L-XSB2C08	H250 5W-573 (#			OFF	
							00:03:19.000	L-2582c08	H2SO SW-573 (F			ON	
							00:03:19.640	L=\cs82c08	H250 5W-573 (P			OFF	
							00:03:20.000	L-X582C08	H250 5/4-573 (F			ON	
							00:03:52.200 00:04:15.600	L-XS82018 HD-325	CNDSER HD-325 48 Heater To 0			DN INTERH	
							00:04:13,600	L-1582018	CNDSER HD-325			OFF	
							00:04:53.840	XN1SA28		AUTO STOP OIL TR	TP	ACTIVE	
							00:04:53.840	KN20A15		STOP OIL LOW PRE		ACTIVE	
							00:04:53.840	TV-1	Throttle Valve			INTERN	
							00104:53.840	TV-2	Throttle Valve			INTERH	
							00:04:53.840	E-VT	Throttle valve			INTERM	
							60:04:53.840	TV-4	Throttle Valve			INTER	
							00:04:53.840	5V+1	Governor Valve			INTERM	
							00:04:53.840	GV=2	Governor Valve			INTERM	
							00:04:53.840	GV+3	Governor valve	1.3		INTERIA	
							00:04:53,840	DEHAL	Turbine trip			NO	
							00:04:53.840 00:04:53.840	L-X583C07 L-X583C05	28 NRV ES-110 38 NRV ES-81			ON	
							00:04:53.840	L-X583C05	48 NRV E5-81 4			ON	
							00:04:53.840	L-X583C01	56 NRV ES-2 (0			ON	

Figure 10. Scenario 3 after a reactor trip, an additional six alarms for total of 29.

0:44:52	Print	MA/CHS ]							Tateguards	Alarms & Events	frends	Alarms & Ever	
	6 CHG/BA	II Rx Piret Out 1	1 16 EW		26 SYS Supv	31 CLG TWR							
		12 Rx First Dut 2											
1.8	8 RCP	13 NIS/RC				=							
RWST/RHR													
RHR/COW	10 RCS		I 20 MS/S/Turb	25 DGN B	30 CR HVAC/Mil	c VAII Alarma		min.					
Narm list, all		1				Ack. page V Auto scr							
	Time Id	-					Time	Id				Event	_
		Dac)					00:03:04.600	L-X582008	H250 SW-573			ON	
		I MITTER					00:03:04.920	L-X582C08	H250 SW-573			OFF.	
		Doti					00:03:05,600	L-X582008	H290 5W-573			ON	
							00:03:05,920	L-XSB2C08	H2S0 SW-573			OFF	
		Doc					00:03:06.560	L-10582008	H250 SW-573			DN	
		Doci Doci					00103106.840	L-X582008	H250 SW=\$73			OFF	
							00:03:07,480	L-X582008	HZSD 5W-573			ON	
							00:03:07.800	L-XSB2C08	HZ50 SW-573			OFF	
		Letter Dec					00:03:08.480 00:03:08.800	L-X582c08 L-X582c08	H2SO Sk-573 H2SO Sk-573			ON	
	La L	Dec .	And an average of the second se				00:03:09.400	L-XSB2C08	H250 5k-573 H250 5k-573			ON	
		Dec					00:03:09.720	L-X582008	H250 SW-573			OFF	
		Doc					00:03:10.400	L-MS82008	H250 SW-573			ON	
		0.00					00:03:10.720	L-XSB2C08	H2S0 SW-573			OFF	
		Dac					00:03:11.320	L-X582008	HZSO SW-573			DN	
		1Mag					00:05:11.640	L-X582008	H250 SW-573			OFF	
		(Dan)					00:03:12,320	L-X582008	H250 SW-573			ON	
		Doc					00:03:12.920	L-X582c08	H250 SW-573			OFF	
		Dog					00:03:13.240	L-R582008	H230 51-573			ON	
		(Dog)					00:03:13.880	L-XSB2C08	H2SO Ste-573			OFF	
		Doci					00:03:14,200	L-X582008	H250 SH-573			ON	
		(Doc)					00:03:14.840	L-XSB2C08	H250 SW-573	(RED LAMP)		OFF	
		Doc					00:03:15.200	L-X582008	HZSO 5W-573	(RED LAMP)		ON	
		(Dac)					00:03:15.800	L-X582C08	H250 5W-573	(RED LANP)		OFF	
		Doc					00:03:16.120	L=X582C08	H2SO Sk-573	(RED LAMP)		ON	
		Doc					00:03:16.720	L-ASB2C08	H250 51-573			OFF	
		(Doc)					00:03:17.120	L=%SB2C08	H250 SW-573			ON	
		Doci					00:03:17.720	L= N582C08	H250 5W-573			OFF	
		Dac					00:03:18.080	L-1582008	H250 SW-573			ON	
		(Died)					00:03:18.680	L-XSB2C08	H250 51-573			OFF	
		Doc					00:03:19.000	L-X582C08	H250 SW-573			ON	
		Doci					00:03:19.640	L=XSB2C08	H250 SW-573			OFF	
		Doc					00:03:20.000	L-X582008	H250 5W-573			ON	
		Doc					00:03:52.200 00:04:13.600	L-XSB2018 HD-325	CNDSER HD-32 48 Heater To			ON INTERM	
		(Doc)					00:04:13,600	HD-325 L-%582018	-48 Heater To CNDSER HD-32			INTERM	
		Dari					00:04:53.840	1-8582018 XN18A28		AUTO STOP OIL T	TD	OFF	
		Disc					00:04:53.840	XN1DALO XN2DA15		STOP OIL LOW PR		ACTIVE	
		(Dag)					00:04:53.840	TV-1	Throttle val			INTERA	
		Dag					00104:53.840	TV-2	Throttle Val			INTERN	
							00:04:53,840	TV-3	Throttle val			INTERM	
							00:04:53.840	TV-4	Throttle Val			INTERN	
							00:04:53.840	6V-1	Governor val			INTERM	
							00:04:53.840	GV=2	Governor Val			INTERM	
							00:04:53.840	GV-3	Governor val	Ive 3		INTERM	
							00:04:53.840	DEHAL	Turbine trip			ON	
							00:04:53.840	L-X583C07		.0. (GREEN LAMP)		ON	
							00:04:53.840	L-X583C05	38 NRV ES-S1	(GREEN LANP)		ON	
							00:04:53.840	L-XSB3C03		(GREEN LAMP)		ON	
							00:04:53.840	L-XSB3C01	58 NRV ES-2	(GREEN LAMP)		ON	

Figure 11. Scenario 3 end of scenario, an additional 11 alarms for a total of 40 alarms.

00:00:00	Preu	PCS/PEL					FREEZE	-	Talcouar	Alarms & Events	Dents	Alarms & Eve	nts
I CTS / Accum	6 CHG/BA	1 11 Rx First Out 1			26 SYS Supy 31 C	LG TWR	1						
2 SW/ESW/A		12 Ry First Out 2		22 Elec Dist									
3 MLB					C 28 CTMT HVAC 1								
A RWST/RHR					39 CTMT HVAC 2								
5 RHR/CCW	10 RCS	15 Milec	20 MSS/Turb	26 DGN B	DO OR HVAC/MILE VAL	Annis.	Sitence Sile						
Repetitions	Time	Id Internet	Alarm description				Time	18	Descriptio	11		Eyent	
		XN23M22 Coc XN23R08 Coc XN23R08 Coc XN23R08 Coc XN23R08 Coc XN23R08 Coc XN23R08 Coc											
							_						
							_						
RX CTRL	RCS/PRZ	CVCS SI	S/RHR CNM	CNS SWS/ES	W CCW	BTRS	NIS TI	JRB CTRL S	SGN/AFW MSS/C	FW CR-HVAC	ELEC	CIRC RMS/GFFD	SEGDs/PRO

Figure 12. Initial alarm display for Scenario 4, five alarms.

0:13:33	Print	MA/CHS					FREEZE		"Yatesuards	Alarms & Events	frends	Alarms & Event	
	6 CHG/BA	11 Rx First Out 1			26 SYS Supv	31 CLG TWR	a second second						
		12 Rx First Out 2											
LA	8 RCP		19 Turb First Out	23 HVAC/RAB/Misc	28 CTMT HVAC 1								
WST/RHR	BPRZ	LA SUN	19 CND	ZA DGN A	29 CTMT HVAC 2								
						CALC BY	The second second						
HR/COW	10 RCS		20 MSS/Turb	25 DGN B	30 OR HVAC/Mile IN		Silence Silence 10	min,					
						ch. pape VAuto							
etilions	Time Id		Alarm description				Time	ld	Description			Event	
		Doci					00:06:35.480	L-X584814		-30 (RED LAMP)		ON	
		Dog					00:06:42.560 00:06:42.560	CE-30 L-X384813	Cond Makeup	-30 (GREEN LAIP)		OPENED OPF	
		Eec.					00:08:01.720	XN10A26		SYSTEM TROUBLE		ACTIVE	
		Doc					00:08:01,720	AH-82A	Normal Purge			STOPPED	
		Dec Dec					00:08:02,360	CP-3	Norm Cont Fu			INTERM.	
		Dod.					00:08:02,360	CP-3	Norm Cont Fu			INTERM.	
		000					00:08:02.360	CP-5	Normal Crunt	Purge Vlv		INTERM.	
		Dati					00:08:02,360	CP-5	Normal Crime			INTERM.	
							00:08:02.360	CP-6		Inlet/Discharge		INTERM.	
		Dec .					00:05:02.360	CP+6		Inlet/Discharge		INTERM.	
		Dec					00:08:02,350	CP-9		Inlet/Discharge		INTERM,	
							00:08:02.360 00:08:03.000	CP-9 CP-3	Normal Purge Norm Cont Fu	Inlet/Discharge		INTERM.	
		Dec .					00:08:03.000	CP-6		Inlet/Discharge		CLOSED	
		Doci					00:08:04.240	OP-5	Normal Crust				
		(Dor)					00:08:04.240	CP-9		Inlet/Discharge		CLOSED	
		Dec					00:08:04.600	CPB-9	North Purge E			INTERM.	
		1000 Dog					00:08:04,600	CPB-9	Norm Funge E			OPENED	
		(Coo)					00:08:04.600	L-XSB7C09	ISOL CP-89 (			OFF	
		Doc					00:08:04.920	CP_D6	Norm Purge I	nlet Flow		CLOSED	
		Doc					00:08:04.920	L-X587C06		D6 (RED LANP)		OFF	
		Ladala (Dad)					00:08:31.720	XN09/003		PRESS AND HEATER	5 ON	ACTIVE	
		Dec .					00:03:31.720	PHTR A	Back Up Heat			ON	
		Doc					00:08:31.720	PHTR B	Back Up Heat			ON	
		Doc Doc					00:05:31.720	PHTR D PK-444A	Back Up Heat			ON	
		Dec					00:08:38.720 00:08:38.720	PK-444A	Pressure Con Pressure Con			INTERM, OPENED	
		Doc					00:08:39.120	XN09A05		HIGH-LOW PRESS		ACTIVE	
		IDiec)					00:08:42.920	XN09602		CONTROL LOW LEVEL	DEVIATION	ACTIVE	
		STED DOC					00:08:46,720	XN05A01				ACTIVE	
		Doci					00:09:02.120	LK-459F	Level Contro	1		OPENED	
		Dec					00:09:04.000	RODSOUT	Rods out			ON	
		Doc					00:09:04.000	ROD_OUT	RODS OUT			ON	
		Dod					00:09:30.200	XN10A35		K ROD C-3 ALERT		ACTIVE	
							00:09:30.200	L-X503c08		MP DT TB 422C2		ON	
		Dec					00:09:30.800	L-X548006	CNMT BLDG SU			ON	
		Doc					00:09:34.320	RODSOUT	Rods out	IN WERT LVL		ON	
		(Dag)					00109:34.320	ROD_OUT	RODS OUT			OFF	
		(Doc)					00:09:34.320	L-XSLBA03	SOURCE RANGE			ON	
		Doc					00:09:34.320	L-1503009		MP DT TE 432C2		ON	
		Doc					00:09:34.320	L-#\$03007		MP DT T8 412C2		ON	
		Eloc)					00:09:34.640	XN2DA09		ACK OPERATIVE		ACTIVE.	
		Dot					00:09:34.640	DEHA2	Runback oper			ON	
		Doc -					00:09:35.920	XN20A09		ACK OPERATIVE		NORMAL	
		1000 Tool					00:09:35.920	GV-4	Governor Val	ve 4		INTERM.	
							00:09:35.920	DEHE-28	Hold			HOLD	
		Doc)					00:09:35.920	DEHA2	Runback oper			OFF	
		inge					00:09:36.880	GV-4	Governor Val	ve 4		INTERM.	

Figure 13.1. Alarm display for Scenario 4 after trip and SI, alarms 1 to 50.

0:13:33	Print	M/CHS					FREEZE		"vateouards	Alarms & Events	Transfo	Alarms & Events
	6 CHG/BA	11 Rx First Out 1	16 EW.		26 SYS SUPV	31 CLG TWR	A CONTRACTOR OF A					
		12 Rx First Out 2										
VL8	8 RCP	13 NIS/RC	19 Turb First Out	23 HVAC/RAB/MIRC	28 CTMT HVAC 1							
WST/RHR	8 PRZ	LA SUN	19 CND	ZA DON A	29 CTMT HVAC 2							
				26 DGN B		V All Alarma	Silence Silence 10	min.				
					41-90 of 105	Ack. page VAuto						
etilions 7	Time Id	the second s	Alarm description				Time	ld	Description			Event
		Das Das					00:06:35.480	L=X584814		-30 (RED LAMP)		ON
		Doc					00:06:42.560	CE-30	Cond Makeup			OPENED
		Dob					00:06:42.560	L-X584813		-30 (GREEN LANP)		OPF
		(Doc					00:08:01.720	XN10A26		SYSTEM TROUBLE		ACTIVE
							00:08:01.720	AH-82A	Normal Purge			STOPPED
		Dec					00:08:02,360	CP-3	Norm Cont Fu			INTERR.
		(HIT)					00:08:02.360	CP-3 CP-5	Norm Cont Pu Normal Cont I			INTERM.
		(Doci					00:08:02.360	CP-5	Normal Comt			INTERM. INTERM.
		Dec					00:08:02.360	CP-6		Inlet/Discharge		INTERM.
		Dec						CP+6		Inlet/Discharge		INTERM.
		Dec					00:08:02.350	CP-9		Inlet/Discharge		INTERM.
		Deci					00:08:02.360	CP-9		Inlet/Discharge		INTERM.
		0.00					00:08:03.000	CP-3	Norm Cont Fu			CLOSED
							00:08:03.000	CP-6		Inlet/Discharge		CLOSED
		(56C)					00:08:04.240	OP-5	Normal Grunt 1			
		(Doc)					00:08:04.240	CP-9		Inlet/Discharge		CLOSED
		Doc					00:03:04.600	CP8-9	North Purge E			INTERM.
		(Doc)					00:08:04.600	CPB-9	Norm Funge E			OPENED
		(Ecc)					00:08:04.600	L-X587C09	ISOL CP-89 (			OFF
		Doci Doci					00:05:04.920	CP_D6	Norm Purge I			
		Dac					00:08:04.920	L-X587C06		D6 (RED LANP)		OFF
		(Doč)					00:08:31.720	XN09C03		PRESS AND HEATER	S ON	ACTIVE
		CHI (000)					00:03:31.720	PHTR A	Back Up Heat	ers Group A		ON
		(Doc)					00:08:31.720	PHTR B	sack Up Heat	ers Group B		ON
		Dec Dec					00:08:31,720	PHTR D	Back Up Heat	ers Group D		ON
		(Doc)					00108138.720	PK-444A	Pressure Con	trol		INTERM.
		CINH Doc					00:08:38.720	PK-444A	Pressure Com	trol		OPENED
		Daci					00:08:39.120	XN09A05		HIGH-LOW PRESS		ACTIVE.
		Dec)					00108:42,920	XN09602		CONTROL LOW LEVEL		ACTIVE
		Doc					00:08:46.720	XN06A01		BIH READER HIG	-LOW FLOW	ACTIVE
		(Doc)					00:09:02.120	LK-459F	Level Contro	1		OPENED
		000					00:09:04.000	RODSOUT	Rods out			ON
		50Q					00:09:04.000	ROD_OUT	RODS OUT			ON
		(Dod)					00:09:30.200	XN10A35		K ROD C-3 ALERT		ACTIVE
		000					00:09:30.200	L-X503c08		WP DT TB 422C2		ON
		Dec Dec					00:09:30.800	L+X548006	CNMT BLDG SU			ON
		Doc Doc					00:09:30.800 00:09:34.320	L-NS4AD06 RODSOUT	CNAIT BLDG SUI Rods out	T ALERT LVL		ON
		Doc Doc					00:09:34.320	RODSOUT ROD_OUT	RODS OUT			OFF
		(Dec)					00:09:34.320	L-XSLBA03	SOURCE RANGE			OFF
		DAC					00:09:34.320	L-3503009		WP DT TE 432C2		ON
		Doc Doc					00:09:34.320	L-XS03C07		MP DT TE 412C2		ON
		Dac					00:09:34.640	XN20A09		ACK OPERATIVE		ACTIVE
		(Dot)					00:09:34.640	DEHAZ	Runback oper			ON
		Doci						XN20A09		ACK OPERATIVE		NORMAL
		500					00:09:35.920	GV-4	Governor Val			INTERM.
		Dod					00:09:35.920	DEHE-28	Hold			HOLD
		(Doc)					00:09:35.920	DEHAZ	Runback oper			OFF
		Doc) Doc					00:09:36.880	GV-4	Governor Val			INTERM.

Figure 13.2 Alarm display for Scenario 4 after trip and SI, alarms 41 to 90.

0:13:33	Print	MMA/CHS.					FREEZE		Tatoguarde	Alarms & Events	Trends	Alarms & Events
CTS / Accum	6 CHG/BA	11 Rx Pirst Out 1	16 FW		26 SYS Supv	31 CLG TWR	A STREET STREET					
		12 Rx First Out 2										
A	8 RCP	13 NIS/RC			28 CTMT HVAC 1							
WST/RHR	BPRZ	L4 SGN	19 CND	LA DON A	29 CTMT HVAC 2							
HR/COW	10 RCS		20 MSS/Turb	26 DGN B		V All Alarma						
arm list, all					56-105 of 105	Ack. page VAuto						
tillions	Time la	đ	Atarm description				Time	łd	Description			Event
		Das					00:06:35.480	L=X584814		-30 (RED LAMP)		ON
		Doc					00:06:42.560	CE-30	Cond Makeup			OPENED
		Doči					00:06:42,560	L-X584813		-30 (GREEN LANP)		OPF
		Maria (Dec)					00:08:01.720	XN10A26		SYSTEM TROUBLE		ACTIVE
		Dec Dec					00:08:01.720	AH-82A	Normal Purge			STOPPED
		Dec Dec					00:08:02,360 00:08:02,360	CP-3 CP-3	Norm Cont FL Norm Cont FL			INTERM.
		000					00:08:02.360	CP-5	Normal Crent			INTERM. INTERM.
		Doci					00:08:02.360	CP-5	Normal Come			INTERM.
		Dec					00:08:02.360	CP-6		Inlet/Discharge		INTERM.
		IDec	THE R. LEWIS CO.					CP+6		Inlet/Discharge		INTERM.
		Dec					00:03:02.350	CP-9		Inlet/Discharge		INTERM.
		(Doc)					00:08:02.360	CP-9		Inlet/Discharge		INTERM.
							00:08:03.000	CP-3	Norm Cont FL			CLOSED
		Doci					00:03:03.000	CP-5		Inlet/Discharge		CLOSED
		Sod North					00:08:04,240	OP-5	Normal Crunt			CLOSED
		(Doc)					00:08:04.240	CP-9		Inlet/Discharge		CLOSED
		Doci					00:05:04.600	CPB-9	North Purge E	wh Flow		INTERM.
		Doc					00:03:04.600	CPB-9	Norm Runge E	exh Flow		OPENED
		Loc					00:08:04.600	L-X587C09	ISOL CP-89 (	GREEN LAMP)		OFF
		Doc					00:08:04.920	CP_06	Norm Purge 1			CLOSED
		Doc					00:08:04.920	L-X587C06		D6 (RED LANP)		OFF
		Doc					00:08:31.720	XN09C03		PRESS AND HEATER	ON	ACTIVE
		1000)					00:03:31.720	PHTR A	Back Up Heat			ON
		Dec .					00:08:31.720	PHTR B	Back Up Heat			ON.
		Dec Dec					00:08:31,720	PHTR D	Each Up Heat			DN
		Doc					00108138.720	PK-444A	Pressure Con			INTERM.
		Dec Dec					00:08:38.720 00:08:39.120	PK-444A XN09A05	Pressure Cor			OPENED
		(Doc)					00108:42,920	XN09802		HIGH-LOW PRESS	(designed and and	ACTIVE ACTIVE
		Teres					00:05:46,720	XN05A01		CONTROL LOW LEVEL		ACTIVE
		Doc					00:09:02.120	LK-459F	Level Contro		San Isak	OPENED
		Dec					00:09:04.000	RODSOUT	Rods out			ON
		iDec)					00:09:04.000	ROD_OUT	RODS OUT			ON
		(Doc)					00:09:30.200	XN10A35		K ROD C-3 ALERT		ACTIVE
		Latin Doc					00:09:30.200	L-X503c08		HP DT TB 422C2		ON
		Doc					00:09:30.800	L+X548006		MP ALERT LVL		ON
		Dóc)					00:09:30.800	L-NS44006	CHAIT BLOG SU	HP ALERT LVL		ON
		Doc Doc					00:09:34.320	RODSOUT	Rods out			OFF
		(Dod)					00109:34,320	ROD_OUT	RODS OUT			OFF
		Terres Doc					00:09:34.320	L-XSLBA01	SOURCE RANGE			ON
		Doc					00:09:34.320	L-3503009		UNP DT TE 432C2		ON
		Doc					00:09:34.320	L-%503c07		MP DT T8 412C2		ON
		ALICAL DOC					00:09:34.640	XN2DA09		ACK OPERATIVE		ACTIVE
							00:09:34.640	DEHA2	Runback oper			ON
		(Doc)					00:09:35.920	XN20A09		ACK OPERATIVE		NORMAL
1770		Line Doc					00:09:35.920	GV-4	Governor Val	ve 4		INTERM.
Ack							00:09:35.920 00:09:35.920	DEHE-28 DEHA2	Hold Runback oper			HOLD
ACR I	00:13:32.2 3		RCP-A SEAL NO.1 LE	AN OFE HIGH I DIALED	nw.		00:09:55.920	GV-4	Governor Val			OFF INTERM.
(must)	10.10.06.6 ×	THOUGH INCO	THE REAL PROPERTY OF LESS	DISSUE FILST LUTY FL			001031301830	0114	povernor val	18.3		TIAL FIGS .

Figure 13.3. Alarm display for Scenario 4 after trip and SI, alarms 56 to 105.

00:00:59	Print	RCS/PR2						nateguarda	Alarms & Events	Doneb	Alarms & Ever	nts
	6 CHG/BA	11 Rx First Out 1	1 15 FW	21 Turb/Aux	26 SYS Supy	31 CLG TWR						
				22 Elec Dist								
5 MLB	8 RCP	13 NIS/RC		23 HVAC/RAB/Misc	28 CTMT HVAC 1	5						
A RWST/EHR	9 PRZ					ñ						
						C VAII Alarms	Silence Silence 10 min.					
	alarms	Contraction of the local division of the loc			1-11 of 11	Ack page V Auto so	Event list				No events	Auto scroll
	Time	Id	Alarm description				Time Id	Description			Event	
		XNI3B(CI Dec)		H FLUX LVL AT SHUTD			11					
	0.00.00.00	KN13C02 Doc KN13C05 Doc		ER DETECTOR HI FLX								
		XN13DOE Doc		ER DETECTOR HI FLX								
	0,00.00.00	XINIBATE DOC	CNDST PUMP B BKR									
	0,00:00.00	XNDOARN (Doc)	MS DRAIN MOT LCV C									
		XN23MW9 Doc XN23R05 (Doc)	RAB NORM SUP PMP									
		XN23505 (Dec)	NEW PRINLOW FLU									
	0.00:00:00	XNIZETRA (Doc)	SFP C INLOW FLOW									
-1		KN23T05 (Dob)	SEP DIALOW FLOW									

Figure 14. Alarm display for Scenario 3 initial condition, all alarms identified by ML as expected.

:02:36	Pina	ATTRA/CITY							ratesuarde	Alarms & Events	Unut	Alar	rms & Eve	nts
	6 CHG/BA					31 CLG TWR								
	7 LTDN/BTRS	12 Rx First Out 2												
8	8 RCP				128 CTMT HVAC 1									
	8 PRZ		10 CND	ZA DGN A	29 CTMT HVAC 2	<b>F</b>								
	TO RCS	15 Misc				Law All Manual	Planas I Impacts an	in the second se						
HR/GCW	10 80.3		20'M96/Turb	25 DON B	30 CR HVAC/MIN		Silence  Silence 10	THER.			_	_		-
	alarms						Event list							
		id.	Alarm description				Time	ld	Description				Event	
	0(CD); == 0	XIVITERO2 Date	SCHURCE HIGHIGE HIGH				00:01:23.200	XN15A20	TURBINE TRIP				ACTIVE	
	0.00.00.0	NULLECO DOC	NOURCE 9.44 ICE 1,02				00:01:23.200	XN1EA25		AUTO STOP OIL T			ACTIVE	
		KINSCON DOG	POWER RAHOE UPPE				00:01:25.200	X7418A60		e this contact the	I IN AWITHRE		ACTIVE	
	0.00.00.0	INTRON Dec	POWER RAVIDELOW				00:01:23.200	TURTRIP	Turbine Trip				TRIPPE	
			ENDST PUMP BEKR				00:01:13.200	DEHAL	Turbine trip				DN	
		INDIATE Dec	NS DRAMPOY LEV O				00:01:23_480 00:01:23.480	XN1EA20 XN1EA60	TURBINE TRIP	C TERE CONTACT TES			NORMAL	
		KN25ROE (Deb)	SFP D'HELD LEVEL				00:01:23.480	XN20A15		STOP DIL LOW PR			ACTIVE	
		VIVE3SOE Dat	NEW PP IN LOW FLOR				00:01:25.480	TV-1	Throttle Val		64.0		INTERA	
		shizero4 Dec	SEF C HILOW FLOW				00:01:23.480	TV-2	Throttle val				INTER	
		WHILETON IDOG					00:01:23,480	TV-1	Throttle Val				INTER	
		XNIBATE DOC		STEP DA THE			00:01:23,450	TV-4	Throttle Val				INTER	
	0:01/23/2	XNISA20 Dec	TURBINE TRIP MANUA				00:01:23.480	6V-1	Governor val				INTER	
	001122.0	KAU200418 (Ded)	TURBINE OLITIZ STOP				00:01:23.480	GV-2	Governor val				INTERN	
	0.01(25.4	HADDAOD IDOC	TI/REDUE LITEAM LTO				00:01:23.480	av-3	Governor Val				INTER	
TACK O	0:01:26.6	XN22A45 Dod	GENERATOR MOTORI	ING PRE-TRIP			00:01:23,480	L KSB3C07		(GREEN LAMP)			ON	
		XNIBARS (Don)	REMOTE THEBRIE TR		ON FAILURE		00:01:23,480	L_K583C05		(GREEN LAMP)			ON	
		silianau IDoci	TURBLE THE DENL				00:01:23.480	L_NSB3C03		(GREEN LAMP)			ON	
	0.01 10.0	XINTRACIN (DOG)	TUREDNE TRH DEN L				00:01:25,460	LASB3C01	58 NRV ES-2				ON	
	KUD1 53 al	XM22A2II (Dog)	BENERATOR BHIT 52				00:01:23.480	L_XSB3A07		7 (GREEN LAMP)			ON	
	a limmeror	VNI22/44M . Por	EXCITATION STELOS	D OF PULSE PWR 3			00:01:23.480	L_KSB3A05	3A NRV ES-79	(GREEN LAMP)			ON	
	UTI (ST. B	ENIZZAZI Dioc	GENERATOR ETTITES	A AUTO TRIP			00:01:23.480	L_XSEBAOB	4A NRV ES-17	(GREEN LAMP)			ON	
Ack in		INTEATH Dad	GENERATOR VOLTAG	E REG THE TO MA			00:01:23.480	LASBJAGI	54 NRV ES-I	(GREEN LAMP)			ON	
							00:01:23.480	L_MSB2016	CNDSER HD-32	2 (RED LAMP)			ON	
							00:01:23.480	L_K582C04	CASING VENT	105-97 (RED LAMP			ON	
							00:01:23.430	L_XSB2C03		105-97 (GREEN LA	HP)		OFF	
							00:01:23.480	L_%SB2B16	CNDSER HD-22				DN	
							00:01:23,480	L1/382804		1GS-98 (RED LAMP			10N	
							00:01:23.480	L_KSB2B03		LOS-98 (GREEN LA	HP)		OFF	
							00:01:23.480	L_NS02012	TURE AUTO ST				:DN	
							00:01:23.480	1_3502812	TURE AUTO ST				ON	
							00:01:23.480	L_NS02A12	TURE AUTO ST				ON	
							00:01:24.160	RV-1	LPT-1 Reheat				INTERP	
							00/01:24.150	RV-2 IV-1	LPT-1 Reheat				INTER	
							00:01:24.160			Intercept Valve				
							00:01:24.160	EV-2 RV-3	LPT-1 Reheat	Intercept Valve			INTER	
							00:01:24.160	RV-4	LPT=2 Reheat				INTER	
							00:01:24.160	IV-3		Intercept Valve			INTER	
							00101:24.160	IV-4		Intercept Valve			INTER	
							00:01:24.440	GV-1	Governor Val				INTER	
							60101:24.440	6V-2	Governor Val				INTER	
							00:01:24.440	GV-3	Governor val				INTER	
							00:01:24.720	PK-464	Sta Hdr Dump				INTER	
							00:01:25.440	XN20A03		N STOP VALVES SH	UT		ACTIVE	
							00:01:25.440	L_X502011	TURE SHUT VI				ON	
							00:01:25.440	L_XS02c11	TURE STOP VL				ON	
							00:01:25.440	L_MS02811	TURE STOP VL				ON	
							00:01:25.440	1_X502A11	TURE STOP VL				ON	
							00:01:25.720	TV-1	Throttle val	ve 1			INTER	(v)

Figure 15. Alarm display for Scenario 3 after a turbine trip, all alarms identified by ML as expected.

:07:45	Canal 6	ANNA/CHS							Alarms & Events Dreads	Alarms & Events
	6 CHG/BA					31 SLG TWR				
	7 LTDN/BTRS	12 Ra First Out 2								
	8 RCP				128 CTMT HVAC 1					
	RPRZ		1 10 CND		29 CTMT HVAC 2	5				
HR/CCW	TU RCS	15 Misc	1 20 MSS/Turb	25 DON B	30 CR HVAC/Misc	A DE Marmie	Silence   Silence 10	min		
						A var winkline	suence   mence to	man.		
							Event list			1-50 of 210 Auto
tillons		1d	Alarm description				Time	la	Description	Event
	0(00:00:00)0	XIVITEE02 (Date)	BOURCE RIANGE HIGH				00:01:23.200	XN18A20	TURBINE TRIP MANUAL	ACTIVE
	0.00.00.0	South Examine	SOURCE GAMOR LOD				00:01:23.200	XN18A25	TURBINE TRIP AUTO STOP OIL TRIP	ACTIVE
	00.00.00.0		POWER RAHOE UPPE				00:01:25.200	XN18A60	REWALF LARETHE LAIN CONTYEL LEFT ON WEITHAT	ACTIVE
	0,06:00:00	INTEDOF (Dec)	POWER RANGELOW				00:01:23.200	TURTRIP	Turbine Trip	TRIPPED
	90-96-00 T	NNRRA22 Dec	ENDST PUMP BEKR				00:01:23.200	DEHAL	Turbine trip	ON
	00.00.0010	INDIATS Dec	MS DRAIN FOR LEV C				00101:23_480	NN15A20	TURBINE TRIP HANUAL	NORMAL
	00.00.00.0	KN25R0E (Dob)	SEP D MORM SUP FIMPS				00:01:23.450	XNIBAGO XN20A15	REMOTE TUNDING TEIN CONTACT FEST OF PAILURE	NORMAL
			MEW PP IN LOW FLOT				00:01:23,480 00:01:23,480	TV-1	TURBINE AUTO STOP DIL LOW PRESS Throttle Valve 1	ACTIVE INTERM.
		WARDER Dac					00:01:23.480	TV-1 TV-2	Throttle valve 2	INTERM.
		WN25TWR DOC					00:01:23.480	E-VT	Throttle valve 3	INTERM.
		XNIESCE Doc	TURBILE THIP AUTO				00:01:23.480	TV-4	Throttle Valve 4	INTERM.
		VNEQAN Deci	TURBINE AUTO STOP				00:01:23.480	GV-1	Governor Valve 1	INTERM.
	00/01/25.4	KUDDADD (Ded)					00:01:23.480	GV-2	Governor Valve 2	INTERM.
		HHINKED DOC			IN FILL LIDE		00:01:23.480	GV-1 GV-3	Governor Valve 3	INTERM
	00.01 83 2	KNISAND Dod					00:01:23-480	L_KSB3C07	28 NRV ES-110 (GREEN LAMP)	ON
		INISAGE (Dor)	TURBINE THE DEN LY				00:01:23,480	LUS83005	3B NRV ES-81 (GREEN LANF)	ON
	00 01 12.4	SHIEATS IDoc	DENERATOR BILA AL				00:01:23.480	LUSB3COT	48 NRV ES-18 (GREEN LAMP)	ON
	00:01 83-8	KITZAN DOG	EXCITATION SYS LOS		HERE'S DR. R. DWIL		00:01:25,480	LASB3C01	58 NRV ES-Z (GREEN LAMP)	ON
		SM22ACI (Cod)					00:01:23.480	L_XSB3A07	2A NVR ES-107 (GREEN LAMP)	ON
		VNI22449 Poc					00:01:23.480	L_KSB3A05	3A NRV ES-79 (GREEN LAMP)	ON
	00/05 09 2	INITALS Dec	EH FLLID LOW PRESS				00:01:23.480	L_XSE3A03	4A NRV ES+17 (GREEN LAMP)	DN
	3,01: 20:00	Minsten Dad	TURBILE TRIP REACT	DIR TRUE FIL			00:01:23.480	LAS83401	54 NRV ES-1 (GREEN LAMP)	ON
		(000)					00:01:23.480	L_NS82016	CNDSER HD-322 (RED LAMP)	ON
	00.05 72.0	YNIISANT DOC	MOR CONTROL LIRGE	ELT ALANA			00:01:23.480	L_X582C04	CASING VENT 105-97 (RED LAMP)	ON
		UNINERUS Dec		LVE CONT SHOT IN			00:01:23.430	L_NSB2C03	CASING VENT 105-97 (GREEN LANF)	OFF
	00:05:31.4	KINGERT (DOE)	ONE HOD AT BOTTOM	1			00:01:23,480	L_XSB2B16	CNDSER ND-22 (RED LAMP)	DN
	00.05.33.4	x(Vtabe) Dec	TWO UR MORE BODS	AT BOTTOM			00:01:23.480	L_X382804	CASING VENT 1GS-98 (RED LANP)	DN
	6,00,00,00	INRAZA (Dac)	BH FLIM LOW COWN				00:01:23.480	L_KSB2B03	CASING VENT LOS-98 (GREEN LAMP)	OFF
		KINGBADE (Dec)		SOH HEADER HIGH	LOW FLOW		00:01:23.480	L_NS02012	TURB AUTO STOP TRIP 63-5	DN
							00:01:23.480	1_3502812	TURB AUTO STOP TRIP 63-4	ON
							00:01:23,480	L_NS02A12	TURE AUTO STOP TRIP 53-3	ON
							00:01:24.160	RV-1	LPT-1 Reheat Stop Valve	INTERM.
							00:01:24.150	RV-2	LPT-1 Reheat Stop valve	INTERN.
							00:01:24.160	IV-1	LPT-1 Reheat Intercept Valve	INTERM.
							00:01:24.160	IV-2	LPT-1 Reheat Intercept Valve	INTERM
							00:01:24.160	RV-3	LPT-2 Reheat Stop Valve	INTERM.
							00:01:24.160	RV-4	LPT=2 Reheat Stop Valve	INTERM.
							00:01:24.160	IV-3	LFT-2 Reheat Intercept Valve	INTERM.
							00101:24.160	IV-4	LPT-2 Reheat Intercept Valve	INTERM.
							00:01:24.440	GV-1	Governor Valve 1	INTERM.
							60101124.440	6V-2	Governor Valve 2	INTERN.
							00:01:24.440	E-VD	Governor Valve 3	INTERM.
							00:01:24.720	PK-464	Sta Hdr Dump Press Cont	INTERM.
							00:01:25.440	XN20A03	TURBINE STEAN STOP VALVES SHUT	ACTIVE
							00:01:25.440	1_X502D11	TURE SHUT VLV 4 SHUT	DN
							00:01:25.440	L_XS02cl1	TURB STOP VLV 3 SHUT	ON
							00:01:25.440 00:01:25.440	L_XS02811	TURE STOP VLV 2 SHUT TURE STOP VLV 1 SHUT	ON
							00:01:25.440	TV-1	THRE STOP VLV I SHUT Throttle valve I	ON INTERM.
							001011231120	TALT.	HUMPENS ARIAG T	TAN FIGU

Figure 16. Alarm display for Scenario 3 after a reactor trip, all but one alarm identified by ML as expected.

0:31:41	Print	AHMA/CHS							Tateguards	Alarms & Events	Drads	Alarms &	& Even	its
CTS/Accum	5 CHG/BA	11 Rx Pirat Out	1 16 EW	21 Turb/Aux	26 SYS Supv	31 CLG TWR								
W/ESW/IA	7 LTDN/BTRS	12 Rx First Out		22 Elec Dist										
VIL8	BROP				VIEL 28 CTMT HVAC 1	<b></b>								
	BPRZ	L4 SUN	I ID CND	JA DGN A	29 CTMT HVAC									
RHR/COW	10 RCS	15 Misc	1 20 MSS/Turb	25 DGN B	30 CR HVAC/MIS		E BRANNE DEBRANN	Concellance I						
AMINGC W	T IN HCS			TO DOUR	30 CPC PLY ACTINITS	c A va watata	Silence Silence 10	2 man.						
							Event list							
petilions	Time	1d	Alarm description				Time	la	Description				Event	
	0(00:00:00)0	XOVITERO2 (Date)			ITEDVIH ALARM BLOC		00:01:25.200	XN18A20	TURBINE TRIP				ACTIVE	
	00:00:00.0	THINCOS IDOG			LI DEV OR MITD DEF		00:01:23.200	NNLEA25		AUTO STOP OIL T			ACTIVE	
	0 00 00 00	K1412005 (Doc)			ILY DEV OR AUTO DES		00:01:25.200	XN15A60		THE CONTACT IS	el un soulthat		ACTIVE	
	0,05.00,0 00.05.00,0	XNIDATE (Doc)	MS DWAN POT LCV				00:01:23.200	TURTRIP	Turbine Trip				TRIPPED	
		TATEMOT Deci	RAB NORM SUP IN				00101:23.480	XN15A20	Turbine trip TURBINE TRIP				NORMAL	
		MAZERCE DOC	SFP D WALD LEVEL				00:01:23.450	XN18A60		TTIP CONTACT TES			NORMAL	
		KN25856 Deb	NEW FP IN LOW FO				00:01:23.480	XN20A15		STOP OIL LOW PR			ACTIVE	
		VINESTINA IDaci	SFP C FILOW FLO				00:01:23.480	TV-1	Throttle val				INTERM.	
		shizertas (Doc)	SEP D HILOW FLO				00:01:23.480	TV-2	Throttle val				INTERM.	
		CHISADS Ded	TURBINE TRIP AUT				00:01:23.480	TV+3	Throttle Val				INTERM.	
	00:01:21 4	XND0A95 (Doc)		OF OR LOW PRESS			00:01:23.480	TV-4	Throttle Val				INTERM.	
		VN20A01 (Dec)	TURBINE STEAM IS				00:01:23.480	GV-1	Governor val				INTERM:	
		(JOG) CEARTON		TRIP CONTACT TEST	OR FAILURE		00:01:23.480	GV-2	Governor val				INTERM.	
		HHRAN DOC		ILOOKING RELEY D			00:01:23.480	GV+3	Governor Val				INTERM.	
	00.01 83 2	KNISALI DOG					00:01:23.480	L KS83C07		O (GREEN LAMP)			ON	
	ALC:10:00	XNEEA29 (Doe)	GENERATON ENT	62.0 TROP			00:01:23.480	L X583C05	38 NRV ES-81				ON	
	00 on h1.4	#)JIIIAIM IDoc	EXCITATION WYO L	GUIL OF PULLE PWG	SUPPLY DR. BLOWH		00:01:23.480	L_ASB3C03	48 NRV ES-18				ON	
	00:01 53,4	KHIZLARY (DOE)	SENERATOR EXC	TER AUTO TRIP			00:01:25,480	L_ASB3C01	5B NAV ES-2	(GREEN LAMP)			ON	
	00.01.537	XM22.845 (200)	BENERATOR VOLT	ARE REG TRIP TH			00:01:23.480	L_XSB3A07	24 NVR ES-10	(GREEN LAMP)			ON	
	00105109.2	NI2RASH DOC		ESUURE			00:01:23.480	L_NSB3A05	3A NRV ES-79	(GREEN LAMP)			ON	
	3.0E 30:00	ENHRADE DOC	TURBINE THE REA	CTOR TRE PA			00:01:23,480	L_XSEBA0B	4A NRV ES-17	(GREEN LAMP)			ON	
	0.05-20.6	WITTER Dad	REACTOR THE MA	HUAL			00:01:23.480	LAS83A01	54 NRV ES-I	(GREEN LAMP)			ON	
	100/00 30 B	KN13A67 (Doc)	ROD CONTROL UR	IGENT ALARM			00:01:23.480	L_NSB2016	CNDSER HD-32	2 (RED LAMP)			ON	
		XINTARD3 DOC		VALVE COLAT SHOT!	IGHUL!		00:01:23.480	L_1582004	CASING VENT	105-97 (RED LAMP			ON	
	DO UNLITE A	ENTERDOT Dec	DHE HOD AT BOTT				00:01:23.480	L_NSB2C03		1GS-97 (GREEN LA	U(P)		OFF	
	00:05:01.4	XMMMOT Doc	TYYO OF MORE RC				00:01:23,480	L_%SB2B16	CNDSER HD-22				IDN.	
	0,00.00.00,0	SMIDA24 Doc	EH FUNDLOW LO				00:01:23.480	L_1/382804		1G5-98 (RED LAME			ON	
1	90 07 109.8	VNICCALL (DOC		WIGCH HEADER HIG			00:01:23.480	L_KSB2B03		LOS-98 (GREEN LA	HP)		OFF	
		(Dec)					00:01:23.480	L_NS02C12	TURB AUTO ST				DN	
	0013411	ANTRASS Doc	RON LOOP TAVE L				00:01:23.480	1_3502812	TURE AUTO ST				ON	
Ack		Doci					00:01:23,480	L_NS02A12	TURE AUTO STO				ON	
		Doc					00:01:24,160	RV-1	LPT-1 Reheat				INTERM.	
		VN09403 (Doc)		EVEL DEMATION AND			00:01:24.160	RV-2	LPT-1 Reheat				INTERN.	
							00:01:24.160	IV-1		Intercept Valve			INTERM.	
	00124 115.4	KINIEWEN Doci		OWER SUPPLY UNDE	RVOLTAGE		00:01:24.160	IV-2		Intercept Valve			INTERM.	
ACK		Dec Dec					00:01:24.160	RV-3 RV-4	LFT-2 Reheat				INTERM.	
ACK		IDOC)					00:01:24.160		LPT=2 Reheat				INTERM.	
							00:01:24.160 00:01:24.160	IV-3 IV-4		Intercept valve Intercept valve			INTERM.	
							00:01:24.440	QV-1	Governor Val				INTERM.	
							60:01:24.440	GV-2	Governor Val				INTERM.	
							00:01:24.440	6V-1	Governor Val				INTERM.	
							00:01:24.720	PK-464	Stm Hdr Dump				INTERM.	
							00:01:25.440	XN20A03		STOP VALVES SH	air:		ACTIVE	
							00:01:25.440	L_X502D11	TURE SHUT VL				ON	
							00:01:25.440	L_3502C11	TURB STOP VL				ON	
							00:01:25.440	L_MS02B11	TURE STOP VU				ON	
							00:01:25.440	L_X502A11	TURE STOP VL				ON	
							00:01:25.720	TV-1	Throttle val				INTERN.	

Figure 17. Alarm display for Scenario 3 after cooldown, all but six identified by ML as expected.

0:36:38	Canada Ca	RCS/ER.							Talognard Alarms & Events Trends	Alarms & Events
	6 CHG/BA	11 Rx Pirst Out 1			26 SYS SUPV	31 CLG TWR				
		12 Rx First Out 1								
LO	8 RCP		18 Turb First Out		Isc 28 CTMT HVAC 1					
					29 CTMT HVAC 2	5				
						Contraction of the second	Francisco Concession			
HR/COW	10 民C金		1 20 MSS/Turb	25 DGN B	30 CR HVAC/Mile	VAI Alarma	Silence Silence 10	min.		
larm list, all	l alarms					Ack. pape V Auto sc				
etilions	Time	1d	Alarm description				Time	Id	Description	Event
	00:00:00:00	X0HIBERS Dag	SOURCE RANGE HIGH	FLUXIVLATSH			00:01:25.200	XN18A20	TURBINE TRIP MANUAL	ACTIVE
	00:00:00.0	WHILEOS IDOG	POWER RANGE UPPE	R DETECTOR HIF	LA DEV DR MATO DEF		00:01:23,200	XN1EA25	TURBINE TRIP AUTO STOP OIL TRIP	ACTIVE
	0.00.00.00	KM12005 Doci	POWER RANGE LOWE	A DETECTOR HIL	LY DEV OR AUTO DEF		00:01:25.200	XN15A60	TEMOTE TURBERS THEN CONTACT TEST OF RELIVED.	ACTIVE
	0,06.60.00	MMIGAZZ DOG	CHOOT PUMP & BART	TRIP/TRIBL			00:01:23.200	TURTRIP	Turbine Trip	TRIPPED
	00.00.00.0	KNEGATE (Dec)	MS EMANI POT LOV OF	VE04			00:01:23.200	DEHAL	Turbine trip	ON
		XN22MOD DIGG	RAB NORM SUF PMPS				00101:23.480	XN15A20	TURBINE TRIP HANUAL	NORMAL
	00.00.00.0	NAZERCE (Dad)	SEP D HULD LEVEL				00:01:23.450	XN18A60	REMOTE TURBING THIS CONTACT TEST OF PAILURE	NORMAL
		KN23866 (Dob)	NEW FP IN LOW FLOW				00:01:23.480	XN20A15	TUREINE AUTO STOP OIL LOW PRESS	ACTIVE
1	00.00.00.0	XINESTEN Dati	SEP & MLOW FLOW				00:01:23.480	TV-1	Throttle Valve 1	INTERM.
		shizertais (Doc)	SEP D IN LOW FLOW				00:01:23.480	TV-2	Throttle valve 2	INTERM.
		WISADS Ded					00:01:23.480	TV+3	Throttle valve 3	INTERM.
	00:01:21 4	XNDA95 Decl	TURBINE AUTO 1708				00:01:23.480	TV-4	Throttle Valve 4	INTERM.
		VN20403 (Dec)	TURBINE STEAM BTOP				00:01:23.480	GV-1	Governor Valve 1	INTERM.
		(0.00 GEARINS	REMOTE LURBINE TRI				00:01:23.480	GV-2	Governor valve 2	INTERM.
		HHRAN DOC	TURBINE TRA GEN LO				00:01:23.480	GV+3	Governor Valve 3	INTERM,
		KNISALI Dod					00:01:23-480	L_KSB3C07	2B NRV ES-110 (GREEN LAMP)	ON
	ALC:10:00.	KNEZAZE (Doc)					00:01:23,480	L_X583C05	38 NRV ES+61 (GREEN LAMP)	ON
		shizzAzs [Doc]	EXCITATION SYS LOD		NAMES OF THE STREET		00:01:23.480	L_NSB3C03	48 NRV ES-18 (GREEN LAMP)	ON
	00:01 53.4	KHIZATA DOG					00:01:23,480	L_ASB3C01	58 NRV ES-2 (GREEN LAMP)	ON
		XM22A49 (Doc)	SENERATOR.VOLTAD				00:01:23.480	L_XSB3A07	2A NVR ES-107 (GREEN LAMP)	ON
		VH28A28 (Doc)					00:01:23.480	L_NSB3A05	3A NRV ES-79 (GREEN LAMP)	ON
		ENHRADE (Doc)	TURBINE THE REACT				00:01:23.480	L_XSE3A03	4A NRV ES=15 (GREEN LANP)	
		WHEEKUB IDad					00:01:23.480			DN
		XN13AD7 (Doc)	ROD CONTROL URSE					L_N583A01 L_N582016	5A NRV ES-I (GREEN LAMP)	ON
		VINTEAD2 (Doc)					00:01:23.480 00:01:23.480		CNDSER HD-322 (RED LAMP)	ON
			MAIN FW HIGH FW VAL					L_X582C04	CASING VENT 105-97 (RED LAMP)	ON
	A LTL RD OO		DHE HOD AT BOTTOM				00:01:23.480	L_NSB2C03	CASING VENT 1GS-97 (GREEN LAMP)	DFF
	00:05 33.4		TWO OF MORE RODS				00:01:23,480	L_XSB2B16	CNDSER HD-22 (RED LAMP)	DN
	0,00.00.00,0	XMIOA24 Doc	EH FUND LOW LOW F				00:01:23.480	L_3582804	CASING VENT 1G5-98 (RED LANP)	DN
	9,00,09,8	VNDOALS (DOC	FHANGING FLIMPS UP				00:01:23.480	L_KSB2B03	CASING VENT LOS-98 (GREEN LAMP)	OFF
		(Doc)					00:01:23.480	L_NS02012	TURB AUTO STOP TRIP 63-5	DN
	00;13:22.4	NITRASI Doc	RON LOOP TAVE LOW				00:01:23.480	1_3502812	TURB AUTO STOP TRIP 63-4	ON
		ILES Doc					00:01:23,480	L_NS02A12	TURE AUTO STOP TRIP 63-3	ON
		Dec					00:01:24.160	RV-1	LPT-1 Reheat Stop Valve	INTERM.
		Doc					00:01:24.160	RV-2	LPT-1 Reheat Stop Valve	INTERN
	00.13.50.2	V/109403 (Dod)	PR2 CHIT HOH LEVE				00:01:24.160	IV-1	LPT-1 Reheat Intercept Valve	INTERM.
	100124 (MS-4	KNABANN DOC	SEN COMPUTER POW		RVOLTAGE		00:01:24.160	IV-2	LPT-1 Reheat Intercept Valve	INTERM
		Linger (Doc)					00:01:24.160	E-VA	LFT-2 Reheat Stop Valve	INTERM.
		Dec .					00:01:24.160	RV-4	LPT=2 Reheat Stop Valve	INTERM.
		Dac					00:01:24.150	IV-3	LPT-2 Reheat Intercept valve	INTERM.
		(Dad):					00101:24.160	IV-4	LPT-2 Reheat Intercept Valve	INTERM.
(Ack)		(Doc)					00:01:24.440	QV-1	Governor Valve 1	INTERM.
							00:01:24.440	GV-2	Governor Valve 2	INTERM,
							00:01:24.440	GV+3	Governor Valve 3	INTERM.
							00:01:24.720	PK-464	Stm Hdr Dump Press Cont	INTERM.
							00:01:25.440	XN20A03	TURBINE STEAN STOP VALVES SHUT	ACTIVE
							00:01:25_440	1_X502D11	TURE SHUT VLV 4 SHUT	DN
							00:01:25.440	L_3S02c11	TURB STOP VLV 3 SHUT	ON
							00:01:25.440	L_XS02B11	TURE STOP VLV 2 SHUT	ON
							00:01:25.440	L_X502A11	TURE STOP VLV 1 SHUT	ON
							00:01:25.720	TV-1	Throttle Valve 1	INTERN.

Figure 18. Alarm display for Scenario 3 with the faults inserted, none of the faults identified by ML as expected. No change in the six previous unidentified alarms.

	Time 00.00.00.0 00.00.00.0 00.00.00.0 00.00.	11 Rx Pirst Out 1 12 Rx Pirst Out 1 13 Nis/RC 14 GGM 15 Nis/RC 15 Nis/RC 16	17 AFW 10 Turb First Out 10 CND 20 MSS/Turb 20 MSS/Turb 500RCE RANGE HICE POWER RANGE UPPE POWER RANGE UPPE CUIDET POMPE BAVE ALE ENANI POT LEX C	24 DGN A 25 DGN B H FLUX LVL 4T SHIFT FR DETECTOR HIFLS ER DETECTOR HIFLS	27 HVAC/Misc 28 CTMT HVAC 1 29 CTMT HVAC 1 30 CR HVAC/Misc V 1-50 of 89 Ac DDWh ALKR/A BLOC DEV DR AUTO DEF		Time				1-50 of 1930	Auto'sci
N.B RWST/RHR RHR/COW Iarm list, all retilions	8 RCP 9 PRZ 10 RC\$ aliarms Time 00 00 00.0 00 00 00 00.0 00 00 00 00.0 00 00 00 00.0 00 00 00 00 00 00.0 00 00 00 0000000000	13 NIS-RC 14 SGA 15 Miles Mile	19 Auro First Out 10 CND 20 MSS/Turb 20 MSS/Turb 20 MSS/Turb 20 MSS/Turb 20 MSS Ratio 20 MSS Ratio 20 MSS Ratio 20 MSS Ratio 21 DDT POINT 8 BW/R 21 DDT POINT 8 BW/R 21 DDT POINT 8 BW/R	23 HVAC/RAB/MB 24 DGN A 25 DGN B H FLUX LVL AT SHIT ER DETECTOR HIFL ER DETECTOR HIFL	28 CTMT HVAC 1 29 CTMT HVAC 2 30 CR HVAC/MISC V 1-50 62 83 Ac DOWN ALARM BL DC DEV DR AUTO DEF		Event list		_		1-50 of 1930	Auto'sc
RWST/RHR RHR/CCW Iarm list, all retilions	9 PRZ 10 RCS alarms Time 00 00 00.0 00 00 00.0	14 SUN 15 Misc Misso Wriscol Cas Wriscol Cas Wriscol Cas Wriscol Cas Wriscol Cas Wriscol Cas Wriscol Cas Wriscol Cas	10 CND 20 MSS/Turb 20 MSS/Turb 50/URCS RANGE HIGH POWER RANGE UPPE 90/WER RANGE UPPE 90/WER RANGE UPPE 90/WER RANGE UPPE 91/00 PP BAIKT	24 DGN A 25 DGN B H FLUX LVL 4T SHIFT FR DETECTOR HIFLS ER DETECTOR HIFLS	29 CTMT HVAC 2 30 CR HVAC/MIRC V 1-50 62 83 Ac DOWN ALARM BL DC DEV DR AUTO DEF		Event list				1-30 of 1930	Auto so
RHR/COW	10 RCS alarms Time 00.00.00.0 00.00.00.0 00.00.00.0 00.00.	15 Milec Id NH1 ISE02 D20 VH1 XC05 D20 VH1 XC05 D20 VH1 XC05 D20 VH1 XC05 D20 XH1 XC05 D20 X	20 MSS/Turb Source Fanige High Power Range UPPE Power Range UPPE Power Range UPPE Power Range UPPE Power Range UPPE Power Range UPPE	25 DON B H FLUX LVL ST SHIIT ER DETECTOR HIFLS ER DETECTOR HIFLS	N CR HVAC/Misc V 1-50 of 89   Ac DOWN ALARM BLOC DEV DR AUTO DEF		Event list		-		1-50 of 1930	Auto's
eHR/CCW larm list, all etilions	10 RCS alarms Time 00.00.00.0 00.00.00.0 00.00.00.0 00.00.	15 Milec Id NH1 ISE02 D20 VH1 XC05 D20 VH1 XC05 D20 VH1 XC05 D20 VH1 XC05 D20 XH1 XC05 D20 X	20 MSS/Turb Source Fanige High Power Range UPPE Power Range UPPE Power Range UPPE Power Range UPPE Power Range UPPE Power Range UPPE	25 DON B H FLUX LVL ST SHIIT ER DETECTOR HIFLS ER DETECTOR HIFLS	N CR HVAC/Misc V 1-50 of 89   Ac DOWN ALARM BLOC DEV DR AUTO DEF		Event list				1-50 of 1930	Auto's
larm list, all setilions	alarms Time 00.00.00.0 00.00.00.0 00.00.00.0 00.00.	44 VM13602 D39 VM13605 D36 VM13606 D38 VM13606 D38 VM13622 D36 VM2364 D32 VM2364 D32 VM2360 D56	Alarm description SOURCE FANGE HIGE POWER RANGE UPPE POWER RANGE LOW CILDET POME & BUR MS ERAIN POT LCV O	H FLUX LVL AT SHIT OR DETECTOR HERLA ER DETECTOR HERLA	1-50 of 89 A		Event list				1-50 of 1930	Auto's
etilions () () () () () () () () () ()	Time 00.00.00.0 00.00.00.0 00.00.00.0 00.00.	XN11807         Date           YN13C05         Doc           XN13C05         Doc           XN13C05         Doc           XN13C05         Doc           XN13C05         Doc           XN13C05         Doc           XN13C05         Doc           XN13A22         Doc           XN23A18         Doc           XN23M02         Doc	SOURCE RANGE HIGH POWER RANGE UPPE POWER RANGE LOW CHIDET POMP 8 BICR MS ERAMI POT LCV O	ER DETECTOR HUFLIN	DOWN ALARM BLOC DEV OR AUTO DEF	k pape   Auto	Time					Auto's
	00.00.00.00.0 00.00.00.0 00.00.00.0 00.00.	XN11807         Date           YN13C05         Doc           XN13C05         Doc           XN13C05         Doc           XN13C05         Doc           XN13C05         Doc           XN13C05         Doc           XN13C05         Doc           XN13A22         Doc           XN23A18         Doc           XN23M02         Doc	SOURCE RANGE HIGH POWER RANGE UPPE POWER RANGE LOW CHIDET POMP 8 BICR MS ERAMI POT LCV O	ER DETECTOR HUFLIN	DEV OR AUTO DEF							
	00-00-00-0 0-01-00-0 00-05-00-0 00-05-00-0 00-00-00-0 00-00-00-0 00-00-00-0 00-00-	WH3C08         D00	POWER RANGE UPPE POWER RANGE LOW CHORT POMP & BICR MS DRAWLPOT LOV O	ER DETECTOR HUFLIN	DEV OR AUTO DEF			ld	Description		Event	
	00.00.00.0 00.00.00.0 00.05.00.0 00.05.00.0 00.00.00.0 00.00.00.0 0.00.00.0	KN4906         Deb           KN19822         Dec           KN29A38         Dec           XN29A38         Dec           XN29A38         Dec	POWER RANGE LOW CLIDGT PUMP & BAR ME SWAM POT LOV O	ER DETECTOR HIFL			00:01:23.200	XN18A20	TURBINE TRIP MANUAL		ACTIVE	
	00:00:00,0 90:00:00:0 00:00:00:0 00:00:00:0 00:00:00	KN19622 Dec KN29A18 Dec KN29M02 Dec	CHOST PUMP & BAR				00:01:23.200	XN18A25	TURBINE TRIP AUTO STOP OIL TRI		ACTIVE	
	00-06-00-0 00-00-00-0 00-00-00-0 00-00-00-0	XN20ATE (Dec)	ME ENAMI POTLEV O				00:01:23.200	XN18A60	REMOTE TOBELNE THEN CONTACT TEST	an serifier	ACTIVE	
	00-00-00:0 0-00-00-0 0-00-00-0	TANTANOT DEC					00:01:23.200	TURTRIP	Turbine Trip		TRIPPED	
	00-00-00-00-00-00-00-00-00-00-00-00-00-						00:01:23.200	DEHAL	Turbine trip		DN	
	0.00.00.00.00		RAB NORM SUP PMPS				00:01:23.480 00:01:23.480	XN15A20 XN18A60	TURBINE TRIP HANUAL		NORMAL	
		KN23966 (Dab)					00:01:23.480	XN18A60 XN20A15	REMOTE TUBBING THIS CONTACT TEST			
		VIVESTEA Date					00:01:23.480	TV-1	TURBINE AUTO STOP DIL LOW PRES Throttle Valve 1		ACTIVE INTERM.	
		TRIZETOS (Doc)	SEP D IN LOW FLOW				00:01:23.480	TV-1 TV-2	Throttle valve 1 Throttle valve 2		INTERM.	
		WHISA28 Doc	TURBINE TRIP AUTO I				00:01:23.480	TV-3	Throttle valve 1		INTERM.	
		XNDOA95 Dec	TURBINE AUTO 170P				00:01:23.480	TV-4	Throttle Valve 4		INTERM.	
		VN20A83 Deci	TURBINE STEAM STO				00:01:23.480	GV-1	Governor Valve 1		INTERM.	
		KNIBAED (Ded)	REMOTE TURBINE TR				00:01:23.480	GV-2	Governor valve 2		INTERM.	
		INTRATO DOC	TUREWE THE GEN U				00:01:23,480	GV-5	Governor Valve 3		INTERM.	
		KNISAD DOG					00:01:23,480	L_KSB3C07	28 NRV ES-110 (GREEN LAMP)		ON	
		WHEEASS (Doc)					00:01:23,480	L_X583C05	3B NRV ES-81 (GREEN LAMP)		ON	
	00 01 21.4	NUZZAZN IDec	EXCITATION SYP LOD				00:01:23.480	L_NSB3C03	48 NRV ES-18 (GREEN LAMP)		ON	
	00.01 53.4	KHIZLARI (DOG)					00:01:23,480	L_NSB3C01	58 NRV ES-2 (GREEN LAMP)		ON	
		SM22A45 Doc					00:01:23.480	L_XSB3A07	2A NVR ES-107 (GREEN LAMP)		ON	
		VHI2NASH (DOC)					00:01:23.480	L_WSB3A05	3A NRV ES-79 (GREEN LAMP)		ON	
		ENTRADE DOC	TURBINE THE REACT				00:01:23,480	L_XSB3A03	4A NRV ES-17 (GREEN LANP)		DN	
		Doc					00:01:23.480	LAS83A01	5A NRV ES-1 (GREEN LAMP)		ON	
		KN13A67 (Doo)	ROD CONTROL URGE				00:01:23,480	L_NSB2016	CNDSER HD-322 (RED LAMP)		ON	
	5,16 20:00	VINPARCE DOC	MAIN FW HIGH FW VA	VE COLT SHOT DIG			00:01:23.480	L_K582C04	CASING VENT 105-97 (RED LAMP)		ON	
		EFELIDAT Dec		W			00:01:23.480	L_NSB2C03	CASING VENT 105-97 (GREEN LANP		OFF	
	00:05:03.4	XHINGOT (Doc)	TWO OF MORE RODS	AT BUTTLM			00:01:23,480	L_%S82816	CNOSER HD-22 (RED LAMP)		<b>DN</b>	
	0.00.00.00.0	XMI0424 Dec	EH FUUD LOW LOW I	PRESSURE			00:01:23.480	L_1/382804	CASING VENT 1G5-98 (RED LAMP)		ON	
		Dati					00:01:23.480	L_KSB2B03	CASING VENT LOS-98 (GREEN LAMP		OFF	
		(Doc)					00:01:23.480	L_NS02C12	TURE AUTO STOP TRIP 63-5		ON	
		and Doc					00:01:23.480	1_1102812	TURE AUTO STOP TRIP 63-4		ON	
							00:01:23,480	LAS02A12	TURE AUTO STOP TRIP 63-3		ON	
		Doc					00:01:24.160	RV+1	LPT-1 Reheat Stop Valve		INTERM.	
	00110100.2	Sold colarol(*	PH2 CONTEMPLEYE				00:01:24.160	RV-2	LPT-1 Reheat Stop valve		INTERN.	
	00 (34195.4	KHRRASS (Dod)	DEH COMPUTER POW	VER BURRLY I WIDER			00:01:24.160	IV-1	LPT-1 Reheat Intercept Valve		INTERM.	
		Marca Doc					00:01:24.160	IV-2	LPT-1 Roheat Intercept Valve		INTERM	
		Doc					00:01:24.160	RV-3	LFT-2 Reheat Stop Valve		INTERM.	
							00:01:24.160	RV-4	LPT=2 Reheat Stop Valve		INTERM.	
		Inter Doc					00:01:24.160	E-VI	LPT-2 Reheat Intercept Valve		INTERM.	
		Linese (Dod):					00101:24.160	IV-4	LFT-2 Reheat Intercept Valve		INTERM.	
		(Doc)					00:01:24.440	GV-1	Governor Valve 1		INTERM.	
		Here Doc					00:01:24.440	0V-2	Governor Valve 2		INTERN,	
		Social Social States					00:01:24.440	GV-3	Governor Valve 3		INTERM.	
		Madaine (Doc)					00:01:24.720	PK-464	Stm Hdr Dump Press Cont		INTERM.	
		Dot					00:01:25.440	XN20A03	TURBINE STEAN STOP VALVES SHUT		ACTIVE	
		Doc					00:01:25.440	1_X502D11	TURE SHUT VLV 4 SHUT		DN	
		500 ( 1 a a a					00:01:25.440	L_3S02c11	TURB STOP VLV 3 SHUT		ON	
							00:01:25.440	LNS02B11	TURE STOP VLV 2 SHUT		ON	
		Dec					00:01:25.440	L_X502A11	TURE STOP VLV 1 SHUT		ON	
		ingel					00:01:25.720	TV-1	Throttle valve 1		INTERN.	

Figure 19.1. Alarm display for Scenario 3 after the final fault inserted alarms 1 to 50.

0:39:36	Print	RCS/BRI					FREEZE		🗶 Salesuarde	Alarms & Events	danati.	Alarms & Ever	ats
CTS / Accum	6 CHG/BA	II Rx First Out 1	16 EW.		26 SYS Supv	1 31 CLG TWR	The second se						
		12 Rx First Out 2											
	8 RCP	13 NIS/RC				Ξ.							
WST/RHR	BPRZ	14 SGN	19 CND	LA DON A	29 CTMT HVAC 2	<b>1</b>							
						<u></u>							
RHR/COW	10 RCS		1 20 MSS/Turb	25 DGN B	30 CR HVAC/Mis	: VAlt Alarma		min.					
larm list, a	all alarms	-											
petillions	Time	id .	Alarm description	and the second			Time	ld	Description			Event	
		Dac)					00:01:23.200	XN18A20	TURBINE TRIP			ACTIVE	
		Doc					00:01:23.200	XN18A25		AUTO STOP OIL TR		ACTIVE	
		Doti					00:01:23.200	XN18A60		E TREP CONTACT TEST	Sn wwith fort	ACTIVE	
		11-1-2 (Eoc)					00:01:23.200	TURTRIP	Turbine Trip			TRIPPER	
		Cletter (Doc					00:01:23.200 00:01:23.480	DEHAL XN15A20	Turbine trip			ON NORMAL	
		Doc)					00:01:23.480	XN15A50	TURBINE TRIP			NORMAL	
		(Doc)					00:01:23.480	XN20A15		STOP OIL LOW PRE		ACTIVE	
		Dec					00:01:23.480	TV-1	Throttle val			INTERM.	
		Doc					00:01:23.480	TV-2	Throttle val			INTERM.	
	No. ITT	Sog rabits	THE OWNER AND A				00:01:23,480	E-VT	Throttle Val			INTERM	
		Doc					00:01:23.480	TV-4	Throttle Val			INTERM.	
		Degi					00:01:23.480	GV-1	Governor Val			INTERM.	
		- (Dog) -					00:01:23.480	GV-2	Governor Val			INTERM.	
		HELE Dec					00:01:23,480	GV+5	Governor Val			INTERM	
		Hard Dod					00:01:23:480	L KS83C07		(GREEN LAMP)		ON	
		(Doc)					00:01:23.480	L X583C05		(GREEN LAMP)		ON	
		Doci					00:01:23.480	LUSB3C03		(GREEN LAMP)		ON	
		10000					00:01:23,480	L_MSB3C01	5B NRV ES-2			ON	
		Hanna (Coo)					00:01:23.480	L_XSB3A07	2A NVR ES-10	7 (GREEN LAMP)		ON	
		In In Inci					00:01:23.480	L_NSB3A05	3A NRV ES-79	(GREEN LAMP)		ON	
		(100) (Doc)					00:01:23.480	L_XSEBA0B	4A NRV ES-17	(GREEN LANP)		DN	
		Linita (Doc) -					00:01:23.480	L-1583A01	5A NRV ES-1	(GREEN LAMP)		ON	
		(Dac)					00:01:23.480	L_NS82016	CNDSER HD-32	2 (RED LAMP)		ON	
		Doc					00:01:23.480	L_X582C04	CASING VENT	103-97 (RED LAMP)		ON	
		Dec					00:01:23.480	LASB2C03	CASING VENT	105-97 (GREEN LAN	P)	OFF	
		100E					00:01:23,480	L_%S82816	CNDSER ND-22			IDN	
		Dec					00:01:23.480	L_X382804		1GS-98 (RED LAMP)		ON	
		Dat					00:01:23.480	L_KSB2B03		195-98 (GREEN LAM	P.)	OFF	
		(Doc)					00:01:23.480	L_NS02012	TURE AUTO ST			ION	
		HORE DOC					00:01:23.480	1_3502812	TURB AUTO ST			ON	
		HUNLOO (Doc)					00:01:23,480	L_NS02A12	TURE AUTO ST			ON	
		Doc)					00:01:24.160	RV-1	LPT-1 Reheat			INTERM.	
		Dod states					00:01:24.160	RV-2 IV-1	LPT-1 Reheat			INTERN. INTERN	
							00:01:24.160			Intercept valve			
		HERE Dec					00:01:24.160	IV-2 RV-3	LPT-2 Reheat	Intercept Valve		INTERM. INTERM.	
		Doc					00701:24.160	RV-4	LPT-2 Reheat			INTERM.	
		(Dag)					00:01:24.160	IV-3		Intercept Valve		INTERM.	
		Dec)					00101:24.160	IV-4		Intercept Valve		INTERH.	
		(Fine)					00:01:24,440	gV-1	Governor Val			INTERM.	
		IDec.					00:01:24,440	GV-2	Governor Val			INTERM	
		Doc					00:01:24.440	GV-3	Governor Val			INTERM.	
	00/35-02 7		CHARGING PLIMPS DE	SUN HEADER HIGH-LC	WFLOW		00:01:24.720	PK-464	Stm Hdr Dump			INTERM.	
		Doc Doc					00:01:25.440	XN20A03		N STOP VALVES SHU	T.	ACTIVE	
		JIENALS DOC					00:01:25.440	L_X502D11	TURB SHUT VL			ON	
		a La Coc					00:01:25.440	L_XS02c11	TURB STOP VL			ON	
		Dod					00:01:25,440	LIG02B11	TURE STOP VL	V 2 SHUT		ON	
		Doc)					00:01:25.440	L_X502A11	TURE STOP VL	V 1 SHUT		ON	
		Doc Doc					00:01:25.720	TV-1	Throttle val	ve I		INTERN.	
RX CTRL	RCS/PRZ	CVCS St	S/RHR CNM/	CNS SWS/ESW	CCW	BTRS	NIS TURG CT	RL SGN/AF	W MSS/CFW	CR-HVAC	ELEC	CIRC RMS/GFFD	SEGDS

Figure 19.2. Alarm display for Scenario 3 after the final fault inserted alarms 40 to 89.

0:18:21	Print	RCS/BRI					FRE	EZE		Tateguards	Alarms & Events	formets	Alarms & Events
CTS / Accum	6 CHG-BA	11 Rx Pirst Out 1	1 16 EW		26 SYS SUDV	1 31 CLG TWR							
W/ESW/IA		12 Rx First Out 2											
6.8	8 RCP			23 HVAC/RAB/MIRC	28 CTMT HVAC 1								
WST/RHR	8 PRZ	14 SUN	ID CND	ZA DGN A	29 CTMT HVAC 2	f.							
RHR/GOW	10 RCS		I 20 MSS/Turb	25 DGN B	30 CR HVAC/Misc	V All Alarma	S		min.				
larm list, al	ll alarms						scroll						
etillons	Time	1d	Alarm description					Time	ld	Description			Event
	0(00:00:00)0		RAS NORM SUP PARTS				11	00:04:12,440	XN10A26		SYSTEM TROUBLE		ACTIVE
	0.00:00:00.0	WILLEROS (Doc)	SFP D HILD LEVEL					00:04:13.120	AM-824	Normal Purge			STOPPED
	0.00.00.0	XM23505 Doc	NEW EP MI LOW FLOR					00:04:13.720	CP-3	Norm Cont PI			INTERM.
	0,00.00.00.00	KNEFTOS (Dec)	STP 2 BILOW FLOW					00:04:13.720 00:04:13.720	CP-3 (P-5	North Cont Pt			INTERM.
								00104113.720	CP-5	Normal Court			INTERM
		AFRICATION Dec	PRZ COME LOW PRES	THE ADDRESS OF A DESCRIPTION OF A DESCRI				00:04:13.720	CP-6	Normal Crunt	Inlet/Discharge		INTERM. INTERM.
		INDIAGE (Dob)	PREUSURIZER HIGHL					00:04:13.720	CP-6		a Inlet/Discharge		INTERM.
		IDaci						00:04:13.720	CP-9		Inlet/Discharge		INTERM.
		INZOANS (Doc)	TURBINE AUTO STOP	OR LOW FREES				00:04:13.720	CP-9		Inlet/Discharge		INTERN.
		Unisate (Doc)						00:04:14.680	(P+3	Norm Cont PL			CLOSED
		XNIE408 Dec	TURBINE THIP REACT					00:04:14.580	CP-6		Inlet/Discharge		CLOSED
		VNNA400 (Deci	ROD CONTROL URGE					00:04:15.640	CP-5	Normal Court			CLOSED
	00.05:55 8			NEUTRON FLUX RATE	ALERT			00:04:15.640	CP-9		Inlet/Discharge		CLOSED
	00.01.05.0	HHIZENA Doc	REACTOR THIP POWE	ER RANGE HOOM FLUR	RATE			00:04:16.000	CPB-9	Norm Purge I			INTERM,
		KN20A03 (Dod)						00:04:16.000	CP8-9	Norm Purge I			OPENED
	\$17,80:00	XINNERDO? (Dida)	ONE ROD AT BOTTOM	M				00:04:16.000	L=X587C09	ISOL CP-B9	(GREEN LAMP)		OFF
	100.000 000.000	#MILTON Dec	TWO DR MORE RODE	MOTTON TA S				00:04:16.320	CP_D6	North Purge 1	Inlet Flow		CLOSED
		Doc						00:04:16,320	L-XSB7C06	AH-82 IN CP.	D6 (RED LAMP)		OFF
		11- (E-00)						00:04:43.160	XN09c03	PRZ CONT LON	PRESS AND HEATER	S DN	ACTIVE
	00107.01.8	WHAT DOC	SQ & HR LVLISP HILL	DIEN				00:04:43.160	PHTR A.	Back Up Heat	ters Group A		ON
		Doc)						00:04:43.160	PHITA B	Back Up Heat			DN
		Dad						00:04:45.150	PHTR D		ters Group D		ION
		(Doc)					14	00:04:50.440	PK-444A	Pressure Cor			INTERM.
	0,01-00-00		CONTROL HOOM (SOL					00:04:50.440	PK-444A	Pressure Cor			OPENED
	00 X08 (10 8	(HIIONU) Decl	CIMIROL RIOM (SO					00104:51,120	XN09A05		HIGH-LOW PRESS		ACTIVE
	00:05-10.0	(Maie)) (Dod)	INFREE COENERATOR					00:04:54.320	XN09802		CONTROL LOW LEVEL		ACTIVE
	0,01180,00	NIMBER Dec	DIESEL SENERATOR	ATROUMLE				00:04:57.150	XN05AD1		S DISCH HEADER HEAD	1000W FC 00	ACTIVE
	00.05/16.5	VNR0416 (Doci	TURBINE TROUBLE	SEED OR MOPERABL				00:05:12.840 00:05:15.360	LK-459F R0DSOUT	Level Contro			OPENED
		INDIEGE Doc						00:05:15.360	ROD OUT	Rods out Rods out			ON ON
	00:05:11.2	RINEFERS DOC		E MECH CLOUPPICE ERI				00:05:41.880	NN10A38		-		
	00:04:11.2	WhiteAcz (Doc)		EVE CONT SHUT JIGN				00:05:41.880	L=x503c08		UK ROD C-3 ALERT		ACTIVE
	00 08.71.2	+NVADO3 IDoc	160VCHC BILLS TROUBL					00:05:42.200	L-1/548006		MP ALERT LVL		ON
		V/16000 (Dod)						00:05:42.200	L-3344006		MP ALERT LVL		ON
		KN25EGT DOC						00:05:46,000	RODSOUT	Rods out	an nearly ere		OFF
	00mmri.6	VNIISBALI (Doc						00:05:46.360	XN20A09		ACK OPERATIVE		ACTIVE
	00.08-11.0	HASACON Dec	400 V EMER BUR 4-SI					00:05:46.360	DEHAZ	Runback open			ON
	00.01117.5	KN24903 (Doc)	KEMRIAY BREAKER A	ASATER CHLOCA				00:05:46.360	ROD_OUT	RODS OUT			OFF
	00:00 12 1	XN20A97 (Doc):	TURB EMER DUL FIME	RUNITREL				00105:46.360	L-XSLBA03	SOURCE RANGE			ON
	00.08.12.1	(NOIR24 Doc)	ROT HE COW LOW P					00:05:46.360	L+#\$03c09	C RUNBE O/TE	MP DT TE 432C2		ON
	00.08 12.8	INTEROT Doc	LOUIS OF BOTH MAIN	FW RUMPS				00:05:46.360	L-1503C07		EMP DT TE 412C2		DN
	00:05:12.8		BVOMI FLIME SHE FAIL					00:05:47.000	DEHE-28	Hold			HOLD
	100:06-13 al			DIBCHAROE PRESILIA				00:05:47.240	GV-A	Governor Va	Ne 4		INTERM.
	00.00115,4	KINDEADE (DOE)	EXCESS LTDM HX XXC					00:05:47.920	XN20A09		ACK OPERATIVE		NORMAL
	00.05 12.7	WN25504 Doc	KPENT F P III LOW FE					00:05:47.920	GV-4	Governor Va			INTERM.
	00:0E(17.0	VNISH(4) (Doc)	EDNTAMMENT DOME					00:05:47.920	DEHAZ	Runback oper			OFF
	00:05:47.2	VENOGRADI (Doll		ICH HEADER HIGHLC	W WEDW			00:05:50.800	PK-464		Press Cont		INTERN.
		KNDARE (Doc)	GROLD & MLE COMPO					00:05:53.080	XN10A39	O/TEMP DT AN			ACTIVE
	(1)(2)(5)(5)(1)(2)(5)	Doll OFASSIAN	GROLIE & MLB COMPO	CINERY OFF NURMEL				00:05:53.080	L-1503408	B TRIP 0/TE	IP DT TB 422C1		ON

Figure 20.1. Alarm display for Scenario 4 after the final fault inserted alarms 1 to 50.

00:18:21	Print	RC5/PR3					FREEZE		Taleguards	Alarms & Events	Lonato -	Alarms & Even	its
CTS / Accum	6 CHG/BA	11 Rx Piret Out 1	1 16 EW		26 SYS Supv	31 CLG TWR	The second se						
		12 Rx First Out 2											
MLB	BRCP				28 CTMT HVAC 1	-							
RWSTIEHR	BPRZ	LASUN	I ID CND	LA DON A	29 CTMT HVAC 2	=							
	TU RCS	15 Miac				-	The second second second						
	TO RCS			25 DGN B		C IV All Allerma	Silence Silence 10	min.					-
							Event list.						Auto'se
petitions	Time	Id	Alarm description				Time	ld	Description			Event	
	4.01: 80:00	WA24HG3 Dagi WA24HG3 Dagi	DIESEL GENERATOR	ATROUBLE			00:04:12.440	XN10A26		SYSTEM TROUBLE		ACTIVE	
	00:08.10.8	KNOTEDE DOC	TURBINE TROUBLE	STEED OR HIGHERARD			00:04:13.120 00:04:13.720	AM-82A CP-3	Normal Purge			STOPPED	
	00:05 11 2	KNITERS Dec					00:04:13.720	CP-3	Norm Cont PU			INTERM. INTERM.	
	00.05112	KNETCHE (Dec)					00:04:13.720	CP-5	North Cont Pu Normal Cont			INTERM.	
		INTERIO DEC					00104113.720	CP-5	Normal Crunt			INTERM.	
		NAVEDON (Dat)	250VOC MUST TROUB				00:04:13.720	CP-6		Inlet/Discharge		INTERM.	
		INISDOJ DOD					00:04:13.720	CP-6		Inlet/Discharge		INTERM.	
	00:05 11 5	VINZGENT (Doci	480 VEMER BUS B-8				00:04:13.720	CP-9		Inlet/Discharge		INTERM.	
		INDERE Dec		BIA-SB TRUE CHALOOM			00:04:13.720	CP-9		Inlet/Discharge		INTERM.	
		90424801 (Dec)					00:04:14.680	(P+]	Norm Cont Pu			CLOSED	
	100:08 // 1/5	XN24B03 Doc	TEMP ALBREAKER				00:04:14:680	CP-6		Inlet/Discharge		CLOSED	
	60,00 115 A	VN20Att (Dec)	TURB EMER OAL PIME	RIGITREL			00:04:15.640	CP-5	Normal Comt			CLOSED	
	00:08:12.1	1105/124 (Ded)	ROT HE COWLOW	FLOW			00:04:15.640	0~9	Normal Furge	Inlet/Discharge		CLOSED	
	60-08-12-4	HHHMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM	LOSS OF BOTH MAIL	FW RUMPS			00:04:16,000	CPB-9	Norm Purge E			INTERM,	
		VINDBADD DOG	RWMU PLOMP AVII PAU	IL MRIS			00:04:16.000	CP8-9	Norm Purge E			OPENED	
	00.05 15.6	XIV00.460 (Doc)	RVVIIL FUNERLOW	DISCHARGE FRESSUR	E		00:04:16.000	L=X587C09	ISOL OP-B9 (	GREEN LAMP)		OFF	
	ooxim that	HUGADE Dad	BICESS LIDH HO CO	WIDW FLOW			00:04:16.320	CR_D6	North Purge I			CLOSED	
	00.05.13.7	XIIIIISON (Dok)	SPENTER HILOW F	LOW			00:04:16.320	L-XSB7C06	AH-52 IN CP-	D6 (RED LAMP)		OFF	
	00:08:17,0	XNDSIA03 (Dog)	CONTAILMENT DOME	E NIGH TEMP			00:04:43.160	XN09c03	PRZ CONT LOW	PRESS AND HEATER	5. DN	ACTIVE	
	00108L117.0	THIRACT DOC		INCH HEADER HIGHL	DIV FILDIV		00:04:43.160	PHTR A.	Back Up Heat	ers Group A		ON	
	00:00:100:00	INCLASE DOC	GROUP & MLB COMP				00:04:43.160	PHTR B	Back Up Heat			DN	
	00-00 (8 S	INVERTO DOC		TOMEST OFF NORMAL			00:04:43.160	PHTR D	Back Up Heat			ION	
	00.00 18.2	XNRIGESCO (Dec)	CHRG PUMPE B TRO				00:04:50.440	PK-444A	Pressure Con			INTERM.	
	100-06-10,2	XIVO9504 Doci	CHRG PUMPS A TRO				00:04:50.440	PRE-444A	Pressure con			OPENED	
	00 008-224-2	HITEMAD Dec		RIP CONTACT TEXT OF			00104:51,120	XN09A05		HIGH-LOW PRESS		ACTIVE	
	00:05:25.2	OFFERATO (Doc)		OCHOAT BELAY MUD			00104154.320	XN09802		CONTROL LOW LEVEL		ACTIVE	
	00.00 28 2	XIVIIIANI Dec		OCHOLIT RELAY MUCH	LE TRUNKIN TRE		00:04:57.160	XN05A01		S DISCH HEADEN HIGH	0W_ T'L_0M	ACTIVE	
	DOMPO25,6	VN22A24 Doc	RENERATOR BUB SC				00:05:12.840	LK-459F	Level Contro	a.		OPENED	
	00.05.25.8	(FILTASE (Diod)	GENERATOR BUR 62				00:05:15.360	RODSOUT	Rods out			ON	
	00:06(26,6	INZERIA DOC		SA DE PULNE PIVIS SU	PART ON BEOMIN		00:05:15.360	ROD_OUT	RODS OUT			ON	
	00:08 (25.8	KNEZARN (Doc)	MEMERATOR EXCITE	GE REO TRIF TO MAN			00:05:41,880	WIDASS		K ROD C-3 ALERT		ACTIVE	
							00:05:41,880 00:05:42,200	L-X503C08	E RUNBE O/TE	MP DT TE 422C2		ON	
		KNY0AS Doc	RES TREF/TAVO HIGH				00:05:42.200	L-3348006	CNNT BLDG SU			ON ON	
		Doci					00:05:46.000	RODSOUT	Rods out	THE ALERI LYC		OFF	
		Doci					00:05:46.360	XN20A09		ACK OPERATIVE		ACTIVE	
	00 0E 342	INDIALS Dec	LOW FUMPS & TROU	IFILE			00:05:46.360	DEHAZ	Runback oper			ON	
		(Mister) (Doc)	REW PUMPS & TROU				00:05:46.360	ROD_OUT	RODS OUT			OFF	
		(Doc)					00105:46.360	L-XSLBA03	SOURCE RANGE			ON	
		c/303,405 (Dioc)	FHR LOOP B DISCHA				00:05:46.360	L-#503c09		MP DT TE 432C2		ON	
		LANSALVER DOC	RHR LOOP & DISCHA				00:05:46.360	L-1503C07		INF DT TE 412C2		ON	
		URIADI Dod	LPHTR IS HIGH-LOW				00:05:47.000	DEHE-25	Hold	the state of the second		HOLD	
		KN21ATI Doci	LP.HTB IB HIGH-LOV				00:05:47.240	GV+4	Governor val	ve 4		INTERM.	
		VN21A/4 (Dot)	LU HTR JA HIGH-LOW				00:05:47.920	XN20A09		ACK OPERATIVE		NORMAL	
		XN20ACE Dec					00:05:47.920	GV-4	Governor Val			INTERM.	
	00:06 56.0	NAMEDOR (Doc)		ER DETECTOR HI FLI	DEV OR AUTO DEE		00:05:47.920	DEHAZ	Runback open			OFF	
	00105.84.0	SUITION (Dog		ER DETECTOR HIPLE			00:05:50.800	PK-464	Star Hdr Dump			INTERM.	
		XNHRADA (Doc)	HOT WELL HIGHLOW	W LEVEL			00:05:53.080	XN10A39	D/TEMP DT AL			ACTIVE	
	00-07:20.3	INDIALE IDOC	LP HTRUA HIGH-LOV				00:05:53.080	L-XS03A08		P DT TB 422C1		ON	

Figure 20.2. Alarm display for Scenario 4 after the final fault inserted alarms 28 to 77.

0:18:21	Print	RCS/ERI					FREEZE		Tatoguarde	Alarms & Events	formals.	Alarms & Even	its
CTS / Accum	6 CHG/BA	11 Rx First Out 1			26 SYS Supv 3	CLG TWR	1						
		12 Rx First Out 2											
A R	8 RCP		18 Turb First Out	23 HVAC/RAB/MIRC	28 CTMT HVAC 1								
WST/RHR	BPRZ	L4 SGN	IN CND	LA DON A	29 CTMT HVAC 2								
RHR/COW	10 RCS		1 20 MSS/Turb	25 DGN B	30 CR HVAC/Mile VA	I Alarma							
larm list, all	l alarms												
	Time	1d.	Alarm description				Turie	ld	Description			Event	
	00:06/25.0	VN22A2S (Dag)	DENERATOR BAR 52.				00:04:12,440	XN10A26		SYSTEM TROUBLE		ACTIVE	
	00.08.25.8	THIERAR DOG	DENERATOR BINA 62				00:04:13.120	AH-824	Normal Purge			STOPPED	
	00.05.25.0	YHIZEATH DOG		IS OF FULSE FWE BUP			00:04:13.720	CP-3	Norm Cont PL			INTERM.	
	00:05:25,6	KNEZA24 (Dec)	GENERATOR EXCITE				00:04:13.720	CP-3	North Cont PL			INTERM.	
	99-04-25.6	XN22815 (Doc		SE REG TRIP TO MANAL			00:04:13.720	CP-5	Normal Count			INTERM.	
	DO 139.234.8	TADIATS Dec	MS DRAM POT LOV C				00:04:13.720	CP-5	Normal Crunt			INTERM.	
	00:08 (29.7		RCS TREF/TAVE HIGH				00:04:13.720 00:04:13.720	CP-6 CP-6		Inlet/Discharge		INTERM.	
							00:04:13.720	CP-6 CP-9		Inlet/Discharge		INTERM. INTERM.	
		INDEAGE Dec	COW FUMPS B TROU				00:04:13.720	CP-9		Inlet/Discharge		INTERM.	
		VINISAAS Doc					00:04:13.720	CP-9	Normal Purge			INTERM. CLOSED	
	Contraction of the local division of the loc	ALVING DOC					00:04:14.680	CP-6		Inlet/Discharge		CLOSED	
		VINPAAKS (Dec)	THR LOOP & DISCHA				00:04:15.640	CP-5	Normal Comt			CLOSED	
		KNOHADI (Ded)	RHR LOOP & DISCHA				00:04:15.640	CP-9		Inlet/Discharge		CLOSED	
		THURSDARD DOC	LP HTTE IA HIGHLOW				00:04:16,000	CPB-9	Norm Purge E			INTERM,	
		KN2FADE IDOG					00:04:16.000	CP8-9	Norm Purge E			OPENED	
		XN24A04 (Doc)	LP HTR 4A HIGHLOW				00:04:16.000	L=X587C09	ISOL OP-B9 (			OFF	
		WARDAGE IDec					00:04:16.320	CP_06	North Purge 1			CLOSED	
	00.05.86.0	KINESDOR DOG		ER DETECTOR HI FLX			00:04:16.320	L-3587C06		D5 (RED LAMP)		OFF	
		STIESCOE Cod					00:04:43.160	XN09C03		PRESS AND HEATER	5 ON	ACTIVE	
		UNISA04 DOC					00:04:43.160	PHTR A	Back Up Heat			ON	
	00:07:20.8	HIZTANS DOC	LP HTR 2A HIGH LOW				00:04:43.150	PHTR B	Back Up Heat			ON	
		(Doc)					00:04:43.150	PHTE D	Back Up Heat			DN	
		000					00:04:50.440	PK-444A	Pressure Con			INTERM.	
		The Doc					00:04:50.440	PK-444A	Pressure Cor			OPENED	
		Doc					00:04:51,120	XN09A05	PRESSURIZER	HIGH-LOW PRESS		ACTIVE	
		-tartier (Doc)					00:04:54.320	XN09B02	PRESSURIZER	CONTROL LOW LEVEL	DEVIATION	ACTIVE	
		Dec Dec					00:04:57.150	XN05A01	CHARICENG PLAP	S DISCH HEADER HIGH	00 TL 000	ACTIVE	
		Doc					00:05:12.840	LK-459F	Level Contro	1		OPENED	
							00:05:15.360	RODSOUT	Rods out			ON	
		Doc Doc					00:05:15.360	ROD_OUT	RODS OUT			ON	
		HEAD DOC					00:05:41,880	XN10A38		K ROD C-3 ALERT		ACTIVE	
		Doc)					00:05:41,880	L-X503C08		MP DT TE 422C2		ON	
		Doc Doc					00:05:42.200	L-XS46006		MF ALERT LVL		ON	
		(Dod)					00:05:42,200	L-NS4AD06		MP ALERT LVL		ON	
							00:05:46,000	RODSOUT	Rods out			OFF	
		Doc					00:05:46.360	XN20A09		ACK OPERATIVE		ACTIVE	
		Doc					00:05:46.360	DEHAZ	Runback oper			ON	
		Doc Doc					00:05:46.360	ROD_OUT	RODS OUT SOURCE RANGE			DFF	
		(000)					00105:46.360 00:05:46,360					ON	
		ALBERT DOC					00:05:46,360	L-XS03c09 L-XS03c07		MP DT TE 432C2		ON	
		(Doc)					00:05:47.000	DEHE-28	Hold	UNP DT TE 412C2			
		Martin Doc					00:05:47.000	DEHE-28 GV-4	Governor Val	hum A		HOLD INTERM.	
		Del					00:05:47.920	XN20A09		ACK OPERATIVE		NORMAL	
		Dec Dec					00:05:47.920	GV-4	Governor Val			INTERM.	
		ALCOLO IN ALCOLO					00:05:47.920	DEHAZ	Runback oper			INTERM. OFF	
(ACE)		(Dag)					00:05:50.800	PK-464	Stal Hdr Dump			INTERM.	
Ack		Doc Doc					00:05:53,080	XN10A39	O/TEMP DT AL			ACTIVE	
Ack)	00-19:19.B	XNORATS DOL	RCP-B SEAL NO.1 LE	AKOFF HIGH LOW FLC	W-		00:05:53.080	L-NSD3AD8		IP DT TB 422C1		ON	

Figure 20.3. Alarm display for Scenario 4 after the final fault inserted alarms 56 to 105.

0:03:07	Print	RCS/ERI	-						Tateguards	Alarms & Events	frends.	Alarms & Even	nts
TS / Accum	5 CHG/BA	II Rx Pirst Out 1	1 16 FW		26 SYS Supv	31 CLG TWR							
		12 Rx First Out 2											
4.8	8 RCP		19 Turb First Cut										
WST/RHR	8 PRZ	14 SUN	ID CND	ZA DGN A	29 CTMT HVAC 2								
HR/CCW	10 RCS		I 20 MSS/Turb	26 DGN B	30 CR HVAC/Misc	V Alt Alarma	Silence  Silence 10	min.					
iarm list, all													
etitions	Time	Id	Alarm description				Time	Id	Description			Event	-
10	00:00:00/0	XNESMOX (Dag)	RAS NORM SUP PARTS	PACK			00:01:38.240	XNIIH05	REACTOR TRI	P MANUAL		ACTIVE	
	00:00:00.0	THISTROS DOG	HEP D HILD LEVEL				00:01:38.240	XN13A07		URGENT ALARM		ACTIVE	
		YNINSSS DOG	NEW EP HI LOW FLOT				00:01:38.240	XN18A06		P REACTOR TRIP P4		ACTIVE	
	0,06:60:00	KNIZSTO4 (Doc)	IFP C III LOW FLOW				00:01:38.240	XN15A28		P AUTO STOP OIL TR	IP.	AGTIVE	
	90-00-00 h	KNESTOE Dec	STPDHILOWFLOW				00:01:38.240	TV-1	Throttle Va			INTERM,	
		Deci					00:01:38.240	TV+2	Throttle Va			INTERM.	
		Dad					00:01:38.240	E-VT	Throttle Va			INTERM.	
		(Doc)					00101:38.240	TV-4	Throttle Va			INTERM.	
		Doc					00:01:38.240 00:01:38.240	GV-1 GV-2	Governor Va			INTERM.	
			and the second second				00:01:38.240	5-V0 E+V0	Governor Va Governor Va			INTERM. INTERM.	
		Dec					00:01:38.240	GV-4	Governor Va			INTERM.	
		Deci					00:01:58.240	DEHAL	Turbine tri			DN ON	
		(Plan)					00:01:38.240	RTEPG	Reactor tri			OFF	
		Mart Dec					00:01:38.240	RTBP5	Reactor tri			DN	
		(Ball					00:01:38,240	RTEP2	Reactor tra			OFF	
		(Daw)					00:01:35,240	RTEP1	Reactor tri			ON	
		IDae					00:01:38.240	L_NS#3C07		10 (GREEN LAMP)		ON	
		000					00:01:38.240	L_NSB3C05		L (GREEN LAUP)		ON	
		HEADER (Doc)					00:01:38.240	L_XSB3C03		8 (GREEN LAMP)		ON	
		Dag					00:01:38.240	L_4583c01		(GREEN LAMP)		ON	
		Diec					00:01:38.240	L_XSE3A07		07 (GREEN LAMP)		ON	
		Doci					00:01:38.240	L_X583A05		9 (GREEN LAMP)		ON	
		(000)					00:01:38.240	L_NSB3A03	4A NRY ES-1	7 (GREEN LAMP)		ON	
		71 Doc					00:01:38,240	L_KSB3A01	SA NRV ES-1	(GREEN LAMP)		ON	
		Doc					00:01:38.240	L_NSB2016		22 (RED LAMP)		ON	
		(Doc)					00:01:38.240	L_XSB2c04	CASING VENT	LGS-97 (RED LAMP)		ON	
		Doci					00:01:38.240	L_XSB2c03		LGS-97 (GREEN LAN	P1-	OFF	
		Doc					00:01:58.240	L_MSB2B16		2 (RED LAMP)		ON	
		(Doc)					00:01:38.240	L_NSB2B04		LGS-98 (RED LAMP)		10N	
Ack		112 () () () () () () () () () () () () ()					00:01:35.240	1_3582803		103-98 (GREEN LAN	P)	OFF	
Ack		Doci (Sala					00:01:38.240	L_NS04C10	REAC TRIP E			ON	
Act							00:01:38.240	L_X504A10	REAC TRIP B			ON	
ACE ACE	Concerned a	XN21404 (Doc)					00:01:38.560	XNLLF03		P TURBINE TRIP P7		ACTIVE	
	00:02:21:3		LP HTR 4A HIGH-LOW	LEVEL			00:01:38,560	XN20A15		O STOP OIL LON PRE	23	ACTIVE	
(Ack) (Ack)		Mariana Doci					00:01:38.550	PK-464		p Press Cont		INTERM.	
Ack		Doc Doc					00:01:38.560	L_NS02012 L_NS02012		TOP TRIP 63-5		ON	
Ack		Doc Doc					00:01:38.560	L_N502812 L_N502A12		TOP TRIP 63-4 TOP TRIP 63-3		ON ON	
Ack		(Dac)					00101138.840	XN12F04		P POWER RANGE HIGH	FLUX RATE	ACTIVE	
		Doc)					00:01:38.840	XN13804		HIGH NEUTRON FLUX		ACTIVE	
Ack		Doc					00:01:38.840	DS309LAMP	Negative Ra		ONLE MERT	ON	
	00-03-07.9	XN21A08 (Doc)	LP HTR 24 HIGH-LOW	LEVEL			00:01:38.840	DS309LAMP	Negative Ra			ON	
		and the second second	- manual monte on	Contract of the second			00:01:38.840	DS139LAMP	Negative Ra			ON	
							00:01:38.840	DS139LAMP	Negative Ra			ON	
							00:01:38.840	L_KSLBF04	SOURCE RANG			ON	
							00:01:38.840	L_XS04007		RATE NC 44U/K		ON	
							00:01:38.840	L_NS04C07		RATE NC 43U/K		ON	
							00:01:38,840	L_X504807		RATE NC 420/K		ON	
							00:01:38.840	L_1504A07		RATE NC 410/K		ON	

Figure 21. Alarm display for the Scenario 4 first test first run. The initial alarms were identified, but none of the other expected alarms were identified after an Rx trip. Two cleared alarms are present.

0:06:08	Print	RCS/ERI							× saleguardi	Alarms & Events	formation	Alarms & Even	
CTS / Accum	6 CHG/BA	11 Rx Piret Out			26 SYS Supv	31 CLG TWR							
		12 Rx First Out											
MLB	8 RCP	13 NIS/RC				-							
			ID CND										
RHR/COW	10 RC3		1 20 MSS/Turb	25 DGN B	30 CR HVAC/Mis	c VAlt Alarma	Silence Silence 10	2 min.					
						Ack page VAuto scr							
petillons	Time	ld	Alarm description				Time	ld	Description			Event	
		prella- Dag					00:01:16.080	XN11F03	REACTOR TRIP	TUREINE TRIP P7		ACTIVE	
		Doc					00:01:16.030	XNIIHOS	REACTOR TRIP			ACTIVE	
		LINE DOG					00:01:16.080	XN13A07		URGENT ALARM		ACTIVE	
		1151 E COO					00:01:16.050	XN18A05		REACTOR TRIP P4		ACTIVE	
		al Dec					00:01:16.080	XN18A28		AUTO STOP OIL TH		ACTIVE	
							00101:16.080	XN20A15		STOP OIL LOW PRE	\$5	ACTIVE	
		Lpica Dad					00:01:15.080	TV-I.	Throttle Val			INTERM.	
		(000)					00:01:16.080	TV-2	Throttle Val			INTERM.	
		Martin Dat					00:01:16.080	E-VT	Throttle Val			INTERM.	
		HE Dec					00:01:16.080	TV-4	Throttle val			INTERM.	
		STUDIE DOC					00:01:15.080	GV-1	Governor Val			INTERM.	
		Dec Dec					00:01:16.080	GV-2 GV-3	Governor Va			INTERM,	
		(Dec)					00:01:16.080		Governor Val			INTERM.	
							00:01:16.080	GV-4	Governor val			INTERM.	
		Deci					00:01:16.080	DEHA1 RTBPG	Turbine trip			DN OFF	
		(Doc)					00:01:16.080	RTBP5	Reactor trip Reactor trip			ON	
		IDec					00:01:16.080	RTEP2	Reactor trip			OFF	
		Dot					00:01:16.030	RTEPL				ON	
		13 Martine (Cool)					00:01:16.080	L_XSB3C07	Reactor trip			ON	
		Helle Doc					00:01:16.080	L_%S83c05		(GREEN LAMP) (GREEN LAMP)		ON	
		Dec					00:01:16.080	L_XSB3C03		(GREEN LAMP)		DN	
		(Dine)					00:01:16.080	1383001	58 NRV ES-Z			ON	
		(000)					00:01:16.080	L_NSB3A07		(GREEN LAMP)		ON	
		Doc					00:01:16.080	L_KSB3A05		(GREEN LAMP)		ON	
		Doc					00:01:16.030	LASBEADE		(GREEN LANP)		DN	
		Doc					00:01:16.080	L 3583A01		(GREEN LAMP)		DN	
		Dec					00:01:16.080	L_X382016		2 (RED LAMP)		ON	
		(There)					00:01:16.030	L_KSB2C04		LGS-97 (RED LAMP)		ON	
		(Doc)					00:01:16.030	L_NSB2C03		105-97 (GREEN LA		OFF	
		(Time)					00:01:16.080	1 3582816	CNDSER HD-23			ON	
		(Doc)					00:01:16.080	L_MS82804		1GS-98 (RED LAMP)		ON	
		(30C)					00:01:16.080	L_X582803		165-98 (GREEN LA		OFF	
		(2152)					00:01:16,080	L_NS04c10	REAC TRIP BR			ON	
		(Doc)					00:01:15.080	L \$504410	REAC TRIP BR			ON	
		(Doc)					00:01:16,080	L_3502c17		OP TRIP 63-5		ON	
		Doc Doc					00:01:16,080	L_x502812		OP TRIP 63-4		ON	
		Dóc)					00:01:16.080	LXS0ZAL2		OP TRIP 63-3		ON	
		Doc					00:01:16.400	PK-464	Stm Hdr Dump	Press Cont		INTERM.	
		(Dad)					00101:15.580	XN12F04		POWER RANGE HIGH	FLUX RATE	ACTIVE	
		(Doc)					00:01:16.680	XN13B04	POWER RANGE	HIGH NEUTRON FLUT	RATE ALERT	ACTIVE	
		Doc					00:01:16.630	DS309LAMP	Negative Rat			DN	
	00:05:10.4	XN30D03 (Doc)		ER FLTR UNIT FAMS R	2 LOW FLOW-DIL		00:01:16.680	DS309LAMP	Negative Rat	e Trip		ON	
	00:05:10.4	XN23F03 Doc	RAB EMER EXH FAN				00:01:16.580	DS139LAMP	Negative Rat	e Trip		ON	
	00:05:20.3	XN02A20 (Doe)	SERV WTR LEAKAGE				00:01:16.630	DS139LAMP	Negative Rat	е тгір		ON	
	00:05:20.5	XN23P02 Doc	WC2-8 CH HI/SW LO				00:01:16.680	DEHA7	Opc mo			DN	
	00;05:20.6	XN23002 (Doc	WC-2 CH 18 CNDSR				00:01:16.680	L_XSLBF04	SOURCE RANGE			ON	
	00:05:28.0	XN23N03 (Dob)	WC-2 CH IB CNDSR	REFRIG HI PRESS			00:01:16.680	L_MS04p07		DATE NC 44U/K		ON	
		Doc)					00:01:16.680	L_X504C07	PR HI FLUX P			ON	
39 (Ack)	00-06:07,2	XNORATE ETASONX	RCP-A SEAL NO 1 LE	EAROFF HIGH LOW FL	DW		00:01:16.680	L_NS04807	PR HI FLUX R	ATE NC 420/K		ON	

Figure 22. Alarm display for the Scenario 4 first test first run, after SI initiated alarms 34 to 83. No expected alarms are identified. Seven cleared alarms are present.

0:03:29	Print	BCS/DR2	the second secon						X Saleguards	Alarous & Events	Trends	Alarms & Events
	6 CHG/BA	11 Rk First Out	1 1 16 FW		26 SYS SUPY	SI CLG TWR						
			2 1 17 AFW									
n A	RRCP	13 NIS/RC	1 18 Turb First Out	23 HVACIRABA								
RWST/RHR.												
						V All Atarms						
larm list, a	ili alarms				1-45 of 45							1-50 of 445
etiliann	Time	10	Alarm description		and the second	and the particular in the second second	Time	-10	Description			Event
		KNIZIMKI Doci	RAD NORM BUP PMP				00:01:21,120	XN11F03		TURBINE TRIP P7		ACTIVE
		WHEERE Dod	SEP D HALO LEVEL				00:01:21.120	XN11405	REACTOR TRIP			ACTIVE
	0,00.00,0	KN23SOE Dod	NEW FP IN LOW FLO				00:01:21.120	RN13A07	ROD CONTROL	URGENT ALARM		ACTIVE
		NIZETTA DOC	SFF C IN LOW FLOW				00:01:21.120	XN15A05		REACTOR TRIP P4		ACTIVE
	00.00.00.0	WALSTON DOL	SFF D W LOW FLOW				06:01:21,120	XN15A28	TURBINE TRIP	AUTO STOP OIL TRIP		ACTIVE
		WHITE IDOC	TURBINE AUTO GTOP				00:01:21.120	XN20A15	TURBINE AUTO	STOP OIL LOW PRESS		ACTIVE
	00:07:21:1	READER BOARD	TUREINE TRIP AUTO	STOP O'L TRUE			00:01:21.120	TV-1	Throttle Val	ve 1		INTERM.
	20/271231.1	ENTRACE DOC	TURBLE THIP REACT	Diff TRain and			00:01:21.120	TV-2	Throttle Val	ve z		INTERM.
	00.011021.1	KNR3AOP DOC	RUD CONTROL URGE				00:01:21.120	TV-3	Throttle Val	ve 3		INTERM.
		TAINGES Dec	REACTOR THIP MAND				00:01:21,120	TV-4	Throttle Val	ve 4		INTERN.
	00:07.27.1	XIVEREDS DOG	REACTOR THE TURE				00:01;21,120	av-1	Governor val			INTERM.
	7.15110:00	NN12BOA (Dor)	POWER RANGE HIGH				00:01:21.120	GV-2	Governor Val	ye 2		INTERM.
	00:01:21.7	XMAREGA DOC	BEAGTOR THE FOW	HE RANGE HIGH F	LLI E RATE		00:01:21.120	E-VD	Governor Val	ve 3		INTERM.
	00.01.23.0	KINDRAGOT (Dac)	TURBINE STEAM STO				00:01:21.120	GV-4	Governor val	ve 4		INTERM.
	00:01/23.6	RN113D07 (Doc)	ONE ROD AT BOTTOM				00:01:21.120	DEHAL	Turbine trip			ON
	00/01/22/0	XN15C07 Doc	TWO OR MORE RODI				00:01:21.120	RTBP6	Reactor trip			OFF
	00 07 74 0	KNODCKI Dec	PRE CONTLOW PRE				00:01:21.120	RTBP5	Reactor trip	E open		ON
	00.01243	XINGGINDE Dad	PRESSURIER MOH				00:01:21,120	RTBP2	Reactor trip			DFF
		Doc					00:01:21,120	RTEPL	Reactor trip			DN
		YNHARIA (Doc					00:01:21,120	L_%583C07		0 (GREEN LAMP)		ON
	00.01:27 T	WINAADO (DOC)	OG A HAPLELSP HUL				00:01:21.120	L_XSB3c05		(GREEN LAMP)		DN
	00001128.1	ANISHADE DOD	SO D VIR LVLISPINIL				00:01:21.120	L_XSB3C03		(GREEN LAMP)		ON
	\$100-011-000	ADDIAND DOC	TURBINE TROUBLE				00:01:21.120	L_KSB3C01	58 NRV ES-2			ON
		(Doc)					00:01:21,120	L_XSE3A07		7 (GREEN LAMP)		ON
							00:01:21,120	L_NSE3AQS	SA NRV ES-79			ON
		Doc					00:01:21.120	L_NSB5A05	4A NRV ES-17			ON
		Handle (Dad)					00:01:21,120	L_NSB3A01	5A NRV ES-1			.DM
		ALLES (Dat)					00:01:21.120	L_%\$82016	CNDSER HD-32			ION
		Daci					00:01:21.120	1_MSB2004		105-97 (RED LAMP)		ON
							00:01:21.120	L_%\$82003		1GS-97 (GREEN LANP)		OFF.
	P.10.103.09	MILEAR Deci	SEMMANUR MACITE				00:01:21.120	L_%582816	CNDSER HD-22			ON
		HEADYN Doc					00:01:21,120	L_X582804		105-98 (RED LAMP)		014
		Doci					00:01:21.120	L_SB2803		1GS-98 (GREEN LANP)		OFF
							00:01:21,120	LNS04c10	REAC TRIP BR			ON
		Deal Deal					00:01:21.120	L_1504A10	REAC TRIP BK			ON
							00:01:21,120	L_X502C12	TURE AUTO ST			ON
		Deci Deci					00:01:21.120	L_XS02812	TURE AUTO ST			ON
		Dec					00:01:21,120	L_NS02A12	TURE AUTO ST			ON
	00-00-60.a	MAINING Doc	LP HTR IA RISH&DW	a main			00:01:21.440	PK-464	Stm Hdr Dump		in Course .	INTERM.
							00:01:21.720	XNI2F04		POWER RANGE HIGH FLUX		ACTIVE
	B. 65-20100	HIZSANT (Doc)	LP HTR #8 PRSB-LOW				00:01:21.720	XN13604		HIGH NEUTRON FLUX RATE	MEENT	ACTIVE
		(Dati)					00:01:21.720	RV-1	LFT-I Reheat			INTERM.
		(LIGE)					00:01:21.720	RV-2 IV-1	LPT-1 Reheat	Intercept Valve		INTERM. INTERM.
		KNTSAG4					00:01:21.720	1V-1 1V-2		Intercept Valve		INTERM. INTERM.
		antistance whom					00:01:21.720		LPT-2 Reheat			INTERN.
							00:01:21,720	RV-3 RV-4	LPT-2 Reheat			INTERN.
							00:01:21.720	EV-4 IV-3		Intercept Valve		INTERN. INTERN.
							00:01:21,720	IV-1 IV-4		Intercept Valve		INTERM.
							00:01:21,720	DS309LAMP	Negative Rat			DN EPOC.
							00104124,720	mado amente.	usdarias kac	e		UN

Figure 23. Alarm display for the Scenario 4 first test second run, after an Rx trip; 26 identified unexpected alarms, 19 unidentified expected alarms.

0:05:37	Print	RCS/ERI	in the second second			H	REEZE		🗙 Salezuardi	Alarms & Events	formation	Alarms & Ev	ents
CTS / Accum	5 CHG/BA	11 Rx First Out			26 SYS Supv 31	CLG TWR							
		12 Rx First Out											
MA	8 RCP		1 III Turb First Out	23 HVAC/RAB/MIRC	28 CTMT HVAC 1								
RWST/RHR	8 PRZ	14 SUN	ID CND	ZA DGN A	29 CTMT HVAC 2								
RHR/COW	10 RCS		1 20 MSS/Turb	25 DGN B	N OR HVAC/MILE TV AI	Alastini	Slience Slience 10	min.					
petitions	Time	Id	Alarm description				Time	ld	Description			Event	
	0(00:00:00)	XNESMUZ (Dag)	RAS NORM SUP PAR	S PACIL			00:01:21,120	XN11F03		P TUREINE TRIP P7		ACTIN	
	0.00:00:00	TALEROS (DOC)	SFP D HILD LEVEL				00:01:21,120	XN11H05	REACTOR TRI			ACTIV	
	0.00.00.00	YNINS05 Dobi	NEW EP HI LOW FLO				00:01:21,120	WIJA07		URGENT ALARM		ACTIN	
	0,00:00:00	KN23T04 (Doc)	SFP C.W LOW FLOW				00:01:21.120	XN18AD5		P REACTOR TRIP P4		ACTIN	
	0.00.00.00	XN29T05 (Doc	SPP D III LOW FLOW				00:01:21.120	XN18A28		P AUTO STOP OIL TR		ACTIN	
	00 0.1.21.1	INIMA18 Dec	TURBINE ALITIA OTON				00:01:21.120	XN20A15		STOP OIL LOW PRE	55	ACTIN	
	00.01121.1	NATER Dat	TURBINE TRM AUTO				00:01:21.120	TV-I	Throttle Va			INTER	
	00/01/21/1	INTRACE DOD	TURBINE TRIP REACT				00:01:21.120	TV-2	Throttle Va			INTER	
	00:05:21.1	XIVISA07 Dec	ROD CONTROL URGE				00:01:21.120	E-VT	Throttle Va			INTER	
		SHITTHOS Dec	REACTOR THIP MAIN				00:01:21,120	TV-4	Throttle va			INTER	
		XN12F04 Doc		ER RANGE HIGH FLUX			00:01:21.120	GV-1 GV-2	Governor Va Governor Va			INTER	
		VN20A00 (Dec)	TURBINE STEAM STC		ACH FE		00:01:21,120 00:01:21,120	GV-3	Governor Va			INTER	
		KNEEDOT (Dec)					00:01:21.120						
		INVECT DOC	TWO OR MORE ROD				00:01:21.120	GV-4 DEHA1	Governor Va Turbine tri			INTER	1995 B
		XNOLAOS (Dec)					00:01:21.120	RTBPG	Reactor tri			OFF	
		XNIAATA (Doc)	SGC HR LVL/00 HILL				00:01:21.120	RTEP5	Reactor tri			OPP	
		INSAAD IDoc	BO A NR LYLNF HILL				00:01:21.120	RTEP2	Reactor tri			OFF	
	00:01 28 1	XIIIAADE Dob	SO B HE LYLISE MIN				00:01:21.120	RTEPL	Reactor tri			ON	
		RNDO/GTO (Dog)	TURENUE TROUBLE				00:01:21.120	L_XSB3C07		10 (GREEN LAMP)		ON	
		Doc					00:01:21.120	L_%583c05		L (GREEN LAMP)		ON	
		0.40					00:01:21.120	L_XSB3C03		S (GREEN LAMP)		ON	
		(Cine)					00:01:21.120	1383001		EGREEN LAMP)		ON I	
		(1)0.01					00:01:21,120	L_NSB3A07		7 (GREEN LAMP)		ON	
		Dec .					00:01:21,120	L_KSB3A05		GREEN LAMP)		ON	
		Dec)					00:01:21,120	LASBIADE		GREEN LANP)		ON	
		Doc)					00:01:21.120	LASEBADI		(GREEN LAMP)		DN	
		NUMATI Dec	LENERATION EXCITE	R ALTE TRU			00:01:21.120	L_1382016		22 (RED LAMP)		ON	
		Doc					00:01:21,120	L_KS82c04		LOS-97 (RED LAMP)		ON	
		() Chail (Dicc)					00:01:21.120	L_NS82C03		105-97 (GREEN LAN	P)	OFF	
		Social Doc					00:01:21.120	1.3582816	CNOSER HD-2	2 (RED LAMP)		ON	
		Doc					00:01:21,120	L_NSB2B04		LGS-98 (RED LAMP)		ON	
		HHATT DOG	HP HTR SE HIGHLOW	W.LEVE_			00:01:21,120	L_X582803		165-98 (GREEN LAH	PÚ	OFF	
		Dod Dod					00:01:21,120	L_1504C10	REAC TRIP B	RK B OPEN		ON	
		Dod)					00:01:21.120	L_1504A10	REAC TRIP B	KR A OPEN		ON	
		Doci					00:01:21.120	L_3502c12	TURB AUTO ST	TOP TRIP 63-5		ON	
	0.00	shi2sAdd (Doc)	IP HTT LA HABH-LOV				00:01:21.120	L_%502812		TOP TRIP 63-4		ON	
	00100100.0	HADRARD Dec	LP HTRUE HIGHLIN	V LEVEL			00701:21.120	L_XS0ZA12		FOP TRIP 63-3		ON	
		Doc Doc					00:01:21.440	PI(-464		p Press Cont		INTER	
		Ded - (Ded)					00101:21,720	XN12F04		P POWER RANGE HIGH		ACTIV	
		(Doc)					00:01:21.720	XN13804		HIGH NEUTRON FLUX	RATE ALERT	ACTIV	
		Doc					00:01:21.720	RV-1		t Stop Valve		INTER	
		analise Doc					00:01:21.720	RV-2		t stop Valve		INTER	
		Diog					00:01:21,720	IV-1		t Intercept Valve		INTER	
		Diaz					00:01:21.720	IV-2		c Intercept Valve		INTER	
	00.03/54.3	XN25861 Dec	DIESEL GENERATOR				00:01:21.720	RV-3		t stop Valve		INTER	
	00;03:54.3	IN24H01 (Doc)	DIENEL GEHERATOR	A TRUMBLE			00:01:21.720	RV-4	LPT-2 Reheat			INTER	
							00:01:21,720	IV-3		t Intercept Valve		INTER	
		Dec					00:01:21.720	IV+4		t Intercept Valve		INTER	49.
		Doc Doc					00:01:21.720	DS309LAMP	Negative Rat	ce map		ON	
RX CTRL	RCS/PRZ	CVCS	SIS/RHR CNM/					IRL SGN/AF	W MSS/CFW	CR-HVAC	ELEC	CIRC RMS/GFFD	SEGDS/F

Figure 24.2. Alarm display for the Scenario 4 first test second run, after SI initiated alarms 1 to 50. Forty two of the 80 expected alarms are identified; 38 expected alarms not identified.

0:05:37	Print	RCS/ERI		FRF	EEZE		🗶 Safeguardi Alarms	& Events Double	Alarms & Events	
TS / Accum	6 CHG/8A	II Rx Piret Out	1 16 FW   21 Turb/Aux   26 SYS Supv   31 CLG TV	VIR						
		12 Rx First Out 2								
1.8	8 RCP		18 Turb First Out   23 HVAC/RAB/Misc  28 CTMT HVAC 1							
	BPRZ	LA SGN	IN CND ZA DGN A 29 CTMT HVAC 2							
					Planes   Planes an					
RHR/COW	10 RC3		20 MSS/Turb 26 DGN B 10 CR HVAC/Mire 1V All Alarma		Silence  Silence.10	min.j				
					Event list					Auto
etillions	Time	Id	Alarm description	70	Time	ld	Description	1012111E	Event	
		And Date			00:01:21.120 00:01:21.120	XN11F03 XN11H05	REACTOR TRIP TUREINE REACTOR TRIP MANUAL	TRIP PA	ACTIVE	
		XINITAAN (DOC)	HE HTE ED HIGHLOW LEVEL		00:01:21,120	XN13A07	ROD CONTROL URGENT A	3034	ACTIVE	
		THERE DOG			00:01:21.120	XNISADS	TURBINE TRIP REACTOR		ACTIVE	
		Linna Dec			00:01:21.120	XN18A28	TURBINE TRIP AUTO ST		ACTIVE	
		Doc)			00:01:21.120	XN20A15	TURBINE AUTO STOP OI		ACTIVE	
	00.02.00.0	NAST BOO DOG	UP HTR 24 HOHA DWY LEVEL		00:01:21.120	TV-I.	Throttle valve L		INTERM.	
	00101100	KN248A7 (Dob)	1/P HTRI 28 HIGH-LOW LEVEL		00:01:21,120	TV-2	Throttle Valve 2		INTERM.	
		Dec Dec			00:01:21.120	E-VT	Throttle Valve 3		INTERM.	
		Doc)			00:01:21,120	TV-4	Throttle valve 4		INTERM.	
		AND CO			00:01:21,120	o√-1	Governor Valve I		INTERM.	
		Dec .			00:01:21,120	GV-Z	Governor Valve 2		INTERM.	
		(Dec)			00:01:21,120	GV-3	Governor Valve 3		INTERM.	
		Anna Dec			00:01:21.120	GV-4	Governor valve 4		INTERM.	
		Doci			00:01:21.120	DEHA1	Turbine trip		MC	
	00002.84.2	KNOREGE DOC	DIEIEL CENERATOR & TROUBLE		00:01:21,120	RTBPG	Reactor trip B close		OFF	
	00:03:84/3	CHEMHON (Doc)	MESEL GENERATOR A TROUBLE		00:01:21.120	RTBP5	Reactor trip B open		ON	
		Doc			00:01:21.120	RTEP2	Reactor trip & close		OFF	
		Doc Con		1	00:01:21.120 00:01:21.120	RTBPL L_XSB3C07	Reactor trip A open 2B NRV ES-110 (GREEN	1 2000	ON	
		(Bool			00:01:21.120	L_%S83c05	3B NRV ES-81 (GREEN )		ON	
		KNINSDOJ Dec	250VDIC BUS TROUBLE		00:01:21.120	L_XSE3C03	48 NRV ES-18 (GREEN		ON	
		NANSDOT IDGE	1214 DC (HIS TROUBLE)		00:01:21.120	1.1583001	5E NRV ES-Z (GREEN L		ON	
		000			00:01:21,120	L_NSB3A07	2A NVR ES-107 (GREEN		ON	
	00/03:55/0	VN26DOI IDIGE	400 VEMER BUS BAB TROUBLE		00:01:21,120	L_KSB3A05	3A NRV ES-79 (GREEN		ON	
		INDIAGOZ Dec				L_NSB3A03	44 NRV ES-17 (GREEN		DN	
		Doc)			00:01:21.120	L_XSB3A01	5A NRV ES-1 (GREEN L		DN	
		HELDER DOC			00:01:21.120	L_1382016	CNDSER HD-322 (RED L	ALCP)	ON	
		Dac			00:01:21.120	L_KSB2C04	CASING VENT LOS-97 (1	RED LAMP)	ON	
		(Jood) E24/20/14	RODT RECOVIDIN FLOW		00:01:21.120	L_NSB2C03	CASING VENT 105-97 (	SREEN LANP)	OFF	
		Doc			00:01:21.120	1_3582816	CNDSER HD-22 (RED LA		ON	
	00:02 66 1	VNERADE DOC	RWMU FUMP A/E FAILURE		00:01:21,120	L_XSB2804	CASING VENT 165-98 (		ON	
		Doc)			00:01:21,120	L_X582803	CASING VENT 105-98 (		OFF	
		Doc .			00:01:21,120	L_NS04C10	REAC TRIP BRK B OPEN		ON	
	00-07-17-8	XIIIIISCA (Doc)	SPENT # P W LOW FLOW		00:01:21.120	L_KS04A10	REAC TRIP BKR A OPEN		ON	
	390,04,00,7	KNOONEL DOLL	CHARGING POMPS ENDER HIGHLIDW FLOW		00:01:21,120	L_3502c12	TURB AUTO STOP TRIP		ON	
		Lines Dec			00:01:21.120 00:01:21.120	L_NS02812	TURE AUTO STOP TRIP		ON	
		(Ding)			00:01:21.120	EX502A12 PK-464	Stm Hdr Dump Press G		ON INTERM.	
		(Doc)			00:01:21.440	XN12F04	REACTOR TRIP POWER R		ACTIVE	
		KAJOBADZ (Doc)	PR2 CONT HIGH LEVEL DEVIATION AND HEATERS DM		00:01:21.720	XN13E04	POWER RANGE HIGH NEU		ACTIVE	
		JUIZSATS (Doc	LP HTR 48 HIGH4, DW LEVEL		00:01:21.720	RV-1	LPT-1 Reheat Stop Va		INTERM.	
		Doc Doc			00:01:21.720	RV-2	LPT-1 Reheat Stop Va		INTERM.	
	00:04:10.1	XINCEARS (Doc)	DOW PUMPS & TROUBLE		00:01:21.720	IV-1	LPT-1 Reheat Interce		INTERM.	
	00184110.0	INDEAR DOE	STW FUMPS & TROUBLE		00:01:21.720	IV-2	LPT-1 Reheat Interce		INTERM.	
		Doc Doc			00:01:21,720	RV-3	LPT-2 Reheat Stop Va		INTERM.	
		(Inter Doc)			00:01:21.720	RV-4	LPT-2 Reheat Stop Va		INTERM.	
	00104(20,1	KNIGRE IDOB	HTR DRILPUMPELO DP LO PLOW		00:01:21,720	IV-B	LPT-2 Reheat Interce		INTERH.	
	00.64(75)0	KINADE (DOC)	HTTP DRN PUMP & LO DPILID FLOW		00:01:21,720	IV+4	LPT-2 Reheat Interce		INTERM.	
(Ack)		Doc		14	00:01:21.720	DS309LAMP	Negative Rate Trip		ON	

Figure 24.2. Alarm display for the Scenario 4 first test second run, after SI initiated alarms 31 to 80. Forty two of the 80 expected alarms are identified; 38 expected alarms not identified.

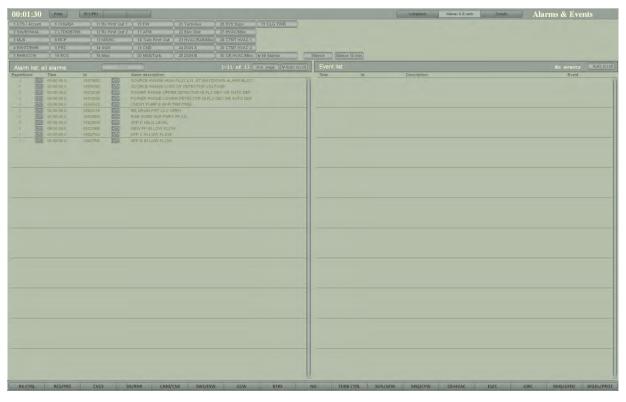
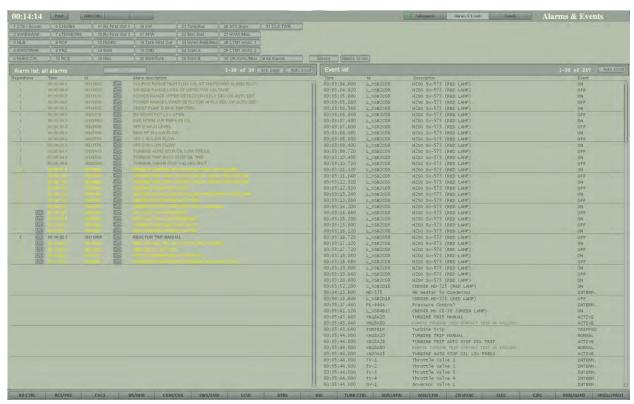


Figure 25. Alarm display for the Scenario 3 first test. Initial alarm screen, all expected alarms identified.

:07:53	Panet	HM/CHS						natozuard:	Alarms & Events	Unat	Alarms & Events
TS / Accum	6 CHG/BA	I Rx Pirst Out 1	1 16 EW		26 SYS SUDV 31 SLG TWR						
VESWIA		12 Ra First Out 2			27 HVAG/Misc						
					28 CTMT HVAC 1						
STIRHE	8 PRZ	LA SUN	1 IO CND	ZA DGN A	29 CTMT HVAC 2						
	TI) RCS	15 Misc	1 20 MSS/Turb	25 DON B	30 CR HVAC/Misc VAII Alarma						
Incom	10 862			TO DOM B	30 CIC HANCINIEC   A VII MURTHI	Silence  Silence 10	innin.				
						Event list					
Home Time		id	Alarm description			Time	Id	Description			Event
Acki DO	0,00;0	KINTEEO2	BOURCE RIANGE HIGH			00:03:04.600	1_1582008	H250 SW-573 (			ON
Ack one		NINCON IDOC	SOURCE GAMOR LOD			00:03:04.920	L_%582c08	H250 SH-573 (			OFE
Ack 00:0			POWER RAHGE UPPE			00:03:05.600	L_3562008	H250 5H-573 (			ON
ACE: 0000		INTEDOR (Dec)	POWER RAVIDELOW			00:03:05.880 00:03:06.560	L_XSB2C08	H250 SW-573 (			DFF
ACK DO D		INDIA15 DOC	MS DRAIN POY LEV C			00103106.840	L_MSB2008	H250 SW-573 (			ON
ACK DO D			INAB NORM SUP FIMPS			00:03:05.840	L_XSB2C08	H250 SW-573 ( H250 SW-573 (			OFF
ACR DOW		INZERICE DOD				00:03:07.800	LASB2CO8	HZS0 SW-573 (			OFF
		VIVE3SEE Dat	HEW FP IN LOW FLOW			00:03:08,480	L.NS82008	H250 SW-573 (			ON
(A2A) 000		INIZETUA (Dec)	SEF 2 HILOW FLOA			00:03:08.800	L_NSB2C08	H250 SW-573 (			OFF
		INDERTYRE IDEAL				00:03:09,400	L_XSB2C08	H250 50-573 (			ON
Ack 00:0		KN18A20 (Doc)	TURBINE TRIP MANUA	AL.		00:03:09.720	L_XSB2c08	H250 SW-573 (			OFF
		IN20AN (Dec)	TURBINE AUTO STOP	OLL NOW PRESS		00:03:10.400	L_3582008	H250 SW-573 (	RED LAMP)		ON
(AER) 00.0	5 24.0	KATSASS (DOG)	TURBINE TRIP ALTO I	ETDIT OIL TRIM		00:03:10.720	L_XSB2C08	H250 3V-573 (	RED LAMP)		OFF
Ack 0000		HUNDAOD DOG	TI RED & STEAM STOR	P WALVES SHUT		00:03:11.320	L_1582008	HZ50 SW-573 (	(RED LANP)		MG
Ack 00:0	05:47,1	XN22A45 Doc	GENERATOR MOTORI	NG PRE-TRIP		00:03:11.640	L_KS82C08	H250 SW-573 (	(RED LANP)		OFF
Ack 00:0	\$ 59.9		LP HTR 2B HIGH-LOW	LEVEL		00:03:12,320	L_XSB2c08	H250 SW-573 (	(RED LAMP.)		ON
ACR NO		() Doci				00:03:12.920	LAS82008	H250 SW-573 (			OFF
(AV K)		Doci				00:03:13.240	L_NS62008	H250 5V-573 (			ON
SACK		1112 E-20				00:03:13.880	L_XSB2c08	HZSO 516-573 (			DFF
		ICL Doc				00:03:14.200	L_#582008	H250 SW-573 (			ON
TACK		Dioc				00:03:14.840	L_XSB2C08	H250 SW 573 (			OFF
ALK		000				00:03:15.200	LAS82008	H250 SW-573 (			ON
DACK!		(Liss)				00:03:15.800 00:03:16.120	L_K582C08	H250 SW-573 ( H250 SW-573 (			OFF
						00:03:16.720	LASB2C08	H250 5W-573 (			OFF
						00103:17.120	L_XSB2008	H250 SW-573 (			ON
						00:03:17-720	L_X582C08	H250 SW-573 (			OFF
						00:03:18.080	LK582008	H250 SW-573 (			ON
						00:03:18.680	L_NS62C08	H250 SV-573 (			OFF
						00:03:19.000	1_3582c08	H250 SW-573 (			ON
						00:03:19.640	L_NSB2c08	H250 SW-573 (			OFF
						00:03:20.000	L_X582c08	H250 SW-573 (			ON
						00:03:52.200	L_1582018	CNDSER HD-325	(RED LAMP)		ON
						00:04:15,600	HD-325	48 Heater To			INTERM.
						00:04:13,600	L_x582018	CNDSER HD-325			OFF
						00:05:17.440	PK-444A	Pressure Cont			INTERM.
						00:05:41.120	L_XSB4B13		30 (GREEN LANP)		DN
						00:05:43.640 00105:43.640	XN18A20 XN18A60	TURBINE TRIP	TREP CONTACT TEET		ACTIVE
						00:05:43.640	TURTRIP				ACTIVE
						00105144.000	WILSA20	TURBINE TRIP			NORMAL
						00:05:44.000	XN18A28		AUTO STOP OIL TRI	p.	ACTIVE
						00105:44,000	XN18A60		TREF CONTACT TEST		NORMAL
						00:05:44.000	XN20A15		STOP OIL LON PRES		ACTIVE
						00:05:44,000	TV-1	Throttle Valy			INTERM
						00:05:44.000	TV-2	Throttle Valv			INTERM
						00:05:44,000	TV-B	Throttle valu			INTERM.
						00:05:44.000	TV+4	Throttle valu			INTERM.
						00:05:44.000	GV-1	Governor valv			INTERN.

Figure 26. Alarm display for the Scenario 3 first test, after a turbine trip. ML identified three additional expected alarms, missed seven expected alarms, and includes three cleared alarms.



*Figure 27. Alarm display for the Scenario 3 first test, after an Rx trip. Six additional alarms were not identified, and there was no change in identified alarms. One cleared alarm is included.* 

# 6.16. Anonymous Peer Review to Validate the Efficacy of Using ML to Develop State-Based Alarm Solutions

In FY19, LWRS Program researchers worked with staff from the Halden Reactor Project (IFE) to develop a state-based alarm system using machine learning. This initial proof of concept R&D was documented in Langstrand, Nguyen, and McDonald (2019). Building on this work, IFE and INL conducted the R&D documented in this report to further develop this approach.

Part of the scope of this new R&D activity is to have the state-based alarm system developed using ML peer reviewed by subject matter experts (SMEs) who are highly familiar with the gPWR simulator to validate the effectiveness of using ML to develop state-based alarm solutions. As such, two SMEs, who were former licensed operators of the commercial nuclear power plant upon which the gPWR is modelled, were recruited to peer review this report and the results of the ML testing.

In synthesizing the SME's comments, a few general themes appear in their review. An overall theme from their comments is that the research results thus far show some promise, but that there is still a considerable amount of additional work needed in order to say more definitively whether this approach has potential or not. Said differently, a key inference from synthesizing the SME's comments is that they found it difficult to say whether or not Halden did a good job in developing a state-based alarm system because the report did not have enough detail to render a verdict one way or the other. For example, when it came to

answering a very direct question about the approach, such as, "Did the ML correctly suppress expected alarms, and correctly 'let through' unexpected alarms?" the SMEs demurred in their response.

A second theme arising from the SME's comments is that there appeared to be cases where Halden's test design was off the mark. In some cases, the SMEs commented that the scenario tested and/or the ML generated output were not of much use to them. While this negative feedback could be taken as harsh, it is hoped that Halden will view this feedback as suggestions for how to improve their development efforts. In fact, a third theme from the SME's comments consists of explicit suggestions from the SMEs on what Halden should consider doing as they continue to perform this research.

The SME's specific comments are as follows:

- a. **6.2.3 Scenario 3**. Figures 8, 9, and 10. A normal shutdown with no faults. All three screens were in bright color and most of the alarms were normal for this scenario. I thought the ML would take all alarms and output in the bolder bright color the abnormal alarms for the plant conditions. If I were shutting down the plant these three screens would be of no use to me. With my understanding this scenario would be a training scenario for normal alarms.
- b. **6.2.4 Scenario 4.** I'm not sure what to make of it. Is it a training scenario for ML? Figures 13-1 through 13-3 are all in bright color except for one alarm on the last page. This statement is at the end of this scenario "the alarms identified as not expected will standout and give the control room staff a better understanding for the cause of the trip or safety injection." I don't see that with these 3 alarm screens.
- c. 6.3.1 Scenario 3 with faults. Figure 17 should be before any faults are inserted. It shows 6 alarms in bright yellow that are normal for the plant conditions which are shutdown and cooled down. Figures 19.1 and 19.2, show the steam line break inside containment on loop B. There is still a large volume of alarms (89) to sort through which would not quickly point me to the cause of the abnormal plant condition. The following are examples of what would help. Steam generator B high-high level and the reason, the lowering pressure in the steam generator causes swell in the steam generator as it rapidly boils due to the reduced pressure. Loop B AFW line isolation because it automatically isolated the B steam generator from the other steam generators. Containment High 1(2) pressure alert. High temperatures in Containment. The ML has to distinguish important abnormal alarms from unimportant abnormal alarms to be useful in guickly identifying a cause. For example, the main steam isolation valves going closed is abnormal but is a result of high containment pressure due to the steam break. Checking the main steam isolation valves went shut would be a follow-up action for me to verify but doesn't help me identify the cause of the event.
- d. **6.3.2 Scenario 4.** The ramp time for the LOCA would cause a few initial alarms as shown in Figure 20.1 and would direct my attention to the whole plant response as the failure ramps in and I would take action. Since the fault is ramped in, I would have time to respond to the plant. I would see pressurizer level lowering, pressure lowering, and I would take manual action to trip the Reactor prior to an automatic action. I would then enter the emergency procedures. In this scenario ML would not help me a lot because it doesn't pinpoint anything specific to me. That is

because after the first alarms of lowering pressure and level deviations my attention would be focused on the plant and not so much on alarm screens. The plant is showing me where its headed. Useful alarms in this case are pressurizer level, pressure and containment pressure. All of those point to a break inside containment. In this scenario ML wouldn't be that useful but if the scenario were a power operated relief valve opening the abnormal condition immediately showing up on the screen would tell me to direct the operator to close the isolation valve for that PORV. If ML were implemented and the Operator immediately looked to the screen for something to pop up from ML it could be useful to them.

- e. Final comments.
  - i. When the Reactor trips the crew goes into emergency procedures. The ML alarm screen would have to be pretty specific with its alarms to be useful at this point. I wonder if ML might be most useful during scenarios that do not put the plant into a Reactor trip.
  - ii. How would you train ML? Use the plant specific simulator?
  - iii. Assuming a plant specific Simulator would be the input, Garbage in = garbage out. The alarm screen would need to be clear of useless or nuisance alarms in order to properly train ML.
  - iv. If all of this is worked out and tested by Operators to show it works and is useful, I think the Regulator and Operators will trust it.
  - v. There are some things to consider when implementing ML. I suggest you take the data stream from the field and separate it into two paths, one for the normal display and the other to the ML computer and a separate display. There would be a separate monitor that displays only the data from the ML computer and not the other data. Leave the normal display screen data alone and let it display all the data as it normally would. The Advantages:
    - All the ML important data would fit on fewer screens and not be mixed in with other data. This would be a reference screen for the Operators to look at to get a better understanding of what is going on which meets the objective. It also leaves the normal display of information alone.
    - 2. It allows for isolation from the normal data the Operators receive. On the outside chance the field data is considered safety related (I doubt it though) the isolator to the ML computer can allow it to be isolated and non-safety related.
    - The regulator may view this as additional information available to the Operators that doesn't interfere in the approved design and data flow path of information. My gut feeling from the little I've learned about ML is it is a great technology and would be accepted if properly developed and implemented.

Overall, while the primary goal of the SME's review was to determine whether Halden's approach was viable, the comments from the SMEs indicate that there is not enough

information in the report to draw a definitive conclusion, and that there were a few issues with the work performed thus far that Halden can hopefully address moving forward. The explicit suggestions offered by the SMEs on how this research could be improved reinforces these first 2 themes.

Future research in this area will need to further validate the ML approach by comparing the state-based alarm solution to a state-based alarm system developed by human subject matter experts. This comparison would be a straightforward approach to performing the necessary step of further validating the effectiveness of using machine learning to develop a state-based alarm system. Differences in performance should be identified and provided as feedback to the developers of the ML approach to modify and improve the effectiveness of this technique.