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SEVERE ACCIDENT MANAGEMENT SYSTEM ON-LINE NETWORK SAMSON

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SAMSON is a computational tool used by accident managers in the Technical Support Centers (TSC) and Emergency Operations Facilities (EOF) in the event of a nuclear power plant accident. SAMSON examines over 150 status points monitored by nuclear power plant process computers during a severe accident and makes predictions about when core damage, support plate failure, and reactor vessel failure will occur. These predictions are based on the current state of the plant assuming that all safety equipment not already operating will fail. SAMSON uses expert systems, as well as neural networks trained with the back propagation learning algorithms to make predictions. Training on data from an accident analysis code (MAAP - Modular Accident Analysis Program) allows SAMSON to associate different states in the plant with different times to critical failures. The accidents currently recognized by SAMSON include steam generator tube ruptures (SGTRs), with breaks ranging from one tube to eight tubes, and loss of coolant accidents (LOCAs), with breaks ranging from 0.0014 square feet (1.30 cm^2) in size to breaks 3.0 square feet in size (2800 cm^2).

1.0 NORMAL OPERATION OF SAMSON

SAMSON operates on a Sun Micro Systems 40 MHz SPARCstation 2GX UNIX machine running Sun Operating System 4.1.2 (Solaris 1.0.1). SAMSON was developed in the Motif™ window environment with MITs X11R5. A 19 inch, 256 color monitor is required to display SAMSON's windows.

1.1 Pre-Accident Operation

Data are collected via a client-server from the plant process computer via a modem and ethernet connection. In the 'normal' mode, SAMSON operates in the background, collecting data, searching the data for an initiation signal, and archiving the data. In addition, SAMSON displays five hours of data in scrollable sensor graphs to allow a user to examine data during normal operation.

When an initiation signal is received, SAMSON automatically switches to 'accident' mode, activating the five default windows and begins making predictions. The initiation signals recognized by SAMSON include a closure of a main steam isolation valve, a feedwater pump trip, a turbine trip, a safety injection actuation signal, or a reactor trip.

1.2 Accident Classification

Once an initiation signal is received, the accident must be classified into an accident type recognized by SAMSON before failure predictions can be made. A rule-based expert system classifies accidents using data collected during the first four minutes of an accident. SAMSON currently recognizes LOCAs and SGTRs. Work continues on expanding the accident types recognized. Since LOCAs and SGTRs are the most likely accidents to lead to core damage and support plate failure based on the Zion IPE, emphasis was placed on recognizing these two accident types. Once the accident is classified, the appropriate neural networks are called to begin making predictions about the failure times.

1.3 Failure Predictions

As data are received, SAMSON processes the data through the appropriate neural networks to make failure predictions. Although data is received only once per minute from Zion's PRIME computer, SAMSON processes all data in under one second, freeing the computer for other calculations as required by plant engineers. Failure predictions are displayed in the 'System Status' window (Figure 1). Three predictions are shown in both an analog and digital form; the time until the onset of core damage (CD), the time until support plate failure (SPF), and the time until reactor vessel failure. Neural networks predict the time until CD and SPF. The time until reactor vessel failure is fixed at one minute after SPF since the accident analysis code used to train the neural networks could not model reactor vessel failure. The pointer on the bar graphs moves up and down as predicted failure times change. The bar graph automatically scales if predicted failure times go off-scale or the selected scale is too large for the current predictions. Once a failure has been predicted, the portion of the window dedicated to that prediction grays, displaying instead that failure has occurred and the time the failure occurred.

Also shown in this window is the time since the start of the accident, the accident classification, and a rate meter. In Figure 1, the accident has been classified as a 0.5 square feet break LOCA. This does not mean that the break is exactly 0.5 square feet in size, but rather that it is from 0.1 square feet in size to 1 square foot in size. The networks that make the predictions were trained on a range of accident sizes, centered around the listed break size, to ensure that predictions would be accurate when the exact break size is unknown.

The rate meter, located to the right of the analog failure meter, displays the instantaneous rate of change in time until the predicted failure, indicating whether the plant is improving or degrading according to the neural networks. Negative rates, shown in red, correspond to a degrading plant state while positive rates, shown in green, indicate that the plant state is improving. The size of the bar indicates the magnitude of change.

1.4 Displays

When SAMSON activates due to an initiation signal, five windows are opened or activated; 'Zion System Status,' 'Predicted TTF History Graphs' (TTF stands for 'Time To Failure'), 'Events Log,' 'Sensor History Graphs,' and 'Sensor Summaries.' The user can reconfigure SAMSON, specifying which windows will open when SAMSON is launched. The 'Zion System Status' window must always be displayed since closing this window stops SAMSON. If SAMSON is used to display data during normal operations, this window is greyed out since the predictions from the neural networks, trained to recognize accident conditions, would be meaningless.

The 'Predicted TTF History Graphs' is a scrollable window showing the history of network predictions for each failure type. The graphs show the predicted time to failure on the vertical axis and the time into the accident on the horizontal axis. Once failure occurs, a message stating that failure has occurred is displayed on the graph.

The 'Events Log' records when key events occur during an accident. Initiation signals are first recorded and displayed, followed by accident classification information. Other information displayed includes:

- When failures occurred
- User actions to override decisions made by SAMSON
- When the break location was determined by SAMSON
- When recirculation of cooling water has been established
- Which sensors have failed based on SAMSON's redundancy checking
- When the network predictions were inaccurate (SPF time to failure (TTF) less than CD TTF. This could occur if bad data is received).

A 'Sensor History' window displays the historical values for any parameter monitored by the plant's process computer. The order of the graphs is user configurable since only three graphs are visible in the scrollable window at one time. If the user wants to view pressurizer pressure, cooling water flow into the reactor and containment pressure simultaneously, the user can order the graphs so those three are grouped together. As the accident progresses or as the displayed values go off-scale, the graphs will automatically adjust scales to accommodate the data.

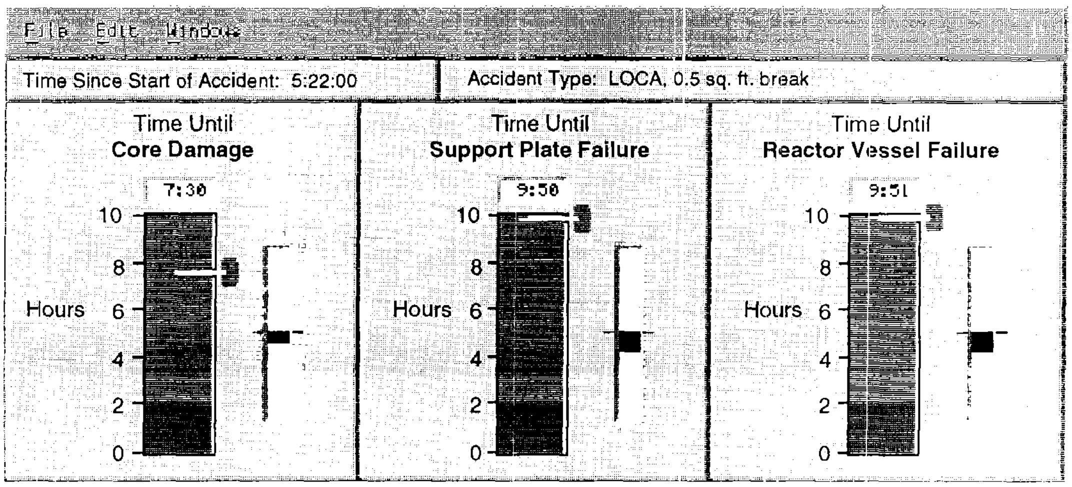

Figure 1: Zion System Status Window

The 'Sensor History' window can display up to five hours of data during normal operations to allow the user to perform trend analysis. SAMSON can monitor and display data for over 1000 different parameters. For accident conditions, only 27 parameters are monitored and displayed. Once an initiation signal is received, the window 'resets,' displaying data since the initiation signal was received.

The 'Sensor Summaries' window displays information about the same parameters displayed on a 'Sensor History' window. In addition to the current sensor value, the 'Sensor Summaries' also displays which sensors have failed. SAMSON uses information from the plant process computer in addition to redundancy checking to determine if a sensor has failed. If the sensor has failed, the value will not be used in the neural networks to make prediction. If no sensors are considered accurate, the neural networks will use a default value. Since this default value may not be close to the real value, the network predictions will have some additional error. However, the default values were determined so the smallest error results (not sending a value when required will cause the network to fail). Each circle next to a sensor name corresponds to an individual sensor.

2.0 Special Operation Of SAMSON

There are several other windows that perform specialized functions. Since these functions are not normally used, the windows are generally closed, but can be called when desired. Certain events can force the user or SAMSON to open these windows.

2.1 Manual Start

SAMSON continually receives data from the plant's process computers, but it is possible that the initiation signal will not be received. If this occurs, the user can manually start SAMSON. During a manual start, the 'Manual Start' window opens prior to the default windows opening. Using this window, the user has two options; to direct SAMSON to reexamine archived data over a specified time for an initiation signal or to start SAMSON assuming an initiation signal was received at a specified time. If the user directs SAMSON to reexamine archived data and an initiation signal is found, SAMSON will process all archived data since the initiation signal and then process new data as it is received. If SAMSON can not find an initiation signal within the specified time, the user is forced to specify a start time for the accident and also classify the accident.

2.2 Accident Classification Override

Since the precise starting time of the accident may not be known if the initiation signal is missed, the accident classification could be wrong. The rule based system used by SAMSON to classify accidents can also fail if data is not received during the first few minutes of the accident or if the first few minutes of data fluctuates too wildly to allow for proper classification. An 'Accident Override' window allows the user to change the accident classification at any time during the accident. Under the 'edit' menu in the 'System Status' window the user can open the accident override window. This window displays the accident type as classified by SAMSON, as well as the other accidents recognized by SAMSON. If the user selects a different accident type, SAMSON is forced to use neural networks for that accident to make failure predictions. The predictions in the 'System Status' window will be the predictions using networks designed for the user-chosen accident. For each graph in the 'Predicted TTF History Graph' window, two lines will be shown; one for the user specified accident type and one for the SAMSON classified accident type. This allows the user to compare network behavior between two accident types. The failure predictions for both accidents will continually be displayed in the history graphs, even though the 'System Status' window displays the current prediction for only the user-chosen accident type. If the user wishes to chose another accident type via the 'Accident Override' window, SAMSON will update both the 'System Status' and 'Predicted TTF History Graphs' windows with the most recent user-chosen accident type. SAMSON will also display the history predictions based on the original classification.

If SAMSON does not recognize the accident type during the first four minutes of an accident, the 'Accident Override' window is automatically opened to force the user to manually classify the accident so SAMSON can begin making predictions. The user can change the classification later in the accident as described above.

2.3 Core Thermocouple Map

A 'Core Exit Thermocouple Map' displays the temperature of the 65 core exit thermocouples. The map is color coded according to the temperature received. If a thermocouple is sending bad data, the sensor will be displayed in black. This map will give the user some indication of flow exiting the core during an accident and help to identify 'hot spots' in the core.

2.4 Recirculation Detection

A recirculation detection module was incorporated specifically for Zion Nuclear Generating Station. The Zion IPE determined that once recirculation of cooling water was established, no additional failures would occur. Once a ruled based system determined that one train of recirculation is established, network predictions are no longer necessary and are terminated. No provision is made if recirculation of cooling water is later terminated since the neural networks have not been trained on data where recirculation fails after it has been established.

2.5 Recovery Strategies

A list of recovery strategies was developed to respond to various accident conditions. The user can open the 'Recovery Strategy' window and query a database for possible recovery actions to prevent further damage from occurring. When strategies are requested, SAMSON sends the current predicted failure time along with several plant parameter values to the database, informing the database of the plant state. If matching strategies are found, SAMSON will display what equipment must be operational or what actions must be taken along with the approximate time to complete the action.

3.0 FUTURE DEVELOPMENTS

Work continues on SAMSON to make it even more capable. Future changes include:

- Creating analysis tools to explain network prediction changes
- Training new neural networks for failure detection
- Forcing SAMSON to continue predictions after predicted failure has occurred
- Training neural networks for sensor validation
- Sensor Validation override
- Integrating normal operation monitoring with accident management operation
- Comparing MAAP runs with the current accident for validation during an accident
- Using additional accident analysis codes for training the neural networks

Session 27
Severe Accident Management-IV