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THE GRAPHICS-BASED HUMAN INTERFACE TO THE DISYS DIAGNOSTIC/CONTROL GUIDANCE SYSTEM AT EBR-II

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ABSTRACT

An initial graphics based interface to the real-time DISYS diagnostic system has been developed using the multi-tasking capabilities of the UNIX operating system and X-Windows 11 Xlib graphics library. This system is interfaced to live plant data at the Experimental Breeder Reactor (EBR-II) for the Argon Cooling System of fuel handling operations and the steam plant. The interface includes an intelligent process schematic which highlights problematic components and sensors based on the results of the diagnostic computations. If further explanation of a faulted component is required, the user can call up a display of the diagnostic computations presented in a tree-like diagram. Numerical data on the process schematic and optional diagnostic tree are updated as new real-time data becomes available. The initial X-Windows 11 based interface will be further enhanced using VI Corporation DATAVIEWS graphical data base software.

INTRODUCTION

The initial development of the DISYS diagnostic and control guidance expert system was conducted by Westinghouse for the U.S. Department of Energy (DOE) during the period of 1982 to 1986[1]. Although perceived as an approach to meeting real-time power plant diagnostic requirements in general, application of DISYS has focused on liquid metal reactor systems because of its origin in the DOE Breeder Reactor Technology program. The DISYS system uses a nodal network knowledge representation scheme arranged in a hierarchical manner to match an operator's mental model of the plant and diagnostic procedures. Sensor measurements, at the bottom of the hierarchy, connect to validation calculations which in turn are mapped to a measure-of-presence of a fault symptom. The measures of fault symptom presence are processed, based on Baye's rule of conditional probability, to determine the degree to which a faulted component or system exists. The diagnostic system also utilizes Fuzzy Logic in determining subsystem and overall system operational status.

In 1988, the DOE University Liquid metal program funded a Penn State project to convert the DISYS system from Pascal to C language operation in SUN workstations[2]. The project included simulation testing of a diagnostic data base for the EBR-II Argon Cooling System (ACS) for fuel handling operations using the B&W Modular Modeling System and IBM Advanced Control System at Penn State. Modularization of the UNIX C version of DISYS was also initiated by externalizing access to plant data using the UNIX shared memory feature and multitasking capabilities. On a UNIX based workstation, plant data is maintained in a shared memory segment updated with real-time plant data or recorded data from disk files during simulation testing. At the end of the C language conversion project the human interface to the

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diagnostic calculations remained in the form of a conventional computer printout presented on the computer console.

MODULARIZATION FOR THE HUMAN INTERFACE

The initial graphics interface under X-Windows was created during the last half of 1989 in a project funded directly by the EBR-II division of ANL. The system was further modularized by also externalizing the large diagnostic data base into a large shared memory segment as represented in Figure 1. The shared memory segment size required for the Argon Cooling System diagnostic data is almost 100 Kbytes which compares to a 4 Kbyte shared memory for plant data from the EBR-II Data Acquisition System (DAS). The single DISYS program of the prior development was also divided into multiple processes on a functional basis also as shown in Figure 1: disys, nni, ui, dicon, asciin, and fillmem. The small disys program is an "application manager" which starts and coordinates the other programs. First, disys starts a process called asciin (ascii input). The asciin process reads the diagnostic data base from a disk file and initializes it in the large shared memory segment. After the nodal network is established, the asciin process is no longer needed. The computer memory required to

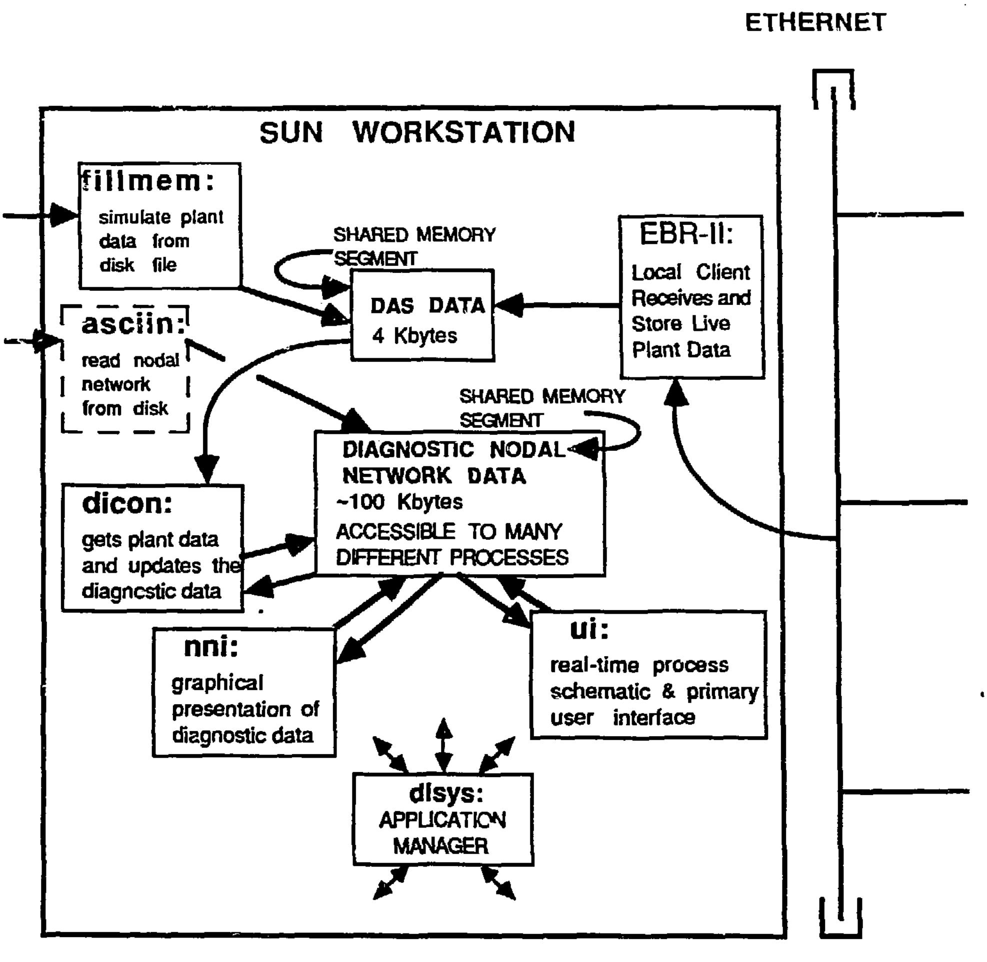

Figure 1: Multiple Program DISYS Diagnostic System in a UNIX Computer.

execute ascii is released for use by other processes to be started next. If simulated plant data from a disk file is to be used instead of live plant data, the fillmem program is initiated and reads a DAS data set into the small DAS shared memory segment every 5 seconds. Otherwise live plant data is obtained from data broadcast on the EBR-II ETHERNET. The remaining processes (dicon, nni, and ui) are next started and coordinated by the disys application manager. The user interface program, ui, presents a process schematic and permits the user to interrogate the system using the computer mouse. The nodal network interface program, nni, is a sleeping giant which is always memory resident once initiated but only overlays it's graphics presentation of a diagnostic calculational tree in response to a specific user request through the user interface program. The dicon process, stripped of all its conventional printouts of diagnostic data and user dialogue, performs the diagnostic computations and leaves the results in the large shared memory segment.

The modularization of DISYS is perceived as a key element in the development of the graphical interface and other diagnostic and control guidance functions in a systematic and flexible manner. New modules, such as the graphics interface, are developed in more manageable sized programs and tested independently of established modules.

THE INTELLIGENT PROCESS SCHEMATIC

A color-coded process schematic of the system being diagnosed is the primary user interface and a black and white rendition of the initial display for the EBR-II Argon Cooling System (ACS) for fuel handling operations is shown in Figure 2. Fuel handling operations and the associated Argon Cooling system are explained in more detail in reference 1. Argon gas is circulated through the fuel unloading machine (FUM) or other flow paths in order to preheat fuel for insertion into the reactor or to cool spent fuel. Sensor locations are indicated with the circular icons attached to the process outline through a short line segment (Figure 3a). The user can open a display of an individual sensor's reading by clicking the computer mouse on the sensor icon. Provisions for opening and closing all sensor displays and all sensor displays of a certain type (temperature, pressure, etc) is provided.

All the valves of the ACS are operated on a fully open or fully closed basis and have a diagnostic calculation performed to determine if they are in the proper alignment for the current mode of operation. A misalignment is indicated by color coding of the valve icon with a red background and setting the associated component status to 0 indicating fully faulted. The diagnostic status of non-valve components which have a status that varies continuously from 0 (fully faulted) to 1.00 (fully unfaulted) are displayed on the process schematic in small rectangles (Figure 3b).

As long as the overall system status displayed at the top of the screen is greater than a threshold value (normally 0.50), the status of the limiting component is displayed with a pink background. The sensor readings responsible for the limiting component status are also automatically opened for display with a pink background. If the system status falls below the threshold, the component with the worst status and the associated sensors are displayed with a red background. Other components with status below the threshold but not equal to the worst component are displayed with a pink background. Pink is used as a warning color and red is used as alarm color. An example of the sensors opened for display and component status during a faulted condition is shown in the black and white rendition of Figure 4. The problem with the system in Figure 4 is that the Argon flow rate (in cubic feet per minute) is too low and the pressure drop across the Fuel Unloading Machine is too high. (The sensors for inlet and outlet pressures, in psig, used in the pressure drop calculation are opened for display in

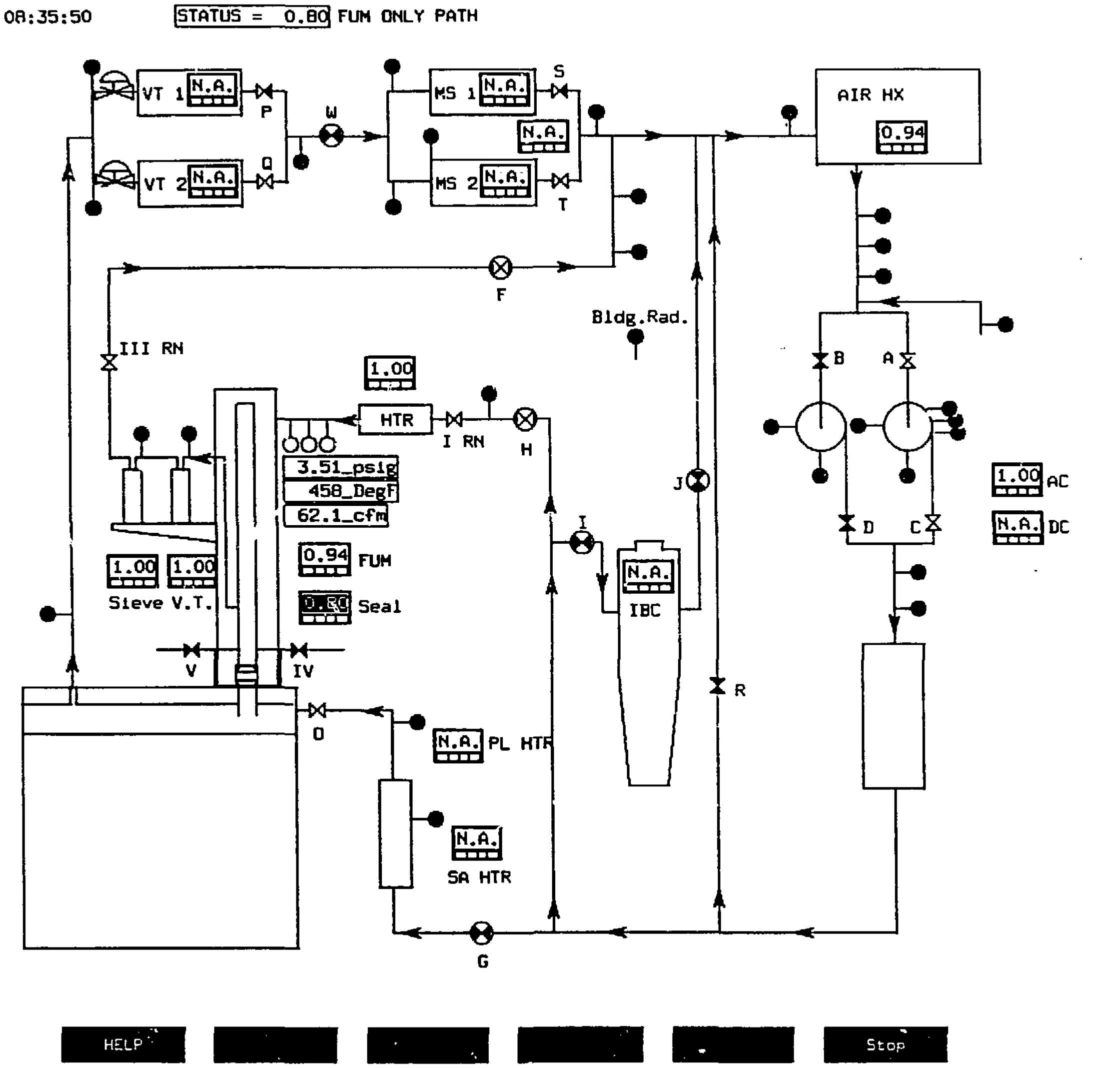

Figure 2: Intelligent Process Schematic for Display of the EBR-II Argon Cooling System (ACS) for Fuel Handling Operations.

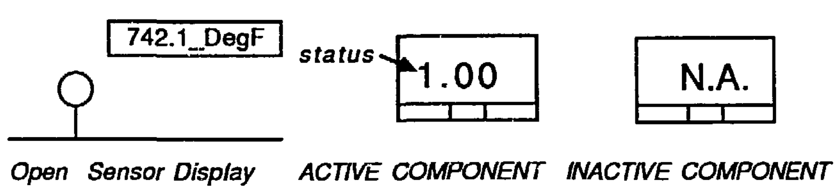

FIG 3A. FIG 3B

Figure 3: Sensor and Component Icons on the Process Schematic Display.

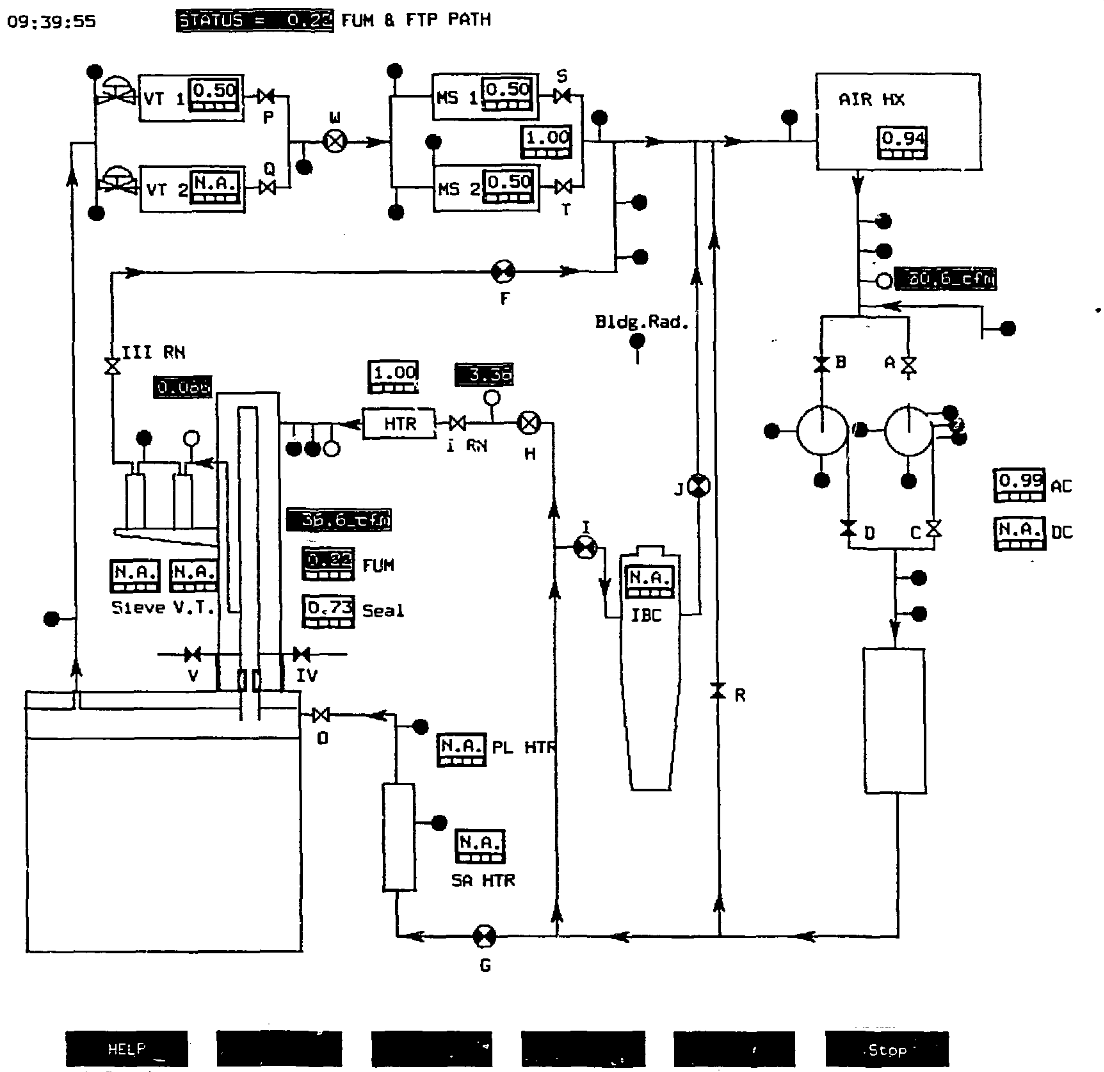

Figure 4: Process Schematic Display when Plugging of the Fuel Unloading Machine (FUM) has been diagnosed.

Figure 4). Under simple faulted conditions, the simple color coding and automatic opening of the problematic sensor readings for display coupled with some familiarity of the user with the system can be sufficient to identify the problem to the user.

THE INTERFACE TO THE DIAGNOSTIC REASONING

For a novice user unfamiliar with the diagnostic calculations and associated rules or when more complicated faulted conditions occur, a display of the diagnostic tree is obtained by clicking the mouse pointer on the display of the problematic component on the process schematic. The result of clicking the mouse on the FUM component icon of Figure 4 is shown in Figure 5. The diagnostic tree overlays the process schematic and presents the numerical results of the intermediate calculational steps. At the bottom of the tree, the circular nodes represent sensors. The sensors

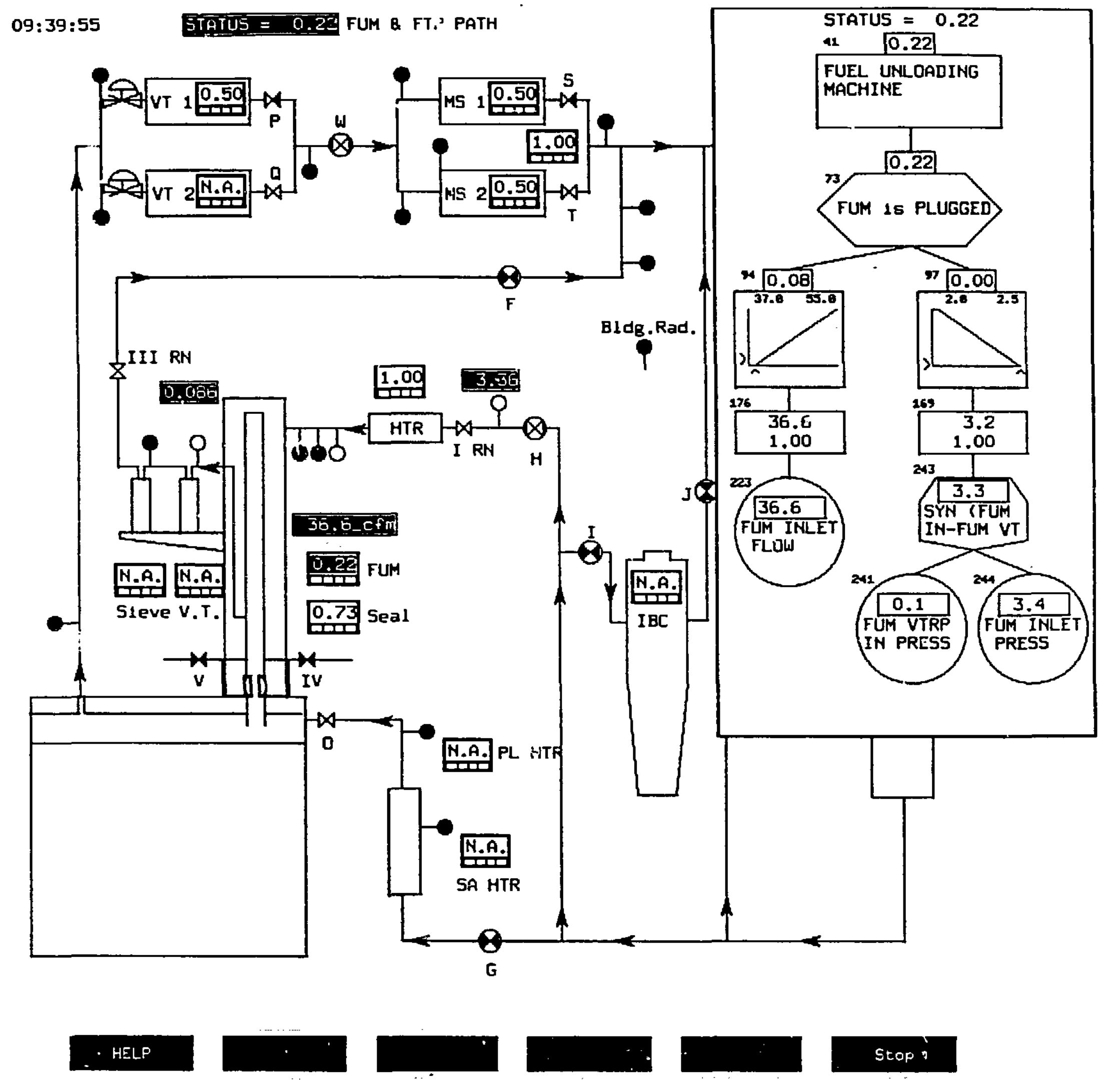

Figure 5: Detailed Diagnostic Explanation of the Calculations behind the FUM PLUGGED Diagnosis of Figure 4 in a tree structured diagram. Overlayed on the schematic only when requested.

connect upward to validation nodes represented by the small rectangle. Synthetic sensors, such as the pressure drop calculation, are represented with a 7 sided polygon. Validated sensor data is input to a MAP node which maps the sensor reading to a measure-of-presence (status) of a particular symptom, 1.0 means the symptom is not present (good status) and 0.0 means the symptom is present (poor status). The square shaped MAP node contains a scale drawing of the piecewise linear function that maps sensor reading represented by the x-axis to symptom status represented by the y-axis. As new real-time data is processed through the diagnostic procedures, the sensor reading and symptom status relative to the map function are graphically indicated on the axes with the ^ and > symbols along the x and y axes respectively. The symptom set for a particular fault is processed in the diagnostic nodes (hexagon shape) based on a modified Baye's rule of conditional probability which takes into account the consistency of a symptom set. The diagnostic calculations link upwards to the component node represented by the large rectangle at the top of the component diagnostic tree.

DISYS AUTOMATIC LEARN MODE

The development of the diagnostic rule base for the Argon Cooling System was initiated during the Westinghouse development and included several iterations with operator input using the DELPHI[3] technique. With the subsequent refinement to the rule base conducted when the interface to on-line data was accomplished, the ACS diagnostic rule base has become reasonably mature. The lengthy development of the rule base for the ACS motivated consideration of an alternate approach to creation of DISYS applications for additional systems at EBR-II. In the ACS rule base development, the rules were created in advance in consultation with plant experts and then adjusted based on actual observed on-line performance of the diagnostic system. The alternate approach first monitors normal system performance, performs a simple statistical analysis and then proposes rules for the user to consider and modify. To initialize the automatic learn mode a skeletal diagnostic data base is required which simply identifies obvious component and system alignments for various modes of operation. For each component the sensors involved in diagnosing the status of the component must also be identified but the rules which map sensor readings to measure-of-presence of a fault are left undefined (no symptoms presence). The true efficacy of the modularized DISYS system of Figure 1 is demonstrated in the automatic learn mode because the learn mode is programmed, started and executed independently of the core diagnostic (dicon) and graphics interface (nni and ui) processes. When the learn process is initiated, it attaches to the nodal network shared memory segment unbeknownst to disys, dicon, ui, and nni. When a MAP node calculation is observed to execute, the learn program accumulates the validated sensor reading used as input to the MAP node in order to later calculate the average and standard deviation (σ) of each input to the MAP node functions. At the end of a training session proposed mappings of validated sensor inputs to measure-of-presence of fault symptoms is proposed for each map node as shown in Figure 6. A plateau of good status indication equal to 1.0 (symptom not present) is centered on the average measurement with a lower limit of the plateau equal to the average value minus a user specified multiple (m) of the standard deviation ($m\sigma$) and an upper limit of the plateau equal to the average value plus $m\sigma$. At each end of the good status plateau, status is linearly reduced to 0 at the minimum observed sensor reading minus $m\sigma$ and at the maximum observed sensor reading plus $m\sigma$. The automatic learn mode was benchmarked against the mature ACS diagnostic rule base with excellent results. The learned mode proposed mappings tend to be much more restrictive because a training period is not likely to contain all extremes in acceptable system operation. The user may of course alter or reject all learn mode proposed mappings based on his expert knowledge about the acceptable extremes in system operation. The utility of the automatic learn mode is being further explored in the creation of a diagnostic rule base for the EBR-II Steam Plant[4].

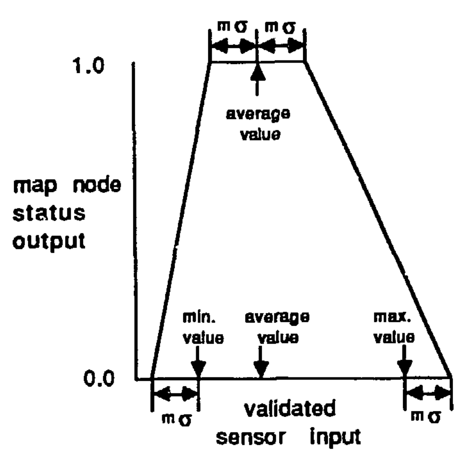

Figure 6: Diagnostic Learn Mode Proposed Map Node Functions.

FUTURE WORK

Current activity with the diagnostic graphics interface is to migrate the system to the VI DATAVIEWS graphics data base package. DATAVIEWS is the preferred tool for building graphics operator interfaces at EBR-II[5] and was not available at Penn State during the initial development of the DISYS graphics interface. At the present time the graphics based DISYS diagnostic system is just maturing to the point that serious consideration can be given to making the system available to plant operators. Enhancements needed to make the system available to plant operators will be identified in close cooperation with the engineering staff of EBR-II and will include a closer look at power plant operator's human factors considerations and verification and validation.

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