CONF-890555--18

CONF-890555--18

DE89 015693

EXPERIENCE WITH MODEL BASED DISPLAY

FOR

ADVANCED DIAGNOSTICS AND CONTROL

by

Jeffery D. Staffon
and
Richard W. Lindsay

EBR-II Division
Argonne National Laboratory
P. O. Box 2528
Idaho Falls, Idaho
83403-2528

Submitted for Presentation
at the
Seventh Power Plant Dynamics, Control
and Testing Symposium

May 15-17, 1989
Knoxville, Tennessee

* Work supported by the U.S. Department of Energy, Reactor Research Technology under Contract No. W-31-109-ENG-38.

EXPERIENCE WITH MODEL BASED DISPLAY
FOR
ADVANCED DIAGNOSTICS AND CONTROL

by

Jeffery D. Staffon
Richard W. Lindsay

INTRODUCTION

A full color, model based display system based on the Rankine thermodynamic cycle has been developed for use at the Experimental Breeder Reactor II by plant operators, engineers, and experimenters. The displays generate a real time thermodynamic model of the plant processes on computer screens to provide a direct indication of the plant performance. Operators and others who view the displays are no longer required to mentally "construct" a model of the process before acting. The model based display accurately depicts the plant states. It appears to effectively reduce the gulf of evaluation, which should result in a significant reduction in human operator errors if this plant display approach is adopted by the nuclear industry. Preliminary comments from users, including operators, indicate an overwhelming acceptance of the display approach. The displays incorporate alarm functions as well as levels of detail "paging" capability. The system is developed on a computer network which allows the easy addition of displays as well as extra computers. Constructing a complete console can be rapid and inexpensive.

DISCUSSION

A reduction in the time and effort required by nuclear plant operators to accurately determine the condition of the plant, especially in off-normal events, is a must. At the Experimental Breeder Reactor II (EBR-II), a display system was devised, based on the early work of Beltracchi (1), which provides a thermodynamic model-based, real-time display of the plant processes. This display provides the operator with the information needed to make rapid, correct decisions. The main display (Figure 1) is based on the Rankine thermodynamic cycle. The display system includes other, lower-level displays which are directly related to the main display.

The display approach was devised in an effort to provide for a much better presentation of plant information to the operators. Several considerations and assumptions were made to assist in the

*
Work supported by the U.S. Department of Energy, Reactor Research Technology under Contract No. W-31-109-ENG-38.

formulation of the display approach. For example, it is assumed that a "typical" operator, no matter how much formal education he or she has, cannot integrate hundreds of individual pieces of information and synthesize a correct mental model of the plant state except when the plant is stable. It is when the plant is not stable that it is desirable for the operator to know exactly what is going on and what effect any control action initiated by the operator may have on the plant.

There is some question whether it is humanly possible for an operator to have a correct mental model of a plant when the plant is in a transient condition. It has been observed that most people have difficulty remembering a seven digit telephone numbers long enough to dial (without rechecking the number once or twice). Remembering 30 to 100 pieces of data and determining a "model" from the information is probably impossible. An additional concern is that it is nearly impossible that any normal human would have the steam tables (or curves) committed to memory such that determination could be made of a plant state whenever the plant was out of the known realm of memorized operational information (as in the TMI accident for example).

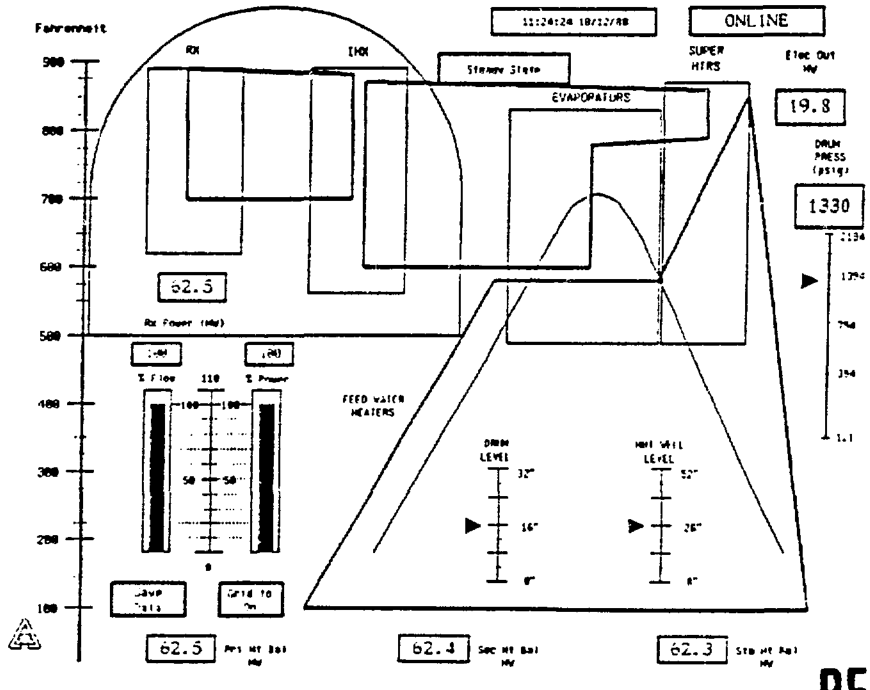

Figure 1
Main Iconic View of EBR-II

The receipt of plant data by an operator and making logical connections that result in formation of a mental concept of plant state may be referred to as "preprocessing". Preprocessing of data has as its objective the mapping of separate data into coherent relationships that can then be examined, and, if necessary, acted upon. Preprocessing of data need not be (and we believe should not be) done by the human now that sufficient computer power is available. The preprocessing of data by the computer may be done in several ways. One way is to process plant data, using a computer, into a display that will represent plant state to the operator. The shortcoming of methods that have been investigated may be illustrated by the following. If the plant signals are mapped into a computer generated display such that some arbitrary geometric figure represents plant state, by pattern recognition, the operator can readily determine when the plant is not in the desired state. A problem with this approach is that the operator must determine the cause of the distortion of the geometric figure, determine what the plant state really is, and then determine the appropriate action to be taken. In addition, there is a potential for multiple simultaneous plant problems, which distort the geometric figure, such that the operator cannot readily determine the source of the problem. Thus valuable time may be wasted while searching for the wrong information.

Processing plant data (the "preprocessing" step) into a graphic figure that represents an accepted model of the plant state can obviate the need for mental preprocessing. The term "accepted", when referring to the plant model, means a model that is universally accepted and which conveys more total information that the sum of the incoming plant signals used to generate the model.

An example of such a model is the Rankine Cycle using a temperature-entropy curve represent the steam-system at EBR-II. A temperature-entropy curve not only provides temperature information to the operator, but information as to subcooling, saturation, and superheat status. Such information is not available from any plant input parameter directly. It is the kind of information needed whenever there is an off-normal condition that results in a pressure-temperature relationship that is not well known by the operator.

The model-based display as used at EBR-II also provides the capability to determine instrument failure by inspection. For example, one of the thermocouples failed that is used in providing an averaged temperature for the secondary sodium entering the superheaters. The failure resulted in a low reading on the display of that averaged value, and simply by noting that the sodium inlet to the superheaters was cooler than the superheated steam out of the superheaters, the correct and obvious conclusion was made that an instrument had failed.

As the model-based display has been developed, there are a number of other important benefits that have become evident. During plant transients, the relationships of all systems in a thermodynamic sense are readily apparent. The display clearly shows the thermal inertia inherent in the system during a plant scram or other rapid transient. This provides a better understanding and feel for the dynamics of the system than previously available. As the operator views the display, operating in real-time, he or she is constantly aware and reminded of system thermodynamics relationships.

Viewing the actual thermodynamic performance of the nuclear plant during operation is of special benefit to the operator from a training perspective. In today's systems, the operator reviews thermodynamics as a basis for requalification exams. The use of model-based displays for plant control then invites the use of the same displays in plant simulators for training.

The rationale in providing the thermodynamic model is that the operator in a conventional control room has little hope of integrating enough information mentally in a real-time situation to make correct decisions and act accordingly if the decision requires the synthesis of a high-level "model" of the actual plant conditions.

DESCRIPTION

The displays used are updated once a second with new data from the EBR-II Data Acquisition System (DAS) via Ethernet. The network is currently comprised of four (4) SUN-3 Series color workstations, a VAX 11/750 and a Concurrent (Perkin/Elmer) 3210. The SUN computers consist of a File Server and (3) "diskless" clients, all of which run SUN/OS, a version of UNIX. The data communication software on the SUNs and VAX utilize standard UNIX internet sockets with both TCP/IP and UDP/IP protocols. The Concurrent 3210 uses third party software to provide the user to network link.

The Concurrent computer (DAS) sends approximately 1000 signal values at one second intervals to the SUN File Server where they are converted and stored in Shared Memory. The File Server then sends a subset of this data to clients running graphics applications.

The graphics software used for the model-based displays is called DATAVIEWS and is marketed by V.I. Corporation. DATAVIEWS contains two packages, 1) DV-DRAW and 2) DV-TOOLS. DV-DRAW allows the designer to quickly create static views containing graphic objects and assigns dynamic and data thresholds for these objects. The subroutine library in DATAVIEWS (DV-TOOLS) allows the programmer to access the graphic objects and manipulate them using data from either a file, a process or a local program variable. The dynamics of the graphic objects are bound to memory addresses in the shared memory segment where the real-time data resides. The shared memory and graphic objects are then updated with new data.

A program developed at Argonne National Laboratory (ANL) called "Grafun", was designed to accommodate any view developed in DV-DRAW and be intelligent enough to interpret the dynamics of the graphic objects. Grafun was written in C and utilizes DV-TOOLS routines and UNIX system and networking routines. Color, object distortion, object dynamics and digital information are used to relay process status to the operator. For the most part color is used to show separation between components. However, color is also used to represent object status (ie. green = ok, yellow = warning, red = alarm). The most powerful dynamic aspect used is object distortion. A simple polygon, when implemented properly, can give the operator a complete picture of a system or process status. Each corner of the polygon is bound to a DAS signal value and is updated once a second. A sensitivity threshold is used to suppress unnecessary movement or redrawing on the screen when the change in new data doesn't warrant an update.

Figure 1 is a high level display that shows the entire process of EBR-II. This display represents three major systems. Figure 2 is a simplified version of Figure 1 and clearly shows the three main systems: 1) The primary sodium system, 2) the secondary sodium system and 3) the steam system. The primary system in figure 2 has 4 dynamic points that control the shape of the polygon representing this system. Point 1 is the sodium inlet temperature to the reactor core, point 2 is the sodium outlet temperature of the reactor core, point 3 is the sodium inlet temperature to the primary side of the Intermediate Heat Exchanger (IHX), and point 4 is the sodium outlet temperature of the primary side of the IHX. Each corner of the polygon is driven by the DAS channel value assigned to it and is plotted in accordance with the temperature scale to the left of the display. As the temperatures within the primary system change, the polygon changes shape appropriately. The secondary system follows the same scenario as the primary system except that it has 6 dynamic points controlling its shape.

Since the steam system represents more than one fluid phase, it is overlayed on top of a temperature entropy diagram. Point 5 represents the sub-cooled water from the feed water heaters entering the steam drum and evaporators. The path from point 5 to point 6 represents the change from subcooled feedwater to saturated steam accomplished by transferring energy from the secondary sodium system in the evaporators. Point 6 is where the saturated steam enters the superheaters and receives additional energy from the secondary system and becomes super heated steam. Between points 7 and 8 the energy is dissipated through the steam turbine-generator. The cycle continues, from the hot well, point 9, and up through the feed water heaters, point 10.

Since EBR-II is tightly coupled between the three major systems, minor changes in the plant cause significant changes in the overall patterns displayed on the screen. This gives the operator advanced warning of potential problems while displaying the overall process.

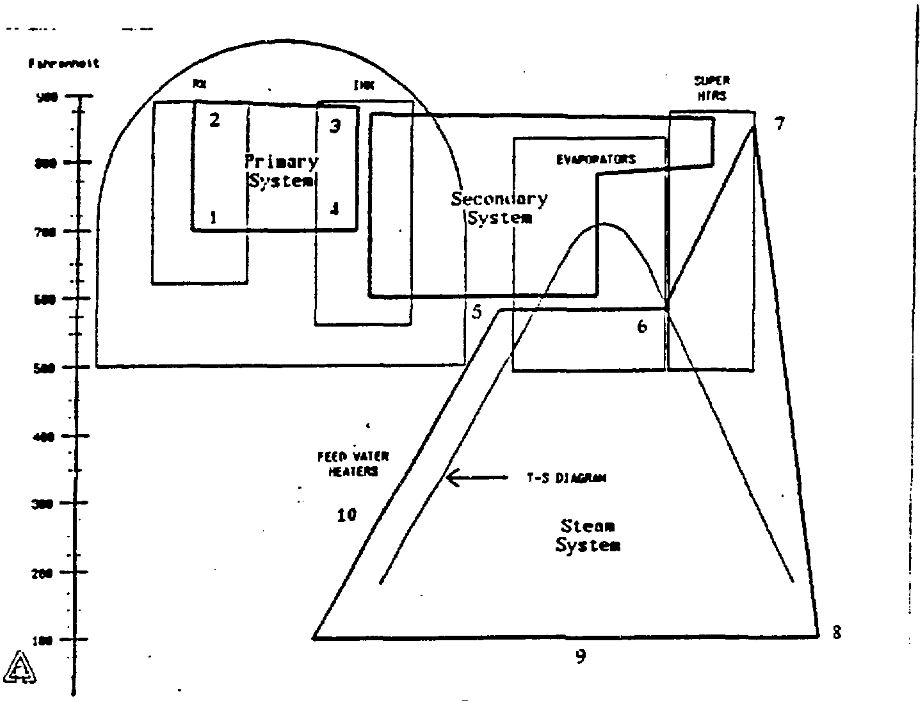

Figure 2
EBR-II Systems Description

CONCLUSION

Initial introduction of the displays to the plant operators has been met with enthusiasm and ready acceptance. The displays have been active in the control room since October of 1987 and were used extensively during the Inherent Safety and Operability Testing of EBR-II during November 1987 and through 1988. It is significant that the display readily shows thermal "decoupling" during plant transients, and it has also shown several instrument calibration drift errors or failures. During dynamic plant maneuvers such as startups, changing power, etc. it is simple to track the thermal wave from the reactor (heat source) through the power plant (heat sink).

If further use and testing support preliminary findings, the concept of model-based displays for monitoring and control of heat engines (power plants) will redefine the present thinking in control room panel display design. The implications are broad and include training advantages, a significant step in operator error reduction, and a much better base to build on for plant automation and the incorporation of computer-based expert operator aid systems.

REFERENCE

1. L. Beltracchi. "A Direct Manipulation Interface for Heat Engines Based Upon the Rankine Cycle. IEEE Transactions on Systems, Man, and Cybernetics, Vol. SMC-17, No. 3, May/June 1987, pp. 478-487