Unit Information System Operational Displays for VVER-1000 Reactors.

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Introduction

The main purpose of the High Level Operational Displays (HLOD) is to provide to an operator summary detail information concerning safety control of NPP, in other words, the displays might be used as a presentation tool of safety parameters and functions. These displays are intended to provide general type of information about the NPP's conditions to the Main Control Room (MCR) operators, Technical Support Center (TSC) personnel and to the NPP managers. The main principles of the HLOD design process were used for elaboration of the Temelin NPP operational displays, which are a part of the plant computerized operator support system (Unit Information System).

Information presented on the operational displays is used by the aforementioned NPP's staff for the following:

1. Provide the capability to the operator to monitor state of NPP, and detect abnormalities for which corrective actions might be taken to terminate the event prior to the initiation of automatic reactor trip and/or safeguard functions.

2. In the case of the events which the operator does not detect or cannot terminate, enable the operator to assess the safety state of the plant and verify proper safeguard function to mitigate the consequences of the event.

3. Provide the capability for an operator to select necessary system displays to get more detailed information about the plant and system state.

The design of the top level operational displays accommodate operational flexibility, i.e., the capability of these displays has to be incorporated into normal control room operator tasks according to the plant operational procedures.

In contradiction to the detail process displays, which have been using in VVER-1000 MCRs, the operational displays present complex functions of the measuring parameters. These functions define the summary of the plant state based on the such categories like mass and energy balances, and give to the MCR operator a concise presentation of the plant safety condition.

All functions described above practically coincide with those for Safety Parameter Display System (SPDS) stipulated in NUREG 0696. That is why, the HLODs might be considered, from one hand, as a supportive SPDS function and as a bridge between SPDS and the rest of the UIS displays.

In order to prepare the operational display architecture, one should define the assumptions based on which the design is to be done. In other words, the following basic parts of the design shall be stipulated:
- The objectives and scope of the operational displays;
- Requirements for the display architecture;
- The main principles of the operational display design that shall be derived from the main principles of the "good" man-machine interface design;
- The Main Control Room (MCR) operators task descriptions;
- The MCR operators response model.

This paper discusses the first three aspects of the operational displays design.

The Main Principles of the Operational Displays Design

Effective display design should conform to a set of higher-level principles /1/. Design principles at this level do not always provide specific design guidance but can serve two important purposes in the display design.

First, collectively they convey a philosophy of display design. When considered together, they summarize important qualities of the display design in the domain of process control.

Second, the following seven principles can be used as a criteria or a checklist to evaluate proposed designs.

The seven principles or the seven concerns about the operational displays design are the following /1/:
1. Efficient Extraction of Information

- data relationship must be the primary focus

- *the unprocessed data must be accessible*

2. Visibility

3. Effective Mapping

4. Reduce Potential for Errors

5. Common Measures of Reference

6. Cognitive Load

7. User's Level of Experience

Brief explanation of the aforementioned principles is provided hereafter.

1. Efficient Extraction of Information.

The most critical aspect of display design in process control environments is making the data accessible to operators. There are two sense of "making the data accessible" that are important to consider. The first sense of the phrase emphasizes enhancing the salience of the important data relationships. The second sense of the phrase emphasizes maintaining a link to the data that compose the display.

2. Visibility.

An effective display in a process control environment should communicate three things to operators:

- the current state of the process or system
- the process alternatives that are possible, and perhaps optimal
- the effect of previous actions (feedback)

Visibility refers to the display's success in communicating these things - in making them visible to operators. To ensure visibility means to ensure that this information is indicated on the display and, just as importantly, that this information is in a form readily understandable to operators.

3. Effective Mapping.

The first two principles focused on the types of information that should be available to operators in an effective display. It is also necessary to emphasize the importance of establishing a coding scheme that gives prominence to important data and moves into the foreground of a display. There is another component of making important system information readily accessible to operators: the mapping between the way the display represents the system and the way operators conceptualize the system.

4. Reducing Potential for Errors.

Reducing the potential for errors is addressed to a large extent by providing visibility. Making operators aware of the system state and allowable actions should do much to guide them to correct actions. One component of determining what actions are appropriate is the display mode. Multiple modes on a display system usually imply that the meaning of some actions changes when the mode changes. In these cases, it is critical that operators are aware of the mode before an action is taken. In general, modes are to be avoided, if possible, because they invite inappropriate actions.

5. Common Measures of Reference

Process control applications typically require that a large set of displays are created to work together. Multiple data sets and multiple views of data sets combined with multiple descriptions of system state are required to support monitoring and diagnosis for a complex system. As a result of this complexity, the design of single displays is no longer the only concern. An equally important concern becomes transition between displays. Single displays cannot simply be brought to the operator's CRT. There must be a more global plan for display design that provides a context - a common frame of reference for each display.

6. Cognitive Load.

Each display and the system of displays, to a large extent, define the information operators are given to perform a wide range of tasks. Display designers strongly influence the structuring of tasks and, therefore, task difficulty. This role should not be taken lightly; an important component of display design is to reduce the non-critical cognitive requirements operators. These unwarranted requirements take two forms. One form is the excessive demand on attention, perception, memory, and computational skills that are not essential to the job. The second form of unneeded cognitive requirements is the burden on the display system user to select the data that compose the current display.

7. User's Level of Experience

An effective set of displays should accommodate both the novice and the skilled performer. To do this, displays must explicitly represent sufficient information to guide novices. Displays, also, should allow skilled performer to adapt the display or display procedures to more efficient methods they have developed. Establishing this adaptiveness is not always easy and certainly not all levels of skill can be accommodated. It is most important to ensure first that novices can use the display well.

MCR Operators Task Description

The general operative management of the VVER-1000 NPPs is carried out by the plant Shift Supervisor. Direct control of the NPP operational process is conducted from MCR by the reactor, turbine operators and unit shift supervisor.

The basic duties of the MCR operative personnel in modes of normal operation are:

Reactor Operator carries out the direct control and management of the reactor with the help of a control system, protection system, system of the physical control of the neutron flux distribution, and temperature control system.

Turbine Operator carries out the direct control and management of the turbine and their auxiliary systems

Unit Shift Supervisor carries out general management of the control actions from MCR.

At the start of an emergency situation, a typical control room staff performs the following functions:

Monitor plant parameters
Analyze abnormal conditions
Take corrective actions
Classify emergency situation
Make initial notification to shift supervisor
Establishing initial trends in plant parameters
Manage plant operations.

General operative duties of the MCR staff in a case of emergency situation are the following:

Monitor sequence of protection system actions and interlocks
Monitor automatic control actions
In a number of situations, stipulated by the operating instructions, the MCR staff carries out necessary operations manually according to the operating procedures.

Scope and Objectives

The purpose of the operational displays is to assist control room personnel in evaluating the safety status of the plant. The HLODs are to provide a continuous indication of plant parameters or derived variables representative of the safety status of the plant. The primary function of the operational displays is to aid the operator in the rapid detection of abnormal operating conditions. The functional criteria for the HLODs presented are applicable for use in the main control room as well as in the other rooms where the operators stations could be located.

It is recognized that, upon detection of an abnormal plant status, it may be desirable to provide additional secondary functions to analyze and diagnose the cause of the abnormality, execute corrective actions, and monitor plant response as secondary HLODs' functions.

As an operator aid, the operational displays serves to optimize the presentation of a minimum set of plant parameters from which the plant safety can be assessed. The grouping of parameters is based on the function of enhancing the operator's capability to assess plant status in a timely manner without surveying the entire control room.

The operational displays are intended to provide an indication of safety status of the nuclear plant which can be resulted either in entry to the Emergency Operating Procedures (EOPs) or as a supportive displays for those Emergency or Normal Operating Procedures.

The Displays' Architecture

As supportive display for the SPDS, the operational displays are connected directly to the polar graphics displays representing the safety status. The SPDS displays are the polar graphic displays of the type traditional for Westinghouse (dynamic polygon). The use of this type of geometric shape tends to support rapid detection and accurate understanding of the cause of an abnormal event.

The operational displays architecture leads the user from the abstract presentation of plant safety as presented by the top-level polar graphic displays which map into the Critical Safety Functions, through the state of the safety systems themselves to the details of a system state.

The HLODs architecture includes 3 plant overview displays as a main part of the displays' set. These displays are directly accessible from any of the top-level SPDS displays. These displays present to the MCR operator an overall picture of the safety status of the plant and of the performance of the safety systems. The data presented on the displays is sufficient for supporting an operator's initial evaluation of anticipated emergency or transient conditions.

The displays provide a spatially dedicated, continuously viewable, integrated presentation of the plant status in a direct manner. Thus, these displays will enhance coordination among MCR personnel during normal, abnormal and emergency situations, and provide a clear, concise and continuous point of reference for operators to assess quickly plant status while performing tasks at the work station. They will also be a useful aid during shift turnover, for assessing plant maintenance activities, printed as a shift report, and for training activities in the main control room. The facility will provide key parameters and status indications independent of other MMI equipment with information which would immediately be available to all operators and any supporting observers without burdening the normal display facilities and without any direct action by personnel other than to look up at the display. In addition, the following requirements apply:

The overview display shall provide for the display of a limited number of key operating parameters. The specific parameters shall be determined in the design process. The overview display shall provide for the display of the operational status, e.g., flow or no-flow, energized or de-energized, on or off, open or close, etc., of a limit number of essential components controlled or monitored from the MCR. The specific displays shall be determined in the design process; however, the following shall be specifically considered for incorporation (for example):

Main reactor parameters;
Reactor coolant pumps;
Steam generator parameters
Feedwater and condensate system pumps;
Isolation valves (e.g., main steam and feedwater);
Safety systems pumps and valves;
Decay heat removal pumps and valves;
Power supply breakers;
Auxiliary power generators;
Safety and relief valves;
Circulating water pumps.

The overview displays provide for the display of high level derived quantities, e.g., those which depend on a particular logic algorithm, where the design process shows such information directly supports the use of the overview display.

One of the main intention of the plant overview display is to provide a navigation mechanism to the MCR operators to reach low level system displays. An example of the plant overview display is presented in Figure 1.

The polar graphics and plant overview displays as a part of the UIS operational displays is supported by a lower level of displays which provide more detailed information related to the plant energy balances and coolant mass balances. This kind of information also helps the MCR operators to identify possible cause of an event they deal with. These displays also use landmarking techniques for orienting the user within the display and between displays and they partially overlap one another in order to make user orientation easier from one display to another. Several examples of these displays are presented in Figures 2 - 4.

A set of the operational displays has special diagrams which define the main control systems efficiency. For example, the display shown in Figure 5 presents P-T diagram to the MCR operator. This diagram might be used by the MCR operators during heatup/cooldwon operations.

A sketch of the HLOD's display architecture and its interface with an operator is shown in Figure 6.

- **Operational Displays Task Description**

The HLOD's displays design is based on the task descriptions which reflect the following displays features:

General Description

Expected display functions as a task support
Method to present the information

Sketch of the display layout;

Description of the information presentation (with references to the graphic shapes (macros) to be used);

List of the display parameters;

Requirements for specific calculations (if necessary)

References:

1. R.J. Mumaw, D.D. Woods, M.C. Eastman Techniques and Principles for Computer-Based Display.- STC Report 90-1SJ4-HUMIN-R1, August 1991.

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3. U.S. NRC (1989b), A Status Report Regarding Industry Implementation of Safety Parameter Display Systems, NUREG-1342, U.S. Regulatory Commission, Washington, D.C., April 1989.

4. U.S. NRC NUREG 0696-1981, Functional Criteria for Emergency Response Facilities, Final Report

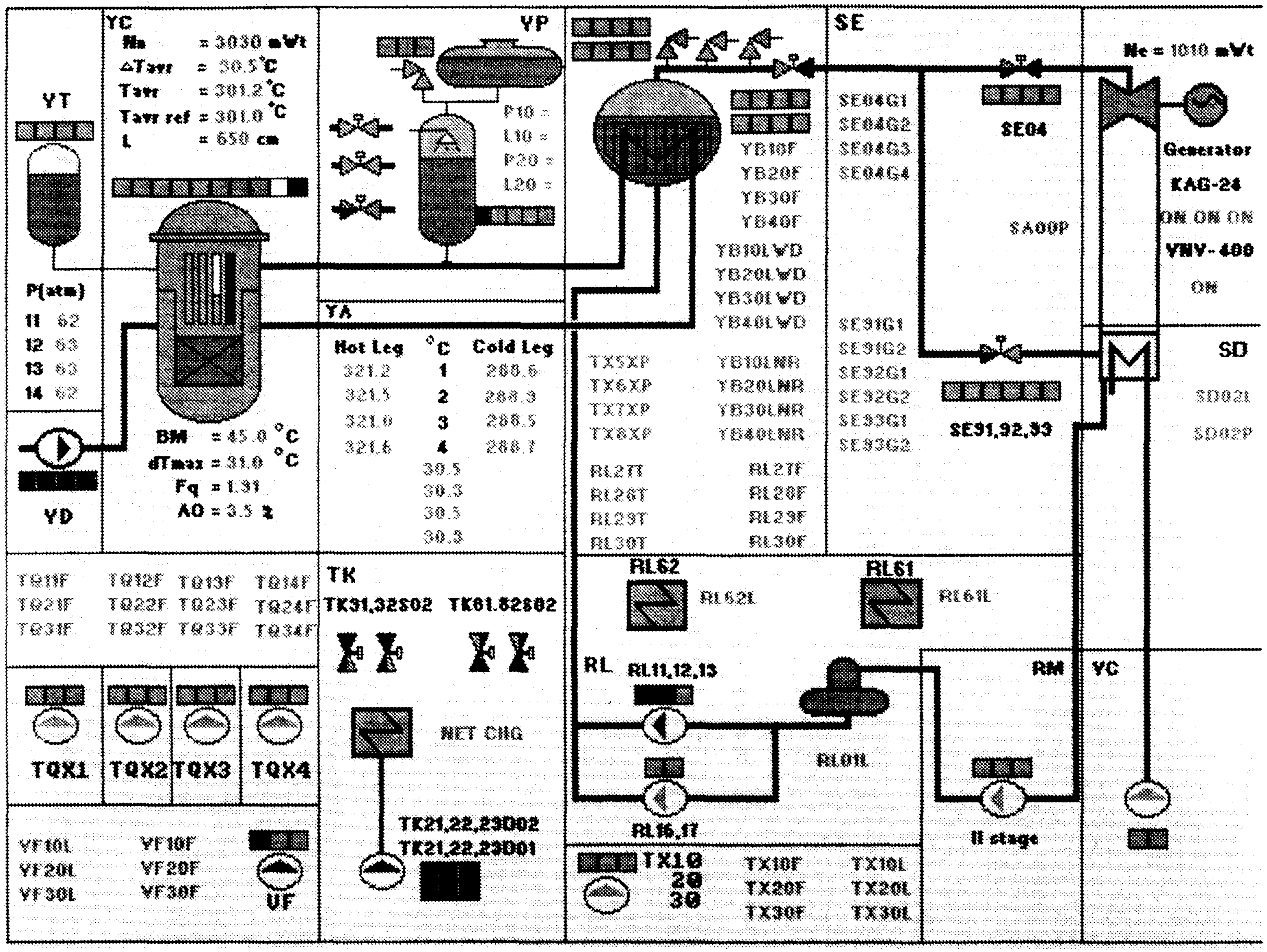

Figure 1 Plant Overview Display

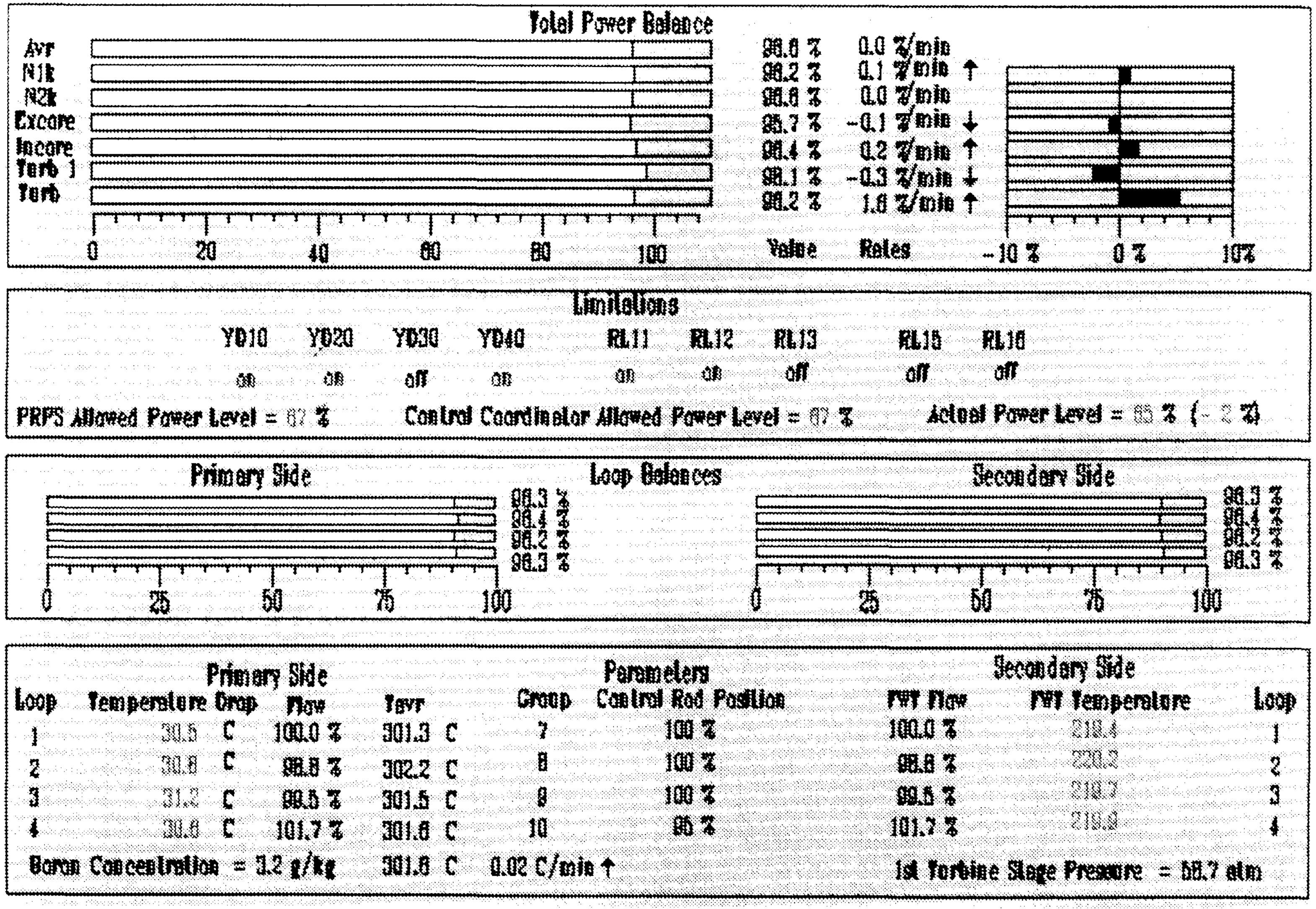

Figure 2 Power Balance

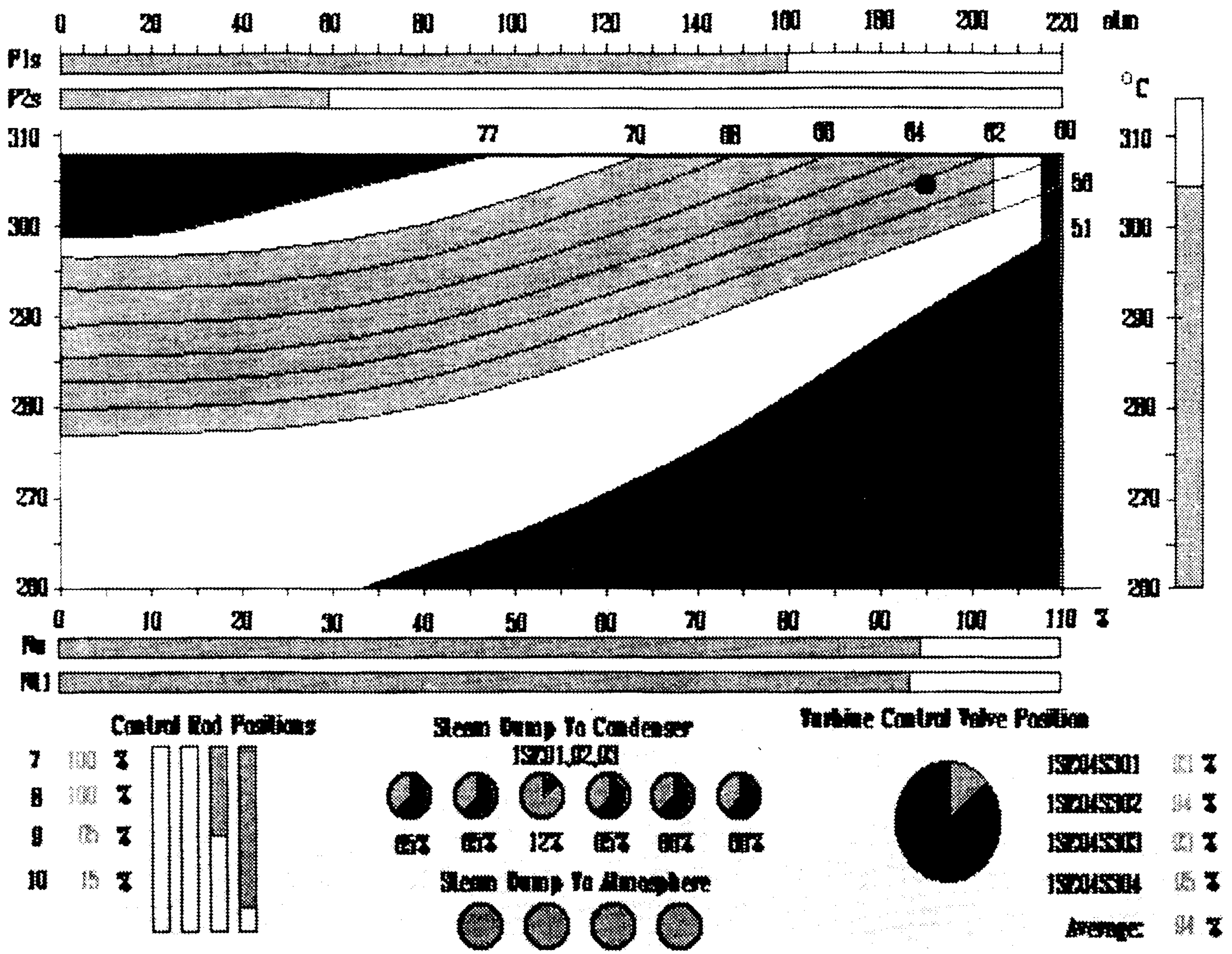

Figure 3 P-T-N Diagram

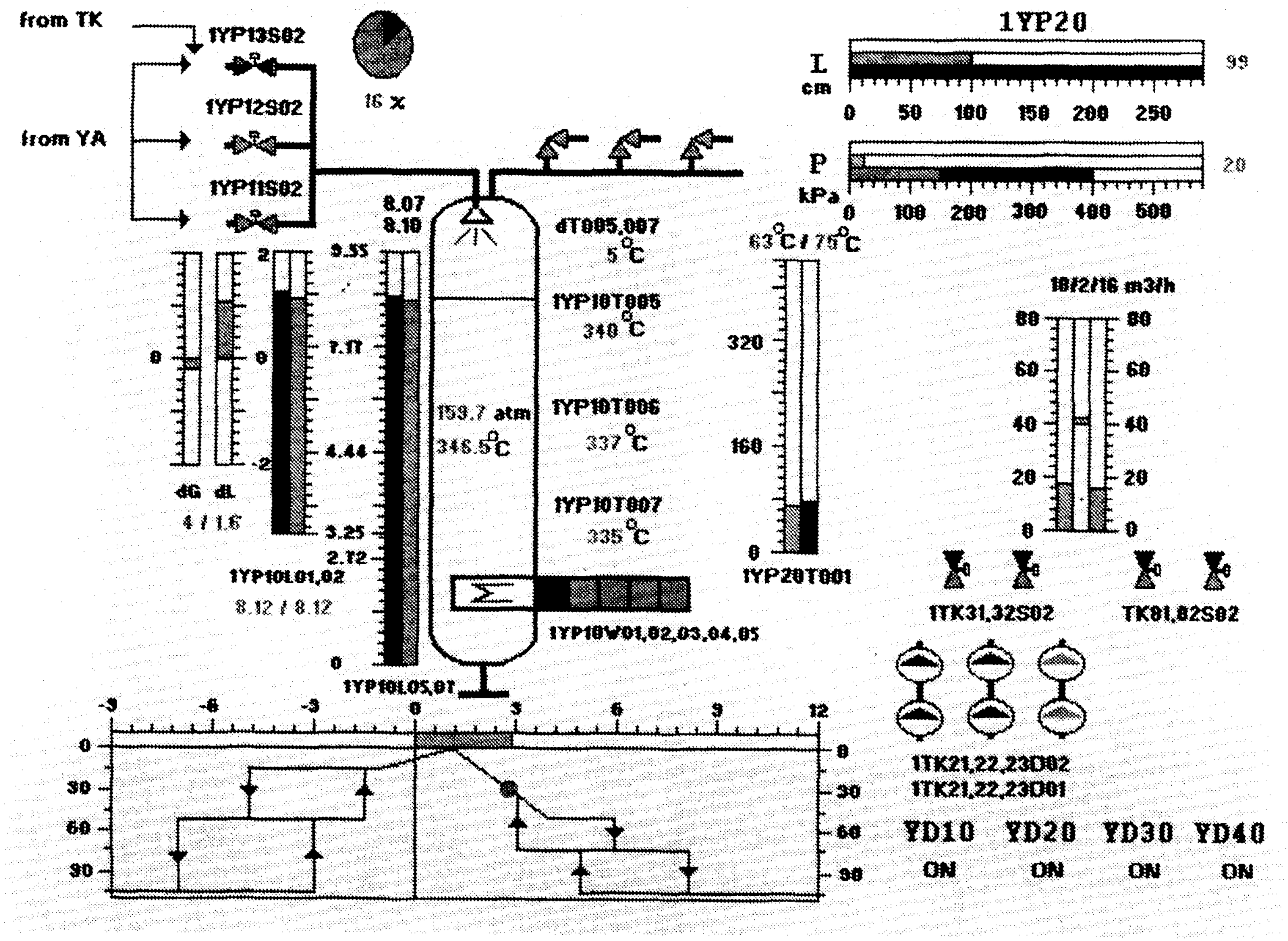

Figure 4 Primary Mass Balance

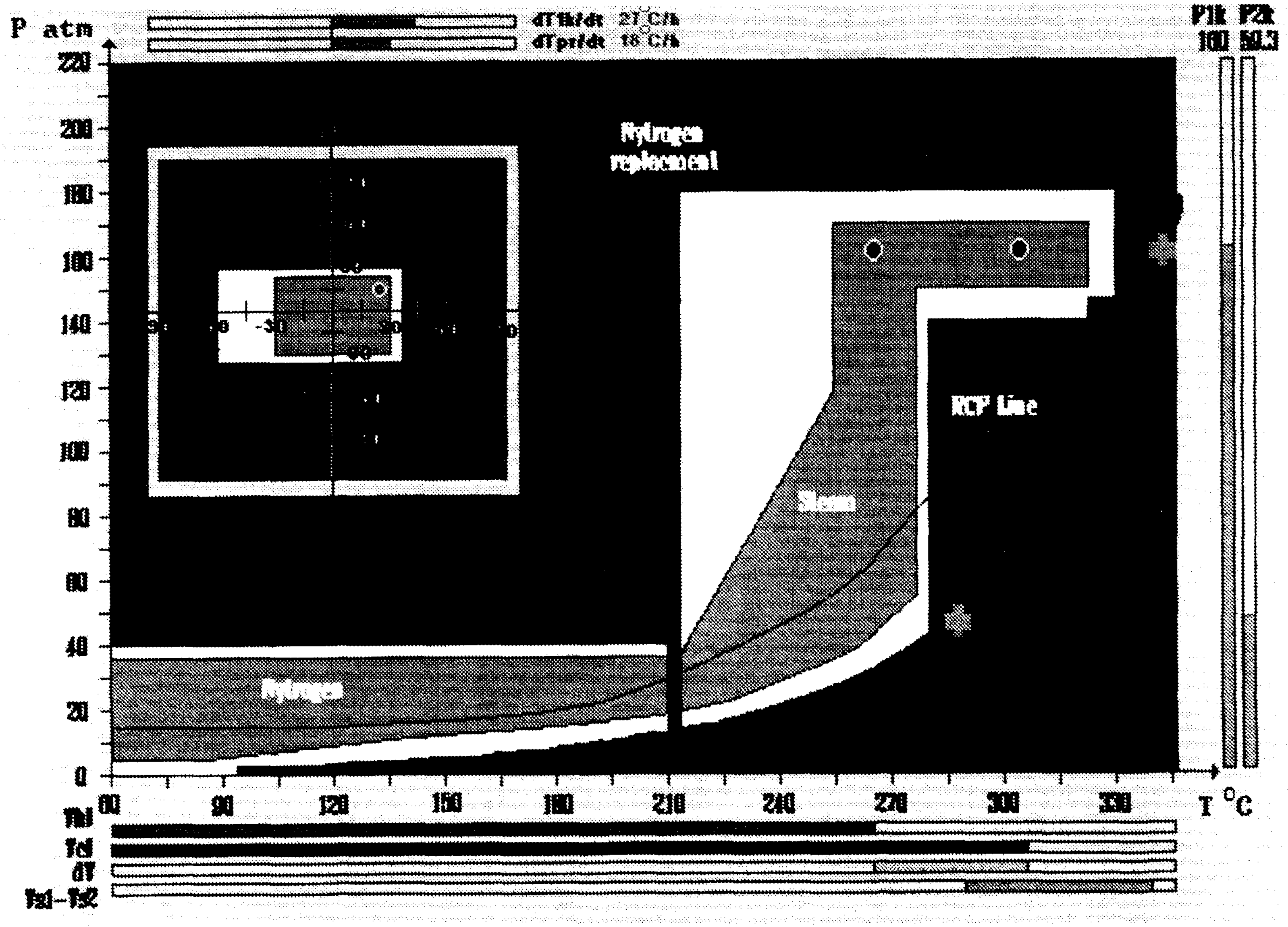

Figure 5 P-T Diagram

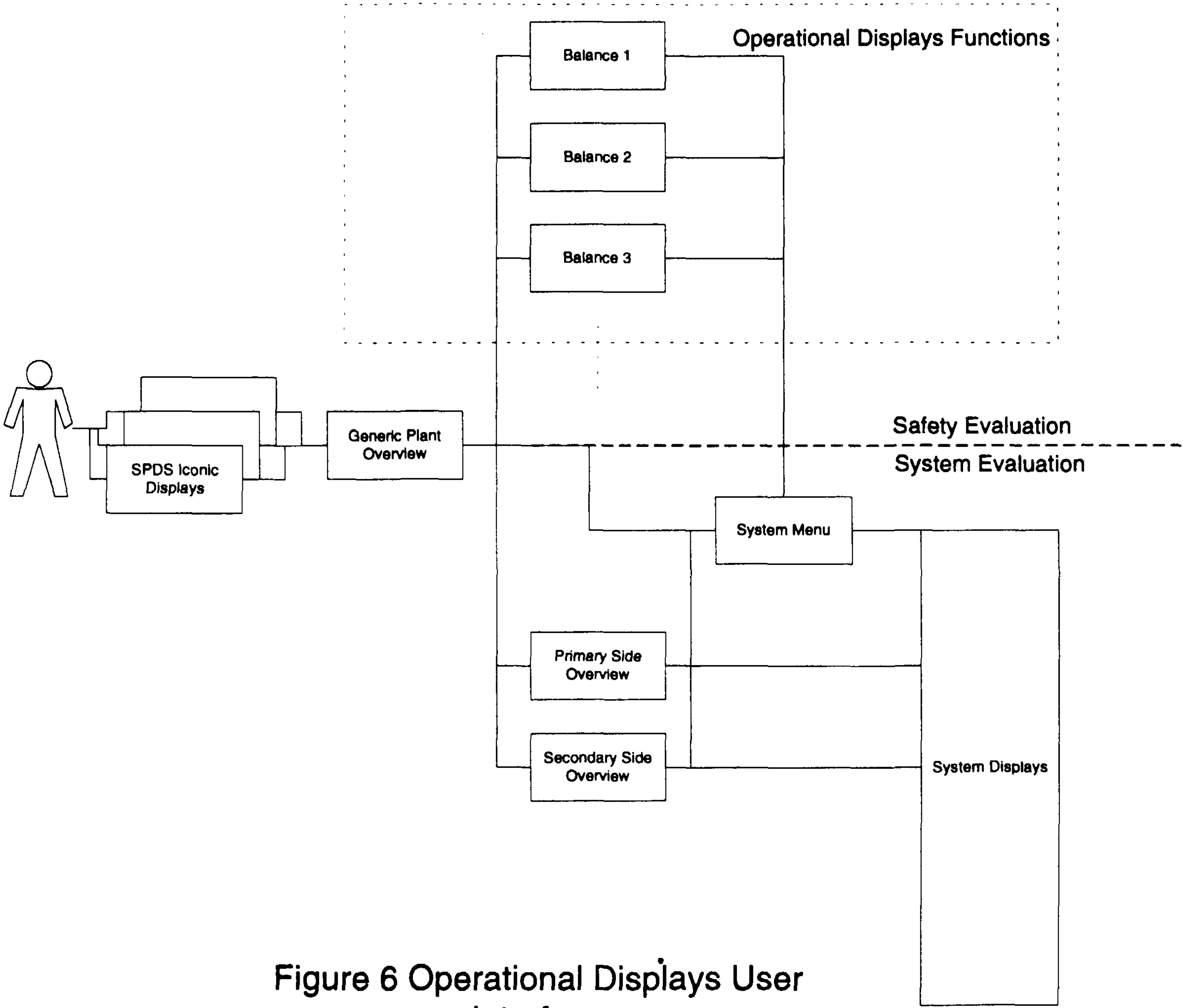

Figure 6 Operational Displays User Interface