PowePlantSim2007
San Diego, California, USA, February 19-22, 2007

Core Monitoring Applications in the Simulator Control Room

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Keywords: Core Monitoring, GARDEL-SIM

ABSTRACT

Almost all boiling water reactors (BWRs) and many pressurized water reactors (PWRs) use a core monitoring system in the plant control room. These core monitor systems combine measured data and physics calculations to provide operations assistance information. For a variety of reasons, these systems are frequently not available in the simulated control room, or are available only via a simplified emulation. This paper presents a product which allows rigorous core monitoring to be present in the control room. Further, this paper discusses the additional instructional capabilities offered by the usage of this software.

1. CORE MONITORING OVERVIEW

There are several types of core monitoring systems, but they are all conceptually very similar. All core monitoring starts at the process computer, which collects a data vector of measured plants signals. These signals include but are not limited to:

- Fixed incore flux detectors
- Movable incore flux detectors
- Excore flux instruments
- Thermocouples
- Pressure taps
- Flow Meters
- Pump speed indicators

These signals are then exported to a signal handling device. They then become the input, or boundary conditions, to a reactor physics computational module. The physics model can be invoked periodically on a fixed interval, automatically in response to a change in plant condition, or manually via a request from the GUI.

Several outputs are generated from the physics models. These include:

- Plant heat balance
- Reactivity components (Fission products, Doppler, etc)
- Thermal Limits (Margin to limit based on local heat generation)
- Measured-to-Computed Detector Comparisons
- Power in uninstrumented locations
- Maneuver Predictions (AFD target, Xe transient, Power/Flow Map, etc)

Operators can then use the outputs for guidance and analysis.

2. CORE MONITORING SYSTEMS

There are several core monitoring systems in use in the industry. The graphical examples herein are taken from the Studsvik core monitoring system GARDEL. However, other core monitoring systems include

- 3D-Monicore (General Electric Corporation);
- PowerPlex (Areva)
- Beacon (Westinghouse)
- CoreMaster I & II (formerly ABB, now Westinghouse)

Additionally, some utilities have developed their own internal core monitoring systems. There are three primary differences among the core monitoring systems. First, the physics software is different for each vendor. However, in all cases, the software engineering grade, either very similar to or identical to that which is used in core design. Second, the backends are all different. Some are GUIs while some are printed pages. Third, there are differences in the kinds of calculations allowed, and whether those are user-configurable. However, in the end, the similarities are more important: data capture to a database, physics calculations, backend display.

3. PLANT VERSUS SIMULATOR

Although conceptually simple, there have been obstacles to implementing core monitoring in the simulator control room. One traditional obstacle is cost. The license fee associated with the software has been prohibitive. A second issue is CPU availability. Many of these systems were designed execute on exotic, expensive hardware.

A third issue is accuracy, and this may be most important from a training point of view. The simulator core models take the place of measured data in the plant. The core monitoring system takes measured data and performs calculations to predict things that are not measured. If the simulator is generating inaccurate "plant data," the simulator core monitoring system will generate an inconsistent plant state, and the predicted results will be unusable.

4. GARDEL-SIM

GARDEL-SIM is the simulator version of the Studsvik Core Monitoring product GARDEL. GARDEL-SIM contains most of the functions of its parent. However, there are several important features.

GARDEL-SIM runs on its own server (PC, Linux, or Unix). Unlike the plant monitoring system, GARDEL-SIM must respond consistently to executive commands such a run, init, freeze, etc. GARDEL-SIM receives these commands from socket calls added to the simulator executive. The executive is connected to the server via IP address or DNS suffix.

GARDEL-SIM must also respond to numbered Initial Conditions (ICs) or backtracks. The communication is the same as above, except the number is also passed via the socket. The GARDEL-SIM snap information is saved on the GARDEL-SIM server.

In the plant, the process computer exports a data vector with the plant state for use by GARDEL. In effect, the process computer performs an analog-to-digital data conversion and writes a file in a specific format to be read by GARDEL. On the simulator, the "plant data" is already digital, so the data file may be written directly from the simulator database to the required location on the GARDEL-SIM server. As in the plant, the time stamp on this file tells the core monitoring system that a new case has been requested.

The GARDEL-SIM data requirement is a CASMO/SIMULATE cycle depletion, which is the same data required by S3R. No additional data is required.

5. BENEFITS

The most direct benefit of GARDEL-SIM is that the core monitoring function is available in the control room. However, a significant secondary benefit is that the three-dimensional state of the core is archived at many discrete time intervals for study. This study can be performed by temporarily halting training, or by examining the data at part of training wrap up, or in the classroom.

Examples of GARDEL-SIM displays are shown in Figures 1-6. In this case the graphical backend, is configured as if GARDEL is the plant core monitoring system. However, other graphical or text-based displays are possible, depending upon what is used at the plant.

6. SUMMARY

Advances in model fidelity and hardware have made core monitoring feasible in the simulator control room. Core monitoring adds plant functions to the simulator experience. Core monitoring also adds three-dimensional detail to the training activity. GARDEL-SIM is the training simulator version of the Studsvik core monitoring product GARDEL. GARDEL-SIM responds to conventional commands from the executive system and instructor station. GARDEL-SIM requires no additional data other than what is required for S3R. The backend display from GARDEL can be configured to match that which is in use at the plant.

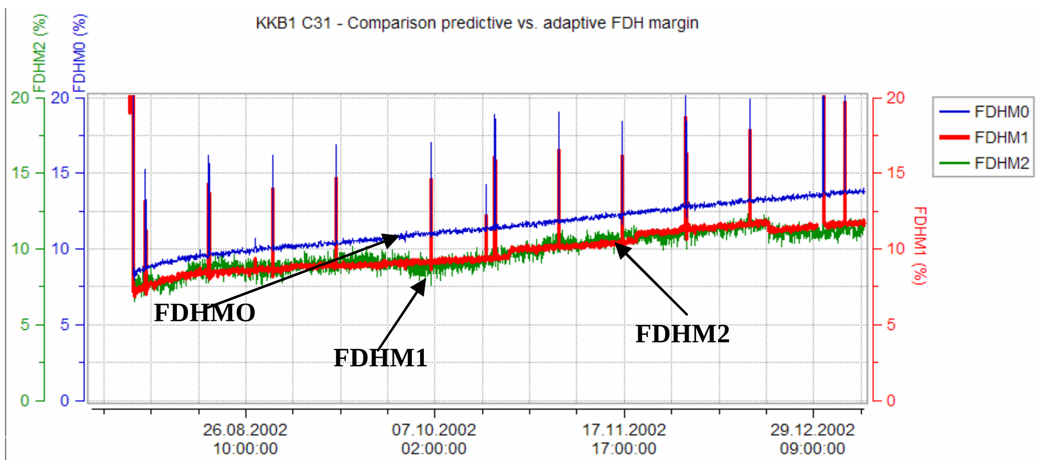

Fig. 1 Comparison of predicted and corrrected FΔh margins

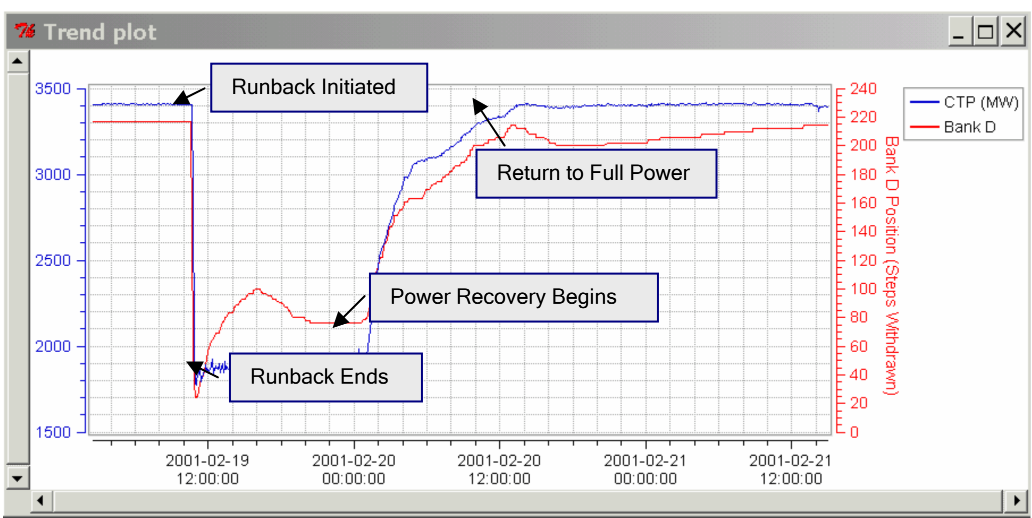

Fig. 2 GARDEL trend plot of key parameters during pump trip

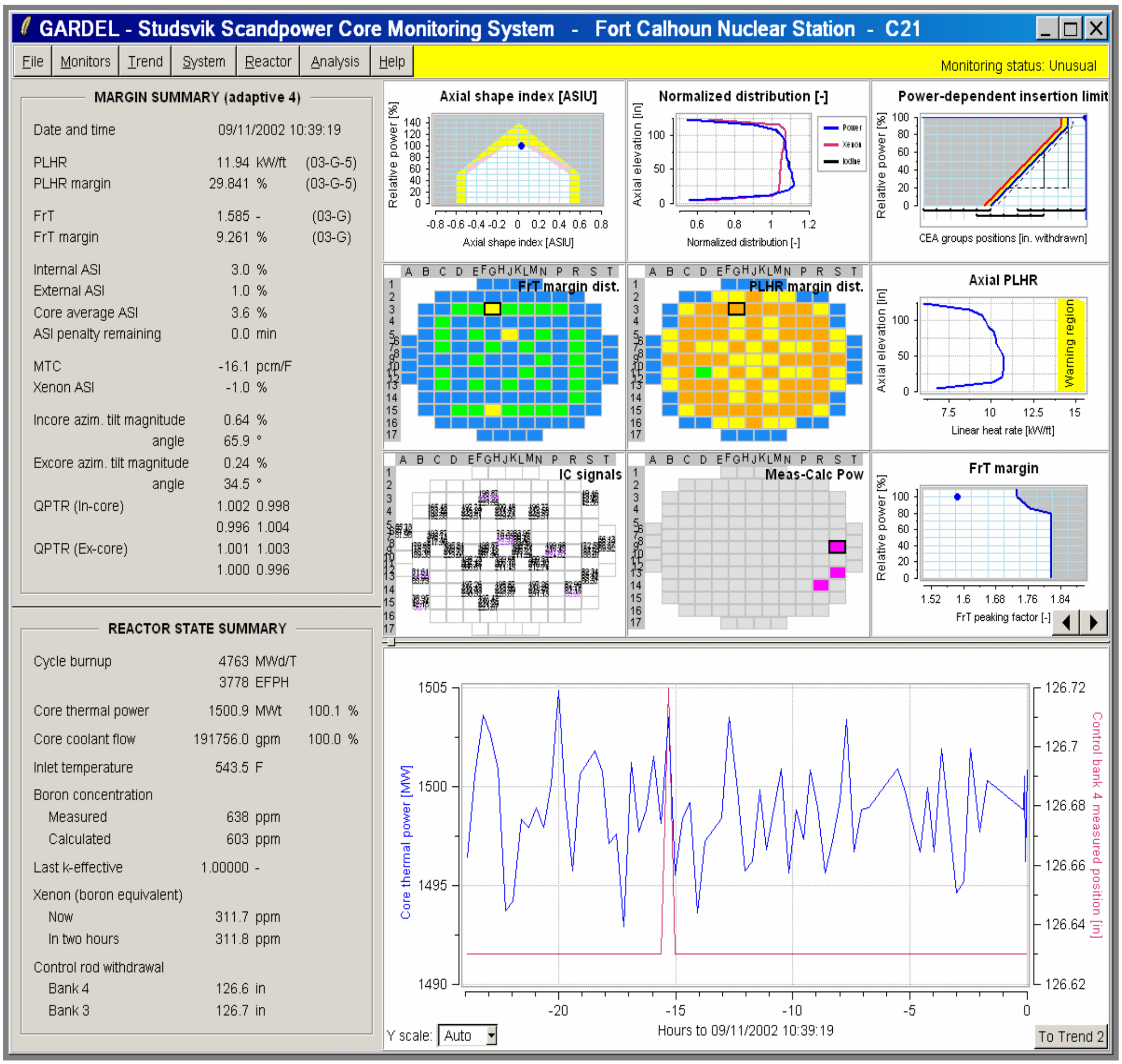

Fig. 3 PWR Main Interface

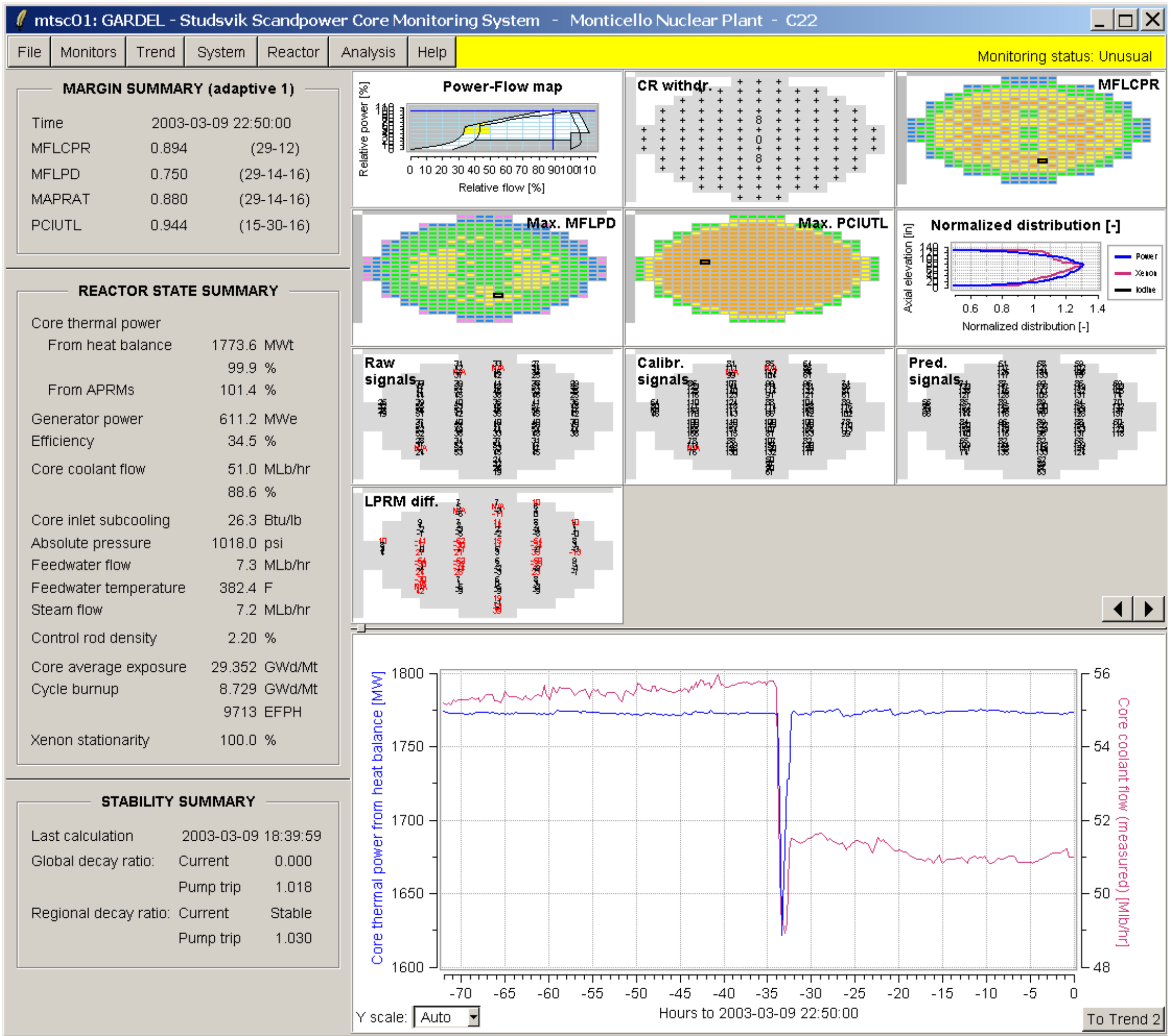

Fig. 4 BWR Main Interface

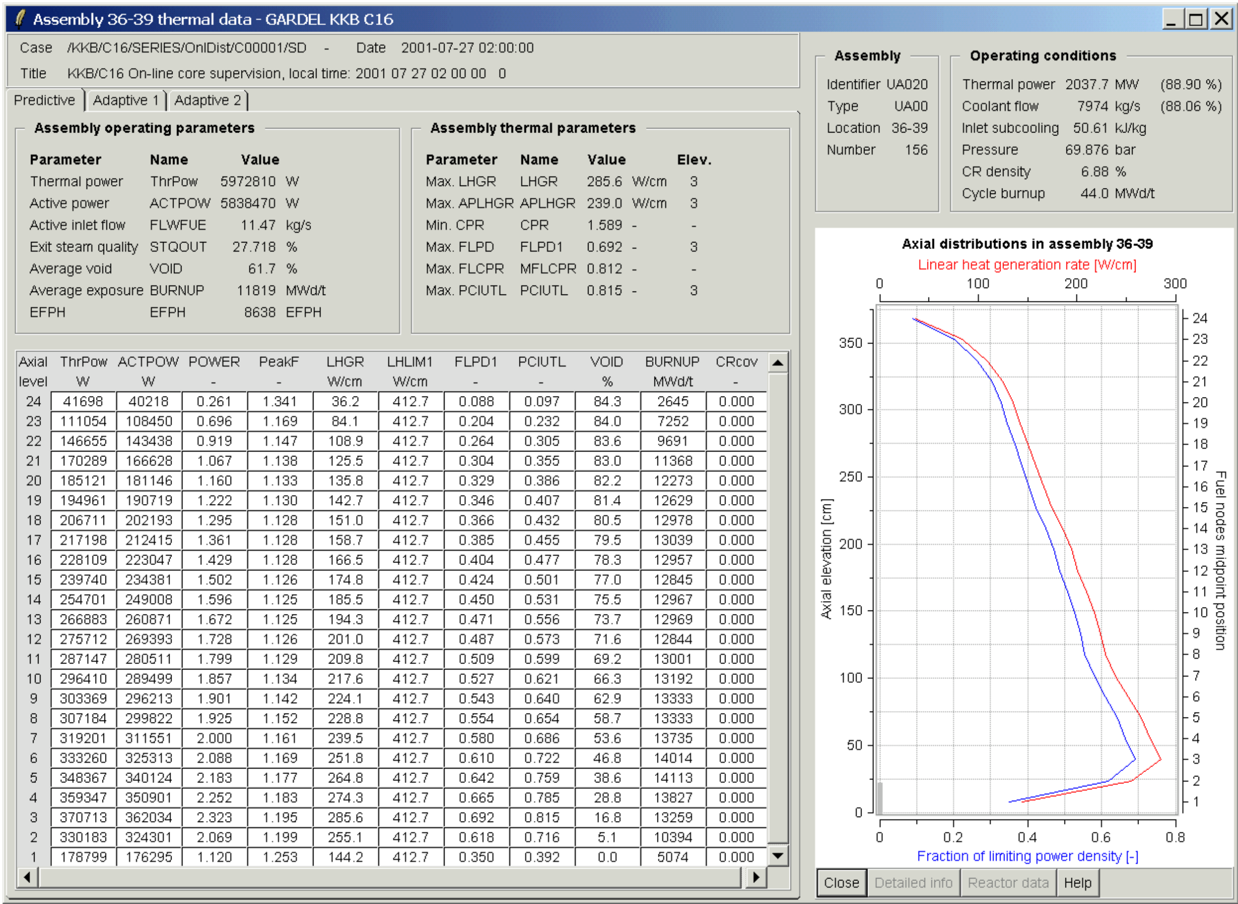

Fig. 5 Detailed Report for a Single Assembly

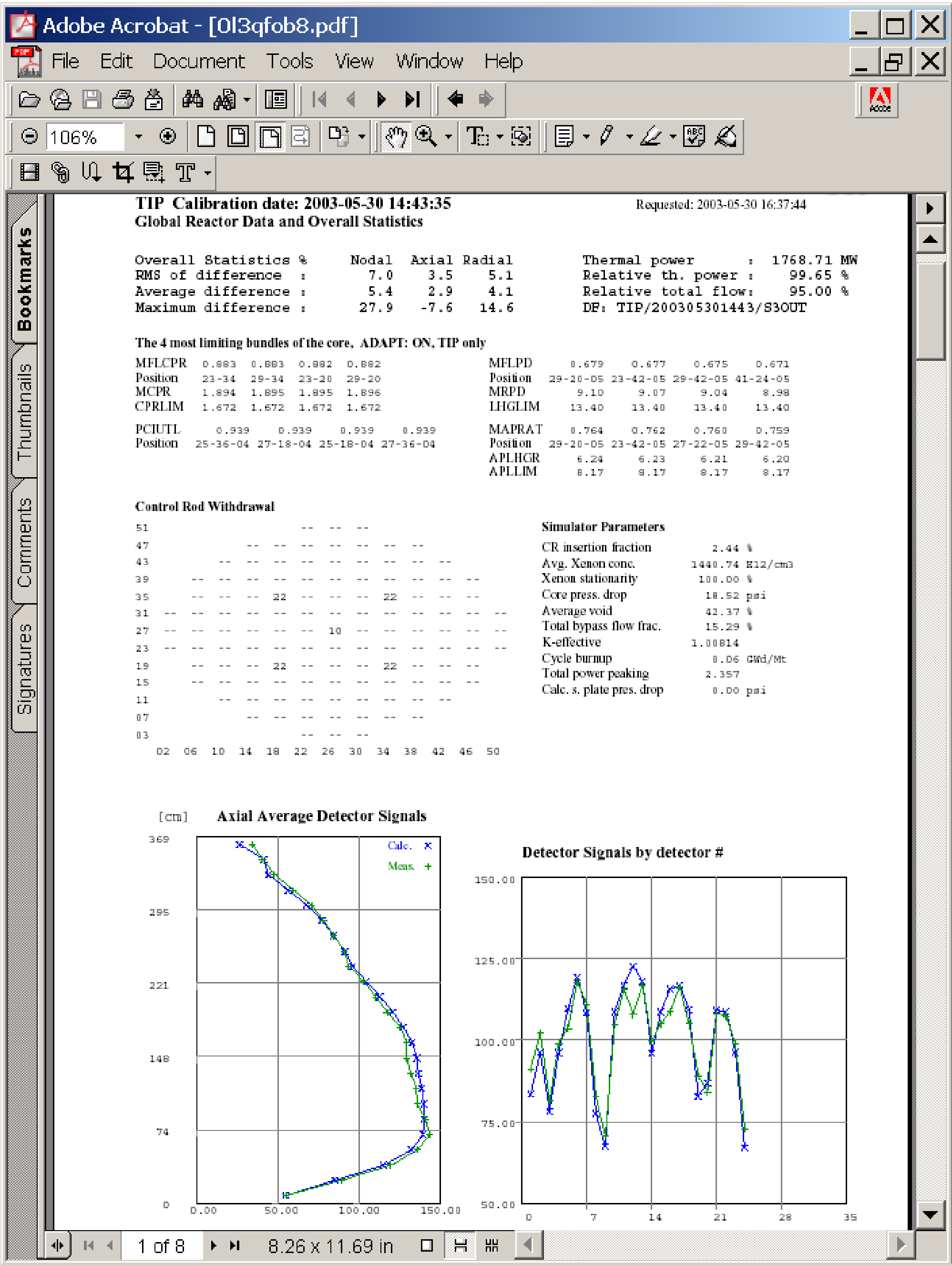

Fig. 4 PDF Format Text Report