# Rod Control System Optimization

## Background

Control system setpoints, which are used to predict the best response to plant process malfunctions, can be assessed by simulating the process as well as the design and control system(s) of the plant nuclear steam supply system (NSSS). Westinghouse offers simulation tools to address the plant NSSS and associated control systems (e.g., LOFTRAN and MATLAB computer codes). Sometimes, however, knowing the response to a plant disturbance allows engineers to synthesize the control system and calculate its setpoints without using a simulation tool/code. In these cases the analysis would not require the LOFTRAN or MATLAB computer codes. We can produce calculations specific to the system to solve a particular issue. This method would eliminate the time needed to build an entire input deck and ultimately solve specific problems with greater accuracy and fewer costs.

Westinghouse's control system setpoints directly support the vintage instrumentation and control (I&C) systems (Foxboro, 7100, 7300, WDPF®, Eagle and Eagle 21). The control system setpoints also support the digital Ovation® system.

Westinghouse can analyze and evaluate the performance of the normal operating control systems (e.g., rod control, pressurizer level and pressure control, feedwater control, and steam dump control) in order to optimize plant responses to the needs of the customer.

## Description

### Rod Control System Optimization

Several plants have experienced periodic hot-leg temperature fluctuations attributed to a rod control system hot-leg flow-streaming phenomenon. In turn, these fluctuations impact the measured rod control system average temperature, or $T_{avg}$ (used as an input to the rod control system on Westinghouse-designed plants), which causes spurious control rod stepping during steady-state operation when the rod control system is in automatic mode. To avoid this rod stepping, some plants operate in the manual rod control mode. Rod control system optimization, however, reduces spurious stepping on the lead rods, which increases the life of the rod control drive mechanisms and maintains optimum $T_{avg}$ control.

If the plant is operating with the manual rod control, it is possible that the operator might not be able to reduce or increase the $T_{avg}$ enough during a normal operating transient (10-step increase/decrease, 50LR/FLR), which could result in actuation of a reactor trip/engineering safety feature actuation system (ESFAS).Westinghouse has found that, for certain plants, it is acceptable to operate in manual control so long as the plant has demonstrated that it will not trip if the rod control system is not credited.

Nuclear instrumentation system (NIS) fluctuations also have been noted at some plants. Since the NIS power is also used as input to the rod control system, fluctuations and variations in this signal can cause spurious rod stepping, depending on the magnitude of the NIS fluctuations.

Based on experience with these issues at several plants, Westinghouse has developed three recommendations for revising the rod control system setpoints and time constants to minimize automatic rod stepping: the margin recovery program, a plant transient simulation, and averaged $T_{avg}$ control.

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## Margin Recovery Program

Westinghouse has designed this program to help customers address I&C system alarms caused by a reduction in operating margin (fuel designs, uprating, reactor temperature detector [RTD], bypass elimination, etc.). This may be offerred as a standalone service or as part of a bigger package (e.g. plant uprate, MUR, SLR, etc.). It can be classified as an integrated control and protection system functional design revision since it includes control system modeling, dynamic control system analysis, protection-related Final Safety Analysis Report (FSAR) accident analysis, and setpoint changes in both the protection and control systems. Several short- and long-term solutions are available, based on customer needs; some solutions need FSAR safety analysis and Technical Specification revisions.

## Averaged $T_{avg}$ Control

One of the main signals used in the automatic control systems in Westinghouse nuclear pressurized water reactors (PWRs) is $T_{avg}$. The signal is used to move the control rods, adjust charging flow rate and pressurizer level and operate the steam dump control system. The input to the Westinghouse standard control system design is an auctioneered high circuit of all rod control system loop $T_{avg}$ signals. The $T_{avg}$ signal generated is based on $T_{cold}$ and $T_{hot}$ measurements.

In recent years, as a result of a number of plant revisions (e.g., low-leakage fuel patterns or other issues such as the identification of the upper plenum flow anomaly), the loop $T_{avg}$ signals have shown greater fluctuations during steady-state operation. Some plants have required revisions to the signal compensation used in the various control systems in order to avoid unnecessary control system operation and deviation alarm actuations. Having already implemented the signal compensations to the rod control system, some plants still have rod movements. Because of this, Westinghouse was asked to consider an average $T_{avg}$ control scheme. A revision to the $T_{avg}$ selector has been proposed, whereby an averaging circuit will be used instead of an auctioneered high circuit. The averaging circuit calculates the average of the available loop $T_{avg}$ signals that can be used in the various control systems. The evaluation determined that it is not necessary to revise the final safety analysis; however, the technical specification basis for the departure from nuclear boiling temperature specification and basis needs to be revised. This will enhance operation and performance.

## Benefits

- Maintain the variables within the plant operating window, preventing a reactor trip or actuation of safety systems

- Avoid troublesome oscillating behavior that could challenge the protection systems or contribute to component fatigue

## Experience

- Rod control system optimization: Salem, Millstone, Catawba, McGuire, South Texas, Comanche Peak, Beaver Valley, Ascó

- Margin recovery program: Farley, Vogtle, Millstone, Seabrook, Indian Point, Sequoyah, Watts Bar, Ascó, Shearon Harris, Almaraz Units 1 & 2, Beaver Valley Units 1 & 2, Ginna, Callaway

- Plant transient simulation: Vogtle, Indian Point, Farley

- Average $T_{avg}$ control: Vogtle

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