

Westinghouse Electric Company Nuclear Power Plants P.O. Box 355 Pittsburgh, Pennsylvania 15230-0355 USA

U.S. Nuclear Regulatory Commission ATTENTION: Document Control Desk Washington, D.C. 20555 Direct tel: 412-374-6206 Direct fax: 724-940-8505 e-mail: sisk1rb@westinghouse.com

Your ref: Docket No. 52-006 Our ref: DCP_NRC_002597

August 19, 2009

Subject: AP1000 COL Standard Technical Report Submittal of APP-GW-GLR-137, Revision 0

In support of the AP1000 Design Certification Amendment Application, Westinghouse is submitting Revision 0 of APP-GW-GLR-005, "Bases of Digital Overpower and Overtemperature Delta-T ($OP\Delta T/OT\Delta T$) Reactor Trips."

Operating Westinghouse pressurized water reactors (W-PWRs) use the Overpower Delta-T and Overtemperature Delta-T (OP Δ T/OT Δ T) reactor trips to protect the specified acceptable fuel design limits. These reactor trips are based on analog technology using the reactor vessel average (Tavg) and Δ T signals (derived from hot leg and cold leg temperatures Thot and Tcold). Westinghouse is upgrading this analog technology to digital technology as part of the reactor protection system for the AP1000. The purpose of this report is to describe the commonality of design bases and analytical methods as well as the differences in detailed implementation between the analog design (with OT Δ T setpoint based on Tavg) and the digital design (with OT Δ T setpoint based on core inlet temperature).

The information included in this report is generic and is expected to apply to all COL applications referencing the AP1000 Design Certification and the AP1000 Design Certification Amendment Application.

It is expected that when the NRC review of APP-GW-GLR-005 is complete, the changes to the AP1000 DCD identified in this report will be considered approved generically for COL applicants referencing the AP1000 Design Certification.

Questions or requests for additional information related to content and preparation of this report should be directed to Westinghouse. Please send copies of such questions or requests to the prospective applicants for combined licenses referencing the API000 Design Certification. A representative for each applicant is included on the cc: list of this letter.

Very truly yours,

Robert Sisk, Manager Licensing and Customer Interface Regulatory Affairs and Standardization



/Enclosure

1. APP-GW-GLR-005 Revision 0, "Bases of Digital Overpower and Overtemperature Delta-T (OPΔT/OTΔT) Reactor Trips"

cc:	D. Jaffe	-	U.S. NRC	1E
	E. McKenna	-	U.S. NRC	1E
	S. Mitra	-	U.S. NRC	1E
	T. Spink	-	TVA	1E
	P. Hastings	-	Duke Power	1E
	R. Kitchen	-	Progress Energy	· 1E
	A. Monroe	-	SCANA	1E
	P. Jacobs	-	Florida Power & Light	1E
	C. Pierce	-	Southern Company	1E
	E. Schmiech	-	Westinghouse	1E
	G. Zinke	-	NuStart/Entergy	1E
	R. Grumbir	-	NuStart	1E
	D. Behnke	-	Westinghouse	1E

ENCLOSURE 1

APP-GW-GLR-005 Revision 0, "Bases of Digital Overpower and Overtemperature Delta-T (ΟΡΔΤ/ΟΤΔΤ) Reactor Trips"

WESTINGHOUSE NON-PROPRIETARY CLASS 3

 Document Number:
 APP-GW-GLR-137
 Revision Number:
 0

 Title:
 Bases of Digital Overpower and Overtemperature Delta-T (OPDT/OTDT) Reactor Trips

AP1000 Standard Combined License Technical Report

Bases of Digital Overpower and Overtemperature Delta-T (ΟΡΔΤ/ ΟΤΔΤ) Reactor Trips

Westinghouse Electric Company LLC Nuclear Power Plants Post Office Box 355 Pittsburgh, PA 15230-0355

©2009 Westinghouse Electric Company LLC All Rights Reserved

WESTINGHOUSE NON-PROPRIETARY CLASS 3

 Document Number:
 APP-GW-GLR-137
 Revision Number:
 0

 Title:
 Bases of Digital Overpower and Overtemperature Delta-T (OPDT/OTDT) Reactor Trips

TABLE OF CONTENTS

Sectio	n Title	Page
1.0	INTRODUCTION AND SUMMARY	3
2.0	BASES FOR THERMAL PROTECTION	5
3.0	DESCRIPTION OF DIGITAL OP ΔT AND OT ΔT REACTOR TRIPS	7
4.0	DIGITAL OP $\Delta T/OT\Delta T$ SETPOINTS IN COLR (CORE OPERATING LIMITS REPORT)12
5.0	REFERENCES	13

1.0 INTRODUCTION AND SUMMARY

Operating Westinghouse pressurized water reactors (W-PWRs) use the Overpower Delta-T and Overtemperature Delta-T ($OP\Delta T/OT\Delta T$) reactor trips to protect the specified acceptable fuel design limits. These reactor trips are based on analog technology using the reactor vessel average temperature (T_{avg}) and ΔT signals (derived from hot leg and cold leg temperatures T_{hot} and T_{cold}), as documented in WCAP-8745-P-A (Ref. 1). Westinghouse is upgrading this analog technology to digital technology as part of the reactor protection system for the AP1000.

The purpose of this report is to describe the commonality of design bases and analytical methods as well as the differences in detailed implementation between the analog design (with $OT\Delta T$ setpoint based on T_{avg}) and the digital design (with $OT\Delta T$ setpoint based on core inlet temperature).

The digital OP Δ T/OT Δ T design provides the following improved features important to safety compared to the analog design:

- 1. Simpler and more direct conversion of the core thermal design limits to protection system setpoints;
- 2. Improved monitoring of thermal power and protection system performance;
- 3. Simplified dynamic compensation;
- 4. Monitoring and prevention of local hot leg saturation conditions that could invalidate core thermal power measurement; and
- 5. Provision for reactor trip on high core inlet temperature if desired.

These features are discussed below.

The analog formulation for the OP Δ T/OT Δ T reactor trips dates from 1966-68 when it was first applied to W-PWRs. At that time, a novel design was proposed to minimize errors in measuring Δ T. To eliminate the errors in obtaining an absolute temperature for T_{hot} and T_{cold} and then subtracting (thus adding the individual errors in measuring T_{hot} and T_{cold}), a four-RTD bridge was proposed. With two hot leg RTDs and two cold leg RTDs, Δ T would be obtained directly across two points of the bridge and T_{avg} obtained across the other two points. That design was soon obsolete as a result of (a) improvements in instrumentation and (b) discovery that errors caused by hot leg streaming were large compared to instrument measurement errors. However, the use of T_{avg} and Δ T was already frozen into the protection system design despite the fact that the core thermal design limits are computed as functions of core inlet temperature (T_{inlet}) and power.

With improved instrumentation for converting RTD resistance to temperature signals, higher protection system accuracy is obtained by measuring T_{cold} and T_{hot} directly. Thus, the OT ΔT equation can be rearranged so that the setpoint is computed as a function of T_{cold} rather than as a function of T_{avg} . With the advent of digital systems, the core thermal power can be more accurately calculated than with the approximations inherent in using a ΔT signal. Thus, the ΔT power signal uses T_{hot} , T_{cold} , and pressurizer pressure to compute cold leg density and hot leg and cold leg enthalpies. This is directly analogous to the ΔT signal but is a much more accurate measure of core thermal power.

The conversion of T_{inlet} and power to T_{avg} and ΔT is a non-trivial process considering the nonlinearities in the density and heat capacity of water. (For example, see Appendix B of Ref. 1.) However, the relation between the protection system setpoints and the core thermal design limits is unchanged. The core thermal design limits and their relation to OP ΔT /OT ΔT setpoints is described further in Section 2.

Since conversion to T_{avg} and ΔT is eliminated, the digital OP ΔT and OT ΔT reactor trip formulation substantially simplifies converting the core thermal design limits (which remain unchanged from those described in WCAP-8745-P-A) to reactor trip setpoints.

The ΔT power signal (described in Section 3) can be directly compared to the measured calorimetric power, and thereby makes it easier to monitor and trend errors. No correction for RCS temperature, pressure, or power level is needed. This enhances monitoring capability of both the protection system performance and thermal power.

Direct use of T_{hot} and T_{cold} instead of T_{avg} and ΔT also simplifies the dynamic compensation for instrument delays and fluid transport time from the cold leg RTD to the core (to adjust for the difference between T_{inlet} and measured T_{cold}), and from the core to the hot leg RTD. The dynamic compensation needs to account for the time difference in each independent signal.

Hot leg boiling is a measurement limit rather than a safety limit. (Section 2-4 of Ref. 1 specifically notes that hot leg boiling is not a core protection limit.) As is now well known, hot leg streaming can cause large variations between local hot leg temperatures. Hence, one RTD could approach saturation—and thus become invalid for measurement—well before the bulk fluid in the hot leg approaches saturation. (In the majority of operating W-PWRs, and also in the AP1000 design, the temperature signals from three separate RTDs, located approximately 120° apart around the hot leg circumference, are combined to obtain a hot leg temperature signal in each protection system division.) The digital design permits setting an individual RTD temperature signal to vote for a trip if it approaches saturation. (See the discussion in Section 3.) This eliminates the need to assign uncertainties to the variation between local RTD temperature and bulk hot leg fluid temperature. This feature also removes the dependency (discussed in Appendix B of Ref. 1) of the analog OT Δ T trip on the steamline safety valves to protect against hot leg saturation.

The OT Δ T trip setpoint is interpolated from a table of the thermal design limits that define allowable power versus T_{inlet} at various pressures. This table, if desired, can specify zero allowable power if inlet temperature rises above a specified value—in effect a reactor trip on high inlet temperature. This feature can be used to back up other trips for additional defense in depth, or to exclude other undesirable operating conditions.

A version of the digital OP Δ T/OT Δ T trip was installed in the Temelin nuclear station (two 1000-MWe units) in the Czech Republic, and has been operating satisfactorily since Unit 1 criticality in 2000.

In summary, the digital $OP\Delta T/OT\Delta T$ reactor trip design has differences in implementation that benefit safety. However, neither the basis nor the measured parameters are changed from the analog design.

Title: Bases of Digital Overpower and Overtemperature Delta-T ($OP\Delta T/OT\Delta T$) Reactor Trips

2.0 BASES FOR THERMAL PROTECTION

The design bases for the reactor thermal protection remain unchanged from those documented in Section 2.3 of WCAP-9272-P-A (Ref. 2). The purpose of the OP Δ T reactor trip continues to be to prevent fuel centerline melt due to excessive linear heat generation rates as measured in kilowatts per foot (kW/ft). The limitations of the digital OP Δ T trip (e.g., speed of transient and range of pressure and flow) are unchanged from the analog OP Δ T as described in Ref. 1. The fuel-temperature design basis is to preclude fuel melting (with 95% probability at the 95% confidence level) for the peak kW/ft fuel rod during normal operation and anticipated operational occurrences (Design Conditions I and II as defined in ANSI/ANS-N18.2/1973, Ref. 5). The AP1000 kW/ft limit for preventing fuel centerline melt is described in Section 4.4.1.2 of the Design Control Document (DCD, Ref. 3).

The purpose of the OT Δ T reactor trip continues to be to prevent departure from nucleate boiling (DNB) (Section 2.3 of Ref. 2). The limitations of the digital OT Δ T trip (e.g., speed of transient and range of pressure and flow) are unchanged from the analog OT Δ T trip as described in Ref. 1. The fuel DNB design basis, as documented in Section 2.3 of Ref. 2, is to preclude DNB (with 95% probability at the 95% confidence level) for the limiting fuel rods during normal operation and anticipated operational occurrences (Design Conditions I and II as defined in Ref. 5). The DNB design basis is reflected in the 95/95 limit of Departure from Nucleate Boiling Ratio (DNBR) as specified by a DNB correlation applicable to the fuel design. The DNB correlation and its design limits for AP1000 application are described in Section 4.4.1.1 of Ref. 3.

With respect to the OT Δ T f₁(Δ I) and OP Δ T f₂(Δ I) penalty functions, the protection system instrumentation design for all operating W-PWRs with OP Δ T/OT Δ T trip includes a signal of axial flux difference, Δ I, to generate reductions in the OP Δ T and OT Δ T trip setpoints. That continues to be the case with the digital OP Δ T/OT Δ T design, with the only difference being that the trip setpoint is the Δ T power signal instead of Δ T. The shape of the penalty function (zero if Δ I is within a deadband range, then a linear increase if Δ I increases outside that range) is also unchanged. The f(Δ I) functions result in more restrictive trip setpoints to account for power distributions in the core potentially more adverse to the design bases than the reference power distribution used for generating the core thermal design limits.

The thermal design limits are typically referred to as Safety Limits in Section 2.1.1 of the plant Technical Specifications, with specific values specified in the Core Operating Limits Report (COLR); and are generated as described in Section 4.3.5 of Ref. 2. As described in that reference, the DNB thermal limits represent the locus of points of core thermal power, primary system pressure, and reactor coolant inlet temperature which ensure that the DNB design basis is satisfied for the reference power shape. The DNBR methodology for generating the thermal limits is the same for either the analog OT Δ T trip or the digital OT Δ T trip. The DNBR methodology for AP1000 application is described in Sections 4.4.1.1.2 and 4.4.2.2 of Ref. 3.

Because DNBR calculations are based on the T_{inlet} and not T_{avg} , conversion to reactor trip setpoints is much simpler for the digital OT ΔT trip than with the analog OT ΔT trip based on T_{avg} . With the digital OT ΔT trip, conversion of the core DNB limits to OT ΔT setpoints requires only subtracting the appropriate uncertainty allowances from the core DNB limit power. The uncertainty analysis to determine the Nominal Trip Setpoint (NTS) error allowances is calculated for the digital design in a manner consistent with WCAP-16361-P (Ref. 4). For these reasons, it **Title:** Bases of Digital Overpower and Overtemperature Delta-T ($OP\Delta T/OT\Delta T$) Reactor Trips

is more appropriate to present the Safety Limits referred to in Section 2.1.1 as functions of cold leg temperature than as functions of T_{avg} .

Title: Bases of Digital Overpower and Overtemperature Delta-T (OP Δ T/OT Δ T) Reactor Trips

3.0 DESCRIPTION OF DIGITAL OP Δ T AND OT Δ T REACTOR TRIPS

Development of the Hot Leg Temperature Signal

Current Westinghouse PWRs have three hot leg temperature signals in each T_{hot} channel, or protection system division, as does the AP1000. These three signals are generated from three locations in the hot leg piping, located approximately 120° apart around the circumference of the pipe. In some operating plants, fluid streams are extracted from these three locations, mixed hydraulically, and passed through a manifold in which RTDs measure the temperature. In other operating plants, three RTDs are placed in thermowells directly in the hot leg pipe. With either system, the hot leg temperature is based on sampling three points in the hot leg fluid stream.

In the analog $OP\Delta T/OT\Delta T$ system, the unweighted average of these three samples is used as the hot leg temperature signal. Changes in hot leg streaming therefore affect the average. The digital design applies the following features to develop a more accurate signal that is less influenced by changes in hot leg streaming:

- Initial filtering of each of the three locally sampled T_{hot-local} signals is done to reduce process and electrical noise. The AP1000 has three hot leg RTDs and thermowells for each of the four protection divisions. The RTD and its thermowell are specified to have response times no greater than a specified value (for example, 4 seconds). This design value is assumed in the safety analysis as the sensor response time, part of the total channel response time. If plant tests demonstrate that the RTD-thermowell combination responds faster than the assigned time constant, additional filtering is applied to reduce process and electrical noise. These filters, if used, are considered part of the sensor delay and would be included in response time testing.
- 2. <u>Streaming Bias</u>: Each $T_{hot-local}$ signal is biased so that it produces a temperature signal equal to the best estimate of the mixed mean hot leg temperature. The bias is proportional to power; that is, zero at zero power and increasing with power. The best estimate of mixed mean hot leg temperature can be determined in various ways. However, errors in determining the mixed mean temperature are not significant contributors to uncertainty in either the ΔT power signal ($q_{\Delta T}$) or the OP ΔT /OT ΔT setpoints.
- <u>Approach to Saturation</u>: Hot leg saturation is a measurement limit rather than a core safety limit. To reduce the influence of hot leg streaming, each T_{hot-local} signal is compared to saturation temperature, as computed from pressurizer pressure. If the T_{hot} signal comes within a preset margin below saturation, the signal is set to the top of the instrument span. (As explained in the steps below, a single T_{hot-local} near saturation would be excluded from downstream calculations. If two T_{hot-local} signals approach saturation, the downstream logic would go to the TRIP state.)
- 4. <u>Redundant Sensor Algorithm (RSA)</u>: After initial filtering and adjusting for streaming, the three signals are compared. If each agrees with the average within a preset tolerance, all three are passed on for downstream processing. If one deviates, it is excluded from downstream processing. As noted above, if two T_{hot-local} signals indicate approach to saturation temperature, the downstream channel will go to the TRIP state.
- 5. <u>Weighted Average:</u> The three T_{hot-local} signals will typically have different noise and streaming characteristics. Weighting factors can be applied based on operating experience

to give higher weight to better signals. The weighting factors are automatically re-adjusted (so they continue to sum to 1.0000 for active channels) in the event that one $T_{hot-local}$ signal is given a BAD quality or fails the RSA check.

6. <u>Dynamic compensation</u>: In the analog design, lead/lags were applied to T_{avg} and ΔT to compensate for instrument delays and transient effects. In the digital design, separate lead/lag compensation is used for the T_{hot} and T_{cold} signals, providing a more accurate indication of coolant temperatures in the reactor core. The T_{hot} lead/lag compensates for fluid transit time from the reactor core to the hot leg RTD location, plus the RTD-thermowell combination and initial filter response time.

Development of the Cold Leg Temperature Signal

In the digital OP Δ T/OT Δ T design, the T_{cold} signal is developed in a manner similar to the T_{hot} signal, with the following differences in details.

- Because temperature streaming is insignificant in the cold leg, only two (instead of three) T_{cold-local} signals exist per division. Design provision is made for biasing the two T_{cold-local} signals proportionally to power (in the same manner as for the hot leg) so that each produces a signal equal to the best estimate of the actual mixed mean cold leg temperature.
- 2. No check for approach to saturation is necessary.
- 3. In the event that the two channels deviate from each other by more than a preset amount, the RSA compares each to the expected cold leg temperature based on power and steamline pressure. If either is within a preset tolerance of the expected temperature, then it is used for downstream calculations. If neither compares favorably with the expected temperature, then the T_{cold} signal for the division receives a BAD quality flag.
- 4. The T_{cold} lead/lag compensates for the RTD-thermowell combination and initial filter, minus the cold-leg-to-reactor-core fluid transit time.

Development of the ΔT Power Signal

In the analog $OP\Delta T/OT\Delta T$, ΔT (T_{hot} minus T_{cold}) is used as the core thermal power indication. In the digital $OP\Delta T/OT\Delta T$ design, a more accurate power signal is generated based on the state properties of water in the hot and cold legs, and on the essentially constant volumetric flow in the cold leg. The equations for the ΔT power signal are:

$$q_{\Delta T} = f(T_H, T_C, P_{PZR})$$

= $\rho(T_C, P_{PZR})[h(T_H, P_{PZR}) - h(T_C, P_{PZR}) - C]/\Delta T^\circ$

where:

 T_C = $(1 + \tau_1 s)/[(1 + \tau_2 s)(1 + \tau_3 s)]T_{cold}$, where T_{cold} is the measured cold leg temperature (lead/lag compensation with time constants τ_1 , τ_2 , and τ_3 applied to compensate for the RTD-thermowell combination and initial filter response time, minus cold-leg-to-core fluid-transport time)

T _H =	$(1 + \tau_4 s)/[(1 + \tau_5 s)(1 + \tau_6 s)]T_{hot}$, where T_{hot} is the measured hot leg temperature (lead/lag compensation applied with time constants τ_4 , τ_5 , and τ_6 to compensate for the RTD-thermowell combination and initial filter response time, plus core-to-hot-leg fluid-transport time)
	A second-order lag is used for T_C and T_H for additional filtering of high frequency noise such as electrical interference.
$\rho(T_C, P_{PZR}) =$	density of water at cold leg temperature T_{C} and pressurizer pressure P_{PZR}
$h(T, P_{PZR}) =$	enthalpy of water at the specified temperature $(T_H \text{ or } T_C)$ and pressurizer pressure P_{PZR}
$\Delta T^{\circ} =$	a conversion factor, so that the value of $q_{\Delta T}$ is 100 percent at normal rated thermal power
C =	A bias coefficient that permits zeroing $q_{\Delta T}$ at zero power (to compensate for small errors in RTD calibration)

The design intent is that the ΔT power signal, $q_{\Delta T}$, be frequently compared to the measured calorimetric power and adjusted as necessary (by adjusting the ΔT° value), similar to standard practice for calibrating the power range neutron flux signal to be equal to the measured calorimetric power. In the AP1000, the reactor operator will have the capability to adjust (calibrate) the ΔT power signal continuously available via the Safety Displays in each division. This is the same design provision that is being made for adjustment of the neutron flux power range signal.

Development of the Digital $OP\Delta T$ Setpoint

The setpoint for the digital overpower trip is continuously calculated with correction (if needed) for adverse axial power distribution.

$$OP\Delta T_{SP} = C_{OP}^{\circ} - f_2(\Delta I),$$

where:

 C_{OP}^{o} = A preset bias, equivalent to K₄ in the analog OP Δ T (Ref. 1)

 $f_2(\Delta I) = A$ function of the neutron flux difference between upper and lower ionization chamber flux signals (to reduce allowable core power, if necessary, because of an adverse axial flux shape)

Increases in ΔI beyond a predefined deadband result in a decrease in the trip setpoint.

Development of the Digital OPAT Margin to Trip

With digital technology, a separate "margin to trip" signal can be generated without increasing either errors or time delays. This permits lead/lag compensation to be put on the "margin to trip" signal to compensate for reactor trip delays (such as for instrument processing, breaker opening, control rod gripper release, and any time necessary for control rod negative reactivity insertion to reduce power).

A reactor trip is initiated if the OP Δ T margin to trip becomes negative (Δ T power signal, $q_{\Delta T}$, exceeds the setpoint) in two of the four divisions; that is:

$$Margin_{OP\Delta T} = [OP\Delta T_{SP} - q_{\Delta T}] (1 + \tau_7 s)/[(1 + \tau_8 s)(1 + \tau_9 s)]$$

where:

 $\tau_7, \tau_8, \tau_9 =$ Lead and lag setpoints provided to compensate, if necessary, for protection-system and control rod insertion delays in reducing core power

A second-order lag is used for additional filtering of high frequency noise such as electrical interference.

Development of the Digital OTAT Setpoint

The setpoint for the overtemperature trip is continuously calculated, with one set of temperature measurements per loop, by interpolating from tabulated core safety limits, with correction (if needed) for adverse axial power distribution:

$$OT\Delta T_{SP} = OT\Delta T_{SP}^{\circ} - f_1(\Delta I)$$

:

where:

- $f_1(\Delta I) = A$ function of the neutron flux difference between upper and lower ionization chamber flux signals (to reduce allowable core power, if necessary, because of an adverse axial flux shape). The source of neutron flux information for $f_1(\Delta I)$ is identical to that for the OP ΔT trip.
- $OT\Delta T_{SP}^{\circ}$ = The core DNB thermal design limit with design axial power distribution, determined by interpolation from specified tables of allowable core thermal power as a function of pressurizer pressure and core inlet temperature, or f(P_P,T_C)
- P_P = Minimum of $[P_{PZR} (1 + \tau_{21}s)/(1 + \tau_{22}s)$ and $P_{PZR}]$. The pressure signal, P_P , is the minimum of the pressurizer pressure signal, P_{PZR} , with and without lead/lag compensation (time constants τ_{21} and τ_{22}). This adjustment compensates for reactor trip delays if pressure is decreasing, but retains conservatism if pressure is increasing.
- T_C = The same signal for core-inlet temperature as used in generating the ΔT power signal, $q_{\Delta T}$; that is, the measured cold leg temperature with lead/lag compensation

Development of the Digital OTAT Margin to Trip

As with the digital OP Δ T trip, a reactor trip is initiated if the OT Δ T margin to trip, including lead/lag compensation, becomes negative (Δ T power signal, $q_{\Delta T}$, exceeds the setpoint) in two of the four divisions; that is,

Margin<sub>OT
$$\Delta T$$</sub> = [OT ΔT_{SP} - $q_{\Delta T}$] (1 + $\tau_{10}s$)/[(1 + $\tau_{11}s$)(1+ $\tau_{12}s$)]

where:

 $\tau_{10}, \tau_{11}, \tau_{12} =$ Lead and lag setpoints provided to compensate, if necessary, for protection-system and control rod insertion delays in reducing core power

A second-order lag is used for additional filtering of high frequency noise such as electrical interference.

4.0 DIGITAL OP Δ T/OT Δ T SETPOINTS IN COLR (CORE OPERATING LIMITS REPORT)

The digital OP Δ T/OT Δ T setpoint values prescribed in the COLR are identified below, with " \geq " or "=" symbols as appropriate. These setpoint values are the values used in the safety analysis of record, as described in Section 5 of Ref. 2, reduced by an uncertainty allowance (Ref. 4) where appropriate.

ΔT Power Signal

The only COLR setpoints in the ΔT power signal generation are the time constants for dynamic compensation of the T_{cold} signal (τ_1 , τ_2 , and τ_3) and the T_{hot} signal (τ_4 , τ_5 , and τ_6). These time constants do not have a "conservative" direction. Larger (or smaller) values will be conservative for some events and non-conservative for other events. Therefore, they are to be set equal to the values used in the safety analyses.

Time constants: $\tau_1 = SA^{(1)}$, $\tau_2 = SA^{(1)}$, $\tau_3 = SA^{(1)}$, $\tau_4 = SA^{(1)}$, $\tau_5 = SA^{(1)}$, and $\tau_6 = SA^{(1)}$.

Digital OPΔT Trip

 $C_{OP}^{\circ} \leq SA^{(2)}$ C_{OP}° is equivalent to the K₄ term for the analog OP Δ T trip (Ref. 1). $f_2(\Delta I)^{(3)}$

Time constants on margin to digital OP Δ T trip: $\tau_7 \ge SA^{(1)}, \tau_8 \le SA^{(1)}, \tau_9 \le SA^{(1)}$

Digital OT∆T Trip

Input table of allowable power versus core T_{inlet} at various pressures⁽²⁾ as discussed in Section 2. $f_1(\Delta I)^{(3)}$

Time constants for pressurizer pressure: $\tau_{21} \ge SA^{(1)}$, $\tau_{22} \le SA^{(1)}$, Time constants on margin to digital OT Δ T trip: $\tau_{10} \ge SA^{(1)}$, $\tau_{11} \le SA^{(1)}$, $\tau_{12} \le SA^{(1)}$,

Notes:

- SA refers to the limiting values used in the safety analysis of record. The lead and lag
 values must equal the values used in the limiting safety analyses for these time constants.
 (Analyses of some events may conservatively neglect lead/lag compensation.)
- (2) These setpoints are more restrictive than the safety analysis values in terms because they include uncertainty allowances.
- (3) The definitions for $f_1(\Delta I)$ and $f_2(\Delta I)$ are identical to current Technical Specification definitions. There is no change in their basis or the methodology for calculating them from the practice with the analog OP ΔT /OT ΔT .

Title: Bases of Digital Overpower and Overtemperature Delta-T ($OP\Delta T/OT\Delta T$) Reactor Trips

5.0 REFERENCES

- 1. WCAP-8745-P-A, "Design Bases for the Thermal Overpower ΔT and Thermal Overtemperature ΔT Trip Functions", September 1986
- 2. WCAP-9272-P-A, "Westinghouse Reload Safety Evaluation Methodology", July 1985
- 3. AP1000 Design Control Document, Revision 17
- 4. WCAP-16361-P, "Westinghouse Setpoint Methodology for Protection Systems AP1000", Rev. 0
 (Note: Rev. 1 will be issued at a later date, and will include setpoints for the digital OPΔT/OTΔT reactor trips.)
- 5. American National Standards Institute N18.2, "Nuclear Safety Criteria for the Design of Stationary Pressurizer Water Reactor Plants", 1973