Subject: OVER TEMPERATURE DELTA-T (OTDT) SCALING		Number: NSD-TB- 91-09-RO	
System(s): WESTINGHOUSE NSSS PROCESS CONTROL SYSTEM		Date: 11/18/91	
Affected Plants: ALL PLANTS WITH W OTDT REACTOR TRIP FUNCTION		S.O.(s): 492/320	
References: PLANT TECH SPECS, PL&S. SCALING MANUALS, NRC INFO NOTICE 91-52	Affects Safety Related Equipment: Yes [X] No [ ]	Sheet: 1 of 8	

INTRODUCTION

NRC Information Notice 91-52 discusses recent events where improper scaling of the Over Temperature Delta-T (OTDT) protection channel allowed the average temperature (T-Avg) lead/lag compensation module to saturate before the T-Avg input reached the upper limit of its range. Saturation of this module prevented further reduction in the OTDT setpoint as T-Avg continued to increase. This channel was, therefore, ineffective in performing its intended safety function.

Although all reported incidents involved 7300 series process equipment, the potential for a similar situation also exists for 7100 and Foxboro equipment. For 7300 equipment, the T-Avg saturation condition was eliminated by redistributing the gains on the OTDT setpoint summing amplifier and the lead/lag compensation module. The input resistor of the OTDT summator was changed from 50k ohms to 24.9k ohms and the gain of T-Avg lead/lag module was reduced by a factor of 50k/24.9k = 2.008. These changes ensured that the OTDT setpoint would reach the trip setpoint before the T-Avg module output saturated.

This Technical Bulletin addresses these modifications and identifies a potential transient concern, solution and recommendations.

BACKGROUND

The OTDT Trip is designed to provide primary protection against departure from nucleate boiling (DNB) during postulated condition II events in Westinghouse reactors. The trip function operates by comparing the temperature difference (DT) between the hot leg and the cold leg of each loop to a calculated

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setpoint (OTDT). A reactor trip is initiated when two or more loop DTs exceed their setpoint. Several terms such as, loop average temperature (T-Avg), pressurizer pressure, and neutron flux distribution in the core (F-DELTA I), are factored into the OTDT trip setpoint calculation (Equation-1).

The setpoint is typically expressed by the following equation:

$$OTDT_{sp} = [K_1 - K_2 (1 + Tau_1 s)/(1 + Tau_2 s) (T_{Avg} - T_{Ref}) + K_3(P - P_{Ref}) - F(Delta\text{-}I)]^*[DELTA\text{-}T] \qquad \text{(Equation-1)}$$

where:

K_1, K_2, K_3 : are gains,

$Tau_1 s$, $Tau_2 s$: are the lead/lag time constants on T-Avg,

T_{Ref} : is the reference T-Avg, typically nominal full power T-Avg

P_{Ref} : is the reference pressurizer pressure, typically nominal pressurizer pressure

F(Delta-I) : is the Delta-I penalty

DELTA-T : is the full power DT

T_{Avg} : is the measured Average temperature

P : is the measured Pressurizer pressure.

When considering implementation of the OTDT setpoint in the protection system, Equation-1 can be reduced and written in the voltage form as follows:

$$V_{OTDT} = G_s \cdot [B_s - G_t \cdot V_t + G_p \cdot V_p - V_{F(Delta\text{-}I)}] \qquad \text{(Equation-2)}$$

where:

V_{OTDT} = OTDT setpoint in volts

G_s = gain on the OTDT summer

B_s = bias on the OTDT summer

G_t = gain on the T-Avg module

$G_t \cdot V_t$ = voltage output of the T-Avg lead/lag module

G_p = gain on the pressurizer module

V_p = voltage equivalent of the pressurizer pressure

$V_{F(Delta-I)}$ = voltage equivalent of the F(Delta-I) penalty

The setpoint calculation in its simple form is shown in Figure-1. As can be seen from the above equations and from Figure-1, as the T-Avg increases, the $OTDT_{sp}$ decreases; as the pressurizer pressure increases the $OTDT_{sp}$ increases and the Delta-I penalty always decreases the setpoint.

DISCUSSION

If the gains and biases in Equation-2 are not distributed properly some of the terms in Equation-2 could reach their maximum (saturate), before the OTDT setpoint reaches its tripped condition. As an example, consider the typical case where the input range of T-Avg is 530°F to 630°F. This corresponds to 0 to 10 volts for 7300, or 1 to 5 volts for 7100 or Foxboro equipment. If the plant is operating at a reduced power level and is at the middle of its T-Avg range (580°F) and the gain G_t on the T-Avg module is 1.6 (i.e., greater than one), then for the 7300 equipment the output of the T-Avg module in steady state will be 5 times 1.6 = 8.0 volts. If the power level is then increased and T-Avg increases to 595°F (65% of its range) the T-Avg module output at this new steady state should be 6.5 times 1.6 = 10.4 volts. However, due to the hardware limitation the output will reach its maximum of 10 volts and its overall contribution to the setpoint will not change for any further temperature increases.

This condition can be resolved by distributing the gains in the Equation-2, i.e.. decrease the G_t and correspondingly increase the gain G_s. The bias B_s, gain G_p and gain on $V_{F(Delta-I)}$ also need to be reduced accordingly.

Transient response situations must also be considered to assure proper operation of the hardware. Specifically, during a transient the amplification associated with the lead/lag compensation unit, (used to anticipate the temperature response of the Reactor Coolant System) could cause saturation preventing further OTDT setpoint decreases on additional temperature (T-Avg) increases.

To illustrate this saturation effect, consider a temperature transient superimposed on the initial steady state conditions (580°F) used in the previous example. Figure 2 gives the output of the T-Avg module, with the lead/lag compensation, to a 2°F/sec temperature increase (postulated rod withdrawal event) for a typical equipment setup (G_t = 0.8, L/L = 28/4). Note that even though the lead/lag module gain is less than 1, the T-Avg module saturates after about 19 seconds (t_o = 5 sec). At this time the input T-Avg has only reached 608°F (580°F + 14 sec times 2°F/sec), which is only about 80% of its possible range.

Even though, the T-Avg module saturation during transients may be unavoidable, the gains can always be redistributed such that the OTDT setpoint reaches a minimum to ensure a trip, i.e., OTDT setpoint reaches the minimum of its range (0 volt, or 1 volt), before the T-Avg module saturates (refer to Figure 3). A technique for achieving this is outlined in the following section.

SOLUTION

The unconservative impact on the OTDT setpoint calculation caused by steady state or transient saturation of the T-Avg lead/lag module can be avoided as follows:

1. Set the gain on the T-Avg lead/lag module to be less than unity. This will keep the T-Avg module from saturating over the entire input range of T-Avg in steady state.

2. Evaluate Equation-2 to determine the Bias (B_s) and OTDT summer gain (G_s) such that the summer output reaches a minimum to ensure a trip condition (output equal to 0 v, or 1 v) before or as the T-Avg lead/lag module output reaches saturation (output equal to 10 v, or 5 v). This is done with the pressure and Delta-I inputs to the Summer acting, to the maximum extent, to keep the setpoint above the trip value.

The second step is illustrated in the following example using the 7300 equipment voltage ranges (0 to 10 v).

Initial conditions (referenced to Equation-2):

a) The output of the OTDT Summer is at the minimum, $V_{OTDT} \leq 0$

b) There is no Delta-I penalty, $V_{F(Delta\text{-}I)} = 0$ v

c) The T_{Avg} lead/lag module reaches saturation, $G_t \cdot V_t = 10$ v

d) $G_p \cdot V_p$ is evaluated at the maximum pressure (usually 2500 psig)

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Solving Equation-2 under these conditions will give a value of G_s.

$$G_s \cdot [B_s - 10 + G_p \cdot 10] \leq 0 \qquad \text{(Equation-3)}$$

or,

$$G_s \geq [G_s \cdot B_s + (G_s \cdot G_p) \ 10] / 10 \qquad \text{(Equation-4)}$$

The value of products $G_s \cdot B_s$, $G_s \cdot G_p$ and $G_s \cdot G_t$ can be determined by comparing Equation-2 to Equation-1 reduced to voltage form, using plant specific parameter ranges and equipment type (7300 in this example). Once G_s is calculated, the bias B_s and the gains G_t and G_p and $F_{Delta(I)}$ need to be calculated based on Equation-2 and the products $G_s \cdot B_s$, $G_s \cdot G_p$ and $G_s \cdot G_t$.

RECOMMENDATIONS

Scaling of the OTDT channel should be examined to confirm that saturation of the T-Avg lead/lag module will not occur in the steady state and that the channel gains are distributed such that, during transient conditions, saturation of this module would occur only after the channel has developed a trip setpoint.

Proper operation of the steady state is assured if the gain of the T-Avg lead/lag module is less than unity.

Equation-2 can be used to verify the proper functionality of the OTDT channel under transient conditions. V_{OTDT} is calculated using the plant specific values for the terms, G_s, B_s, and $G_p \cdot V_p$ (under maximum pressure condition) and assuming the maximum value at the output of the T-Avg lead/lag module (10 v or 5 v) and the minimum value (0 v or 1 v) of $V_{F(Delta-I)}$. If the value of "V_{OTDT}" is equal to or less than the minimum of the equipment (0 v for 7300, or 1 v for 7100 or Foxboro) then the OTDT scaling is done properly. If the value of "V_{OTDT}" does not meet this criteria, then the gain G_s and bias B_s must be adjusted as outlined in the solution section. Once G_s is calculated, the gains G_t, G_p and $F_{Delta(I)}$ need to be calculated based on Equation-2.

OTDT CIRCUIT BLOCK DIAGRAM

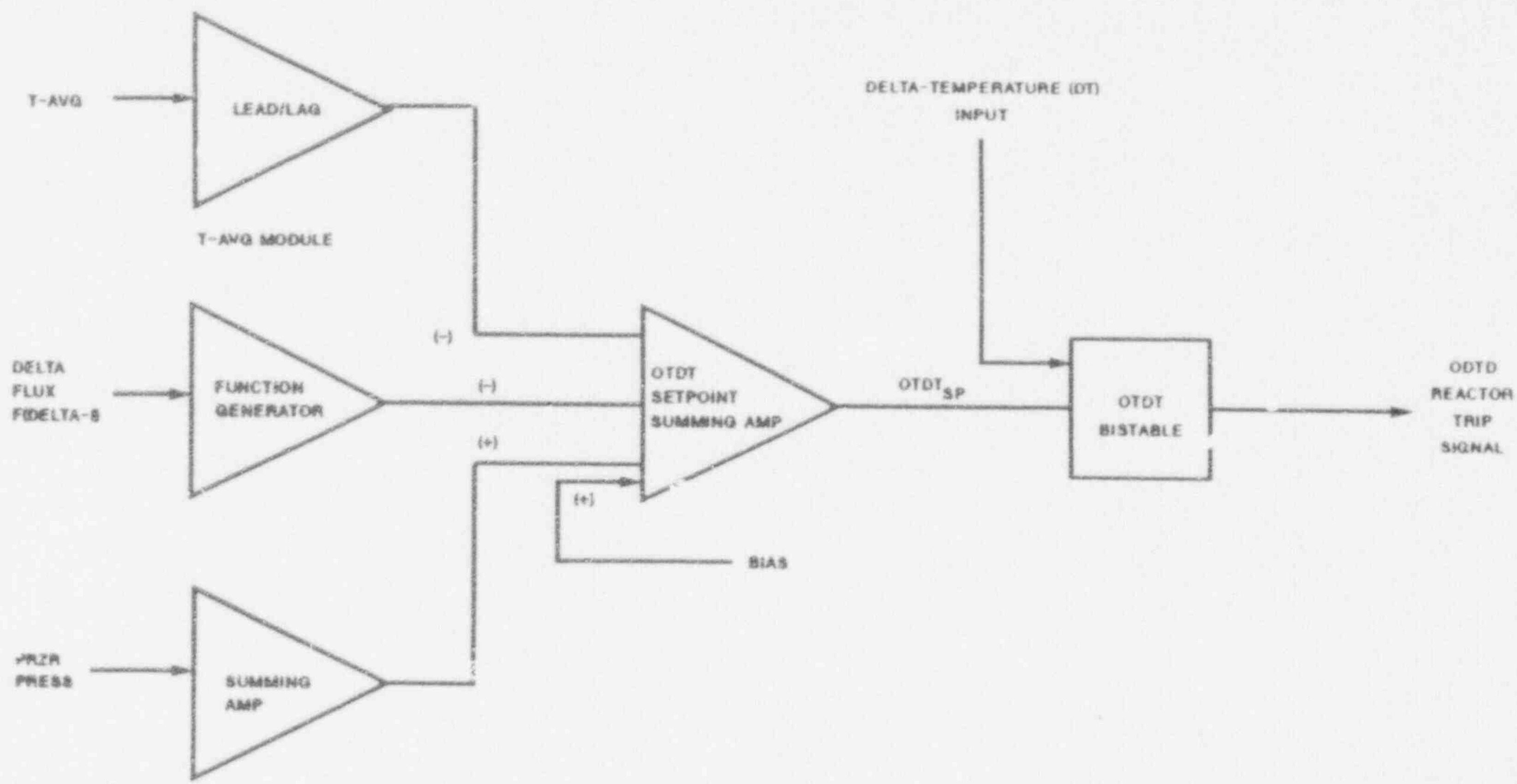

FIGURE 1

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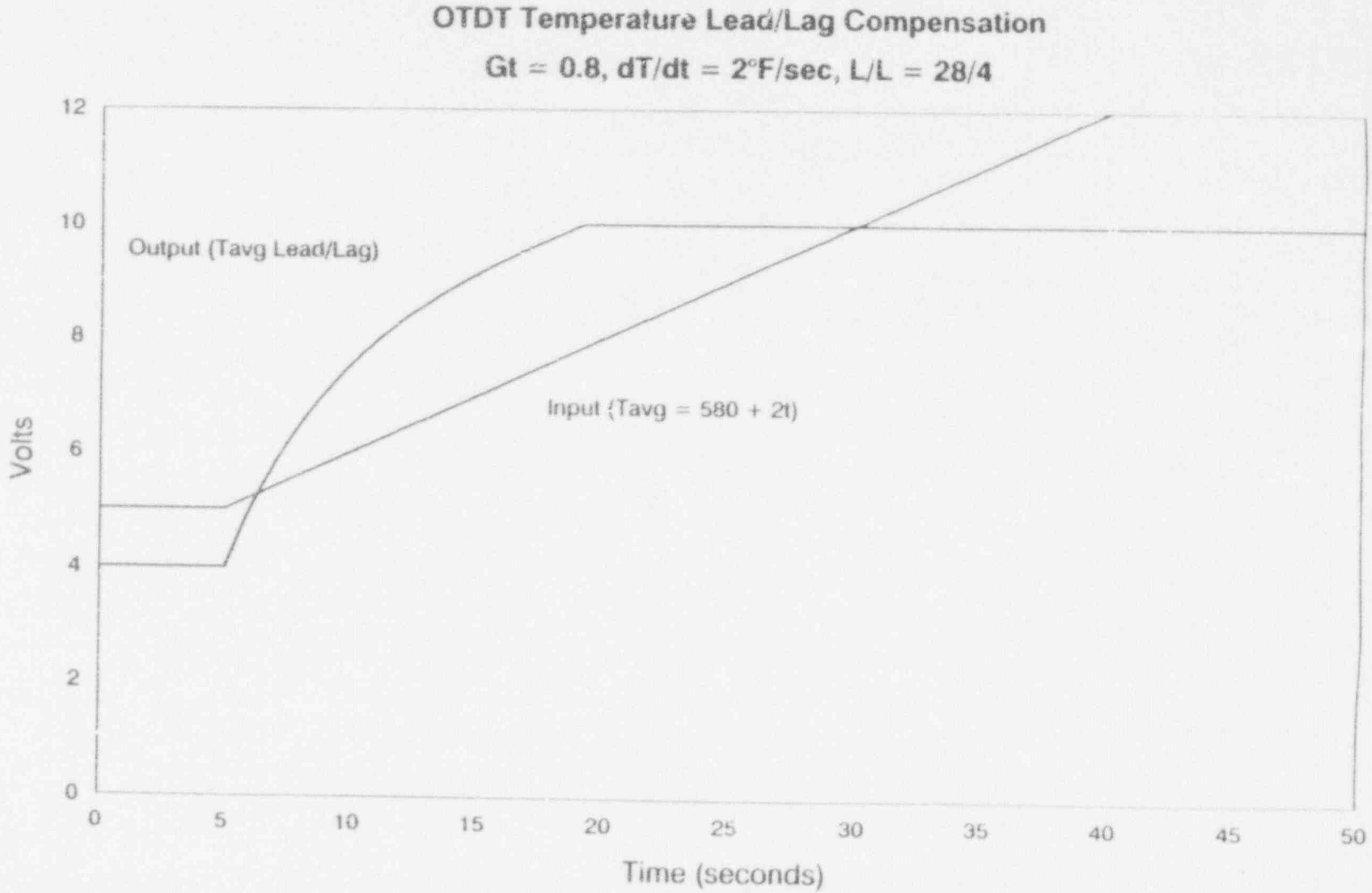

FIGURE 2: OTDT LEAD/LAG MODULE SATURATION

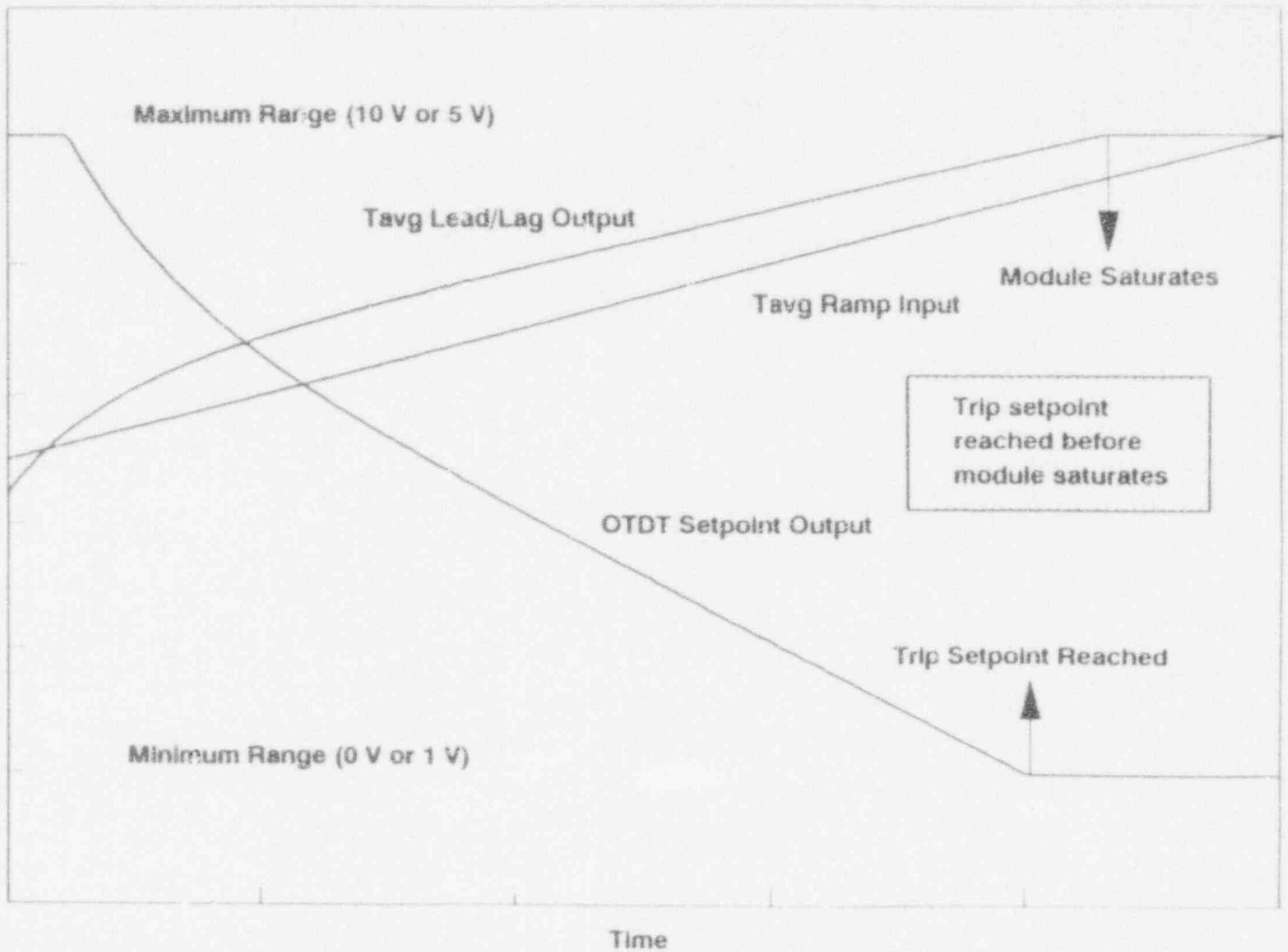

FIGURE 3: ILLUSTRATION OF SOLUTION