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Proposal of CPC Function Improvement

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Abstract

The concept of VLDT (Variable Low DNBR Trip), a new CPC trip function, was proposed and applied to the events of increase in secondary heat removal, such as an excess feedwater event and an IOSGADV (Inadvertent Opening S/G Atmospheric Dump Valve). Major assumption used in this study was no time delay to LOOP (Loss of Offsite Power) after turbine trip. In case of using this VLDT function, safety criterion of DNB would not be violated under the same condition as previous analysis without any change in thermal margin.

I. Introduction

In this study, new CPC VLDT function was proposed and applied to the events of increase in secondary heat removal under the condition of no time delay to LOOP after turbine trip. An Excess Feedwater Event and IOSGADV were analyzed as a typical fast and slow transients, respectively. It shows that the new CPC VLDT function could generate the trip signal early enough to accomodate the margin degradation due to LOOP.

II. Analysis Method and Assumption

Event characteristic of increase in secondary heat removal was increase in power due to thermal reactivity feedback resulted from negative MTC, however, events initiation and causes were different [1]; excess feedwater event was caused by the failure opening of a feedwater control valve or an increase in feedwater pump speed and an increase in main steam flow was caused by an IOSGADV or the turbine control valve malfunction.

II.1. Excess Feedwater Event (Typically Fast Transient)

The maximum feedwater flow increase at full power is approximately 40% above normal feedwater flow [2]. The sequences of event were a decrease in the RCS and S/G pressures, an increase in S/G water level, and increase in power. Detection of these conditions is accomplished by the PRZ low pressure alarms. In analyzing this event, CPC VOPT function was used and its setpoint was 121% of rated full power containing CPC power measurement uncertainty (5%) and power defect (6%) due to temperature decalibration effect [3]. To illustrate the effect of no time delay to LOOP after turbine trip, the change in DNBR was shown in Fig. 1. Judging from the Fig. 1, safety criteria would not be satisfied with this trip function and setpoint.

II.2. IOSGADV (Typiaclly Slow Transient)

IOSGADV event will result in steam release at 11% of full power turbine flow rate [2]. The opening of a steam generator ADV increase the rate of heat removal by the S/Gs, causing cooldown of the RCS. Core power increases from the initial value of 102% of rated core power and reach a asymptotically stabilized value of about 115%. The transient of this event would not limited by VOPT (115% of setpoint was used in this case). The feedwater control system supplies feedwater to the S/Gs such that S/G water levels are maintained. It was assumed that the operator manually trips the reactor. The effect of no time delay to LOOP after turbine trip was illustrated Fig. 2. Shown in excess feedwater event, safety criteria would not be satisfied with current methodology.

III. Solutions

There could be two approaching methods to ensure the safety design limit, SAFDL, for the condition of no time delay to LOOP after turbine trip, one is ROPM increase and the other is the change in trip setpoint or trip logic so that SAFDL would not be violated due to core flow decrease resulted from LOOP.

In case of adopting the method of ROPM increase, thermal margin would be decrease as much as ROPM increase. So this approach would be limited to current thermal margin to CPC/COLSS [3].

III.1. VLDT application

The best merit in CE-type plant was on-line digital system CPC/COLSS. The CPC (Core Protection Calculator) is an on-line digital system which provides pretrip and trip contact output signal to the Reactor Protection System(RPS). The CPC dynamic compensation algorithms provide dynamic adjustments to processed sensor parameters so as to ensure that the low DNBR and high local power density trips [5], respectively, assure that the Specified Acceptable Fuel Design Limits(SAFDL) on Departure from Nucleate Boiling(DNB) and center line fuel melting are not exceeded during Anticipated Operational Occurrences (AOOs).

If no time delay to LOOP after turbine trip was assumed in safety analysis, CPC low DNBR trip function might be meaningless because DNBR would be decreased after reactor trip below DNB SAFDL due to LOOP coincident to turbine trip. New trip function which generate trip signal prior to CPC low DNBR trip was required to avoid DNB SAFDL violation.

In safety analysis, one of the most powerful trip function was VOPT trip for power increase events [3]. A VLDT (Variable Low DNBR Trip) function similar to VOPT was proposed and applied to the event of increase in secondary heat removal. A VLDT is based on auctioneered DNBR from real DNBR and CPC dynamically compensated DNBR. A variable, FLWDNBR, is calculated which follows changes in the auctioneered DNBR within rate limites. FLWDNBR cannot be changed from its previous value by more than an amount depending on the data base rate limites, DELDNBR, and computing interval. The VLDT setpoint is computed by subtracting a fixed DNBR bias, ΔSPvld, to the variable FLW. The VLDT setpoint is limited by a minimum allowable value, SPvmin.

FLWDNBR = MAX (DNBR, FLWp+DELDNBR)

FLW = FLWDNBR

$$SPvldt = MAX\ (FLW - \Delta SPvld,\ SPvmin)$$

$$IF\ DNBR \le SPvldt \quad then \quad Trip\ Signal\ Generation$$

DELDNBR : maximum decrease for FLWDNBR within an execution of UPDATE
FLW : rate limited minimum of auctioneered DNBR
ΔSPvld : amount, by which VLDT setpoint is below FLW, addressable constant
SPvmin : minimum allowable value of VLDT setpoint, addressable constant

III.2 Determination of DELDNBR, ΔSPvld and SPvmin

DELDNBR and ΔSPvld both were determined to cover a fast transient. The rate of change in FLW and trip time by VLDT rate function were dependent to DELDNBR, ΔSPvld, respectively.

A SPvmin, VLDT floor trip setpoint, could be obtained from CETOP run, core T/H calculation code. Physical meaning of this method was to re-calculate the required trip time so that margin degradation due to LOOP should not be greater than one maintained at that time.

IV. Results

As shown in Fig. 1 and 2, safety design criteria could not be satisfied with current analysis methodology without change in VOPT setpoint or ROPM. By using this new CPC VLDT function, trip signal was generated sufficiently early enough to accomodate margin degradation due to LOOP. The change in FLW described in Section III was shown in Fig. 3 and 4. for excess feedwater event and IOSGADV, respectively. Typically fast transient, excess feedwater event was covered by DNBR rate trip, whereas slow transient, IOSGADV, was protected by the floor trip in CPC VLDT function. The DNBR change for these events limited by VLDT function were in Fig. 5 and 6., and DNB SAFDL would not violated.

V. Conclusions

To accomodate no time delay to LOOP after turbine trip without any change in analysis condition, new CPC VLDT function was applied to the events of increase in secondary heat removal. This new CPC VLDT function could be applied to both events of rapid and smooth change in DNBR. So, its feasibility was proven for these events. But, in order to cover any other AOOs, this VLDT function would be verified for general application.

Reference

1. YGN 3/4 FSAR Chapter 15.
2. C.S. Ko, "Fluid System Engineering Design Data for Plant Safety, Performance and Containment Analysis of YGN 3/4", 10487-FS-DD012, August 1991.
3. C.E., "Functional Design Requirements for CPC", CEN-305-P Rev.02, May 1988
4. D.A. Bajumpaa, "Joint Agreement on the Range of the RCS Cold Leg Temperature, CPCs Trip Timing and Setpoints to be used in the YGN 3/4 FSAR Chapter 15 Safety Analysis", K-DEM-SA-91-032, November 1991.
5. A.T. Shesler, "CPC Dynamic Compensation Algorithm", 00000-NSP-3706, April 1977

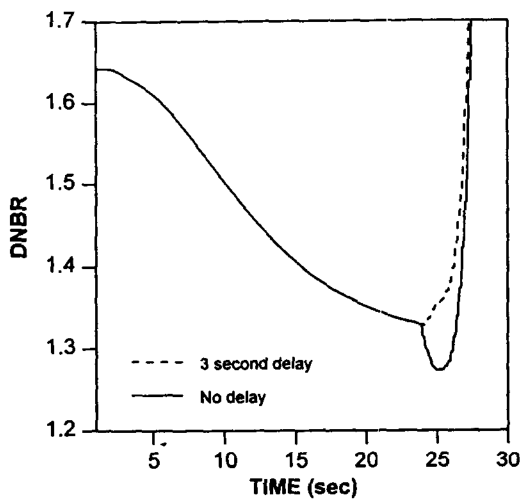

Figure 1. Effect of time delay to LOOP for Excess Feedwater Event

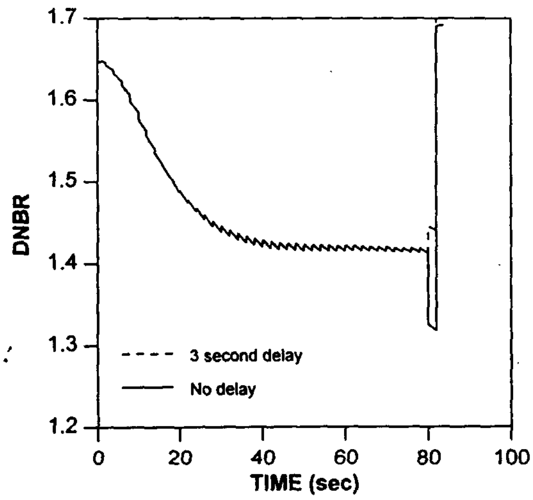

Figure 2. Effect of time delay to LOOP for IOSGADV

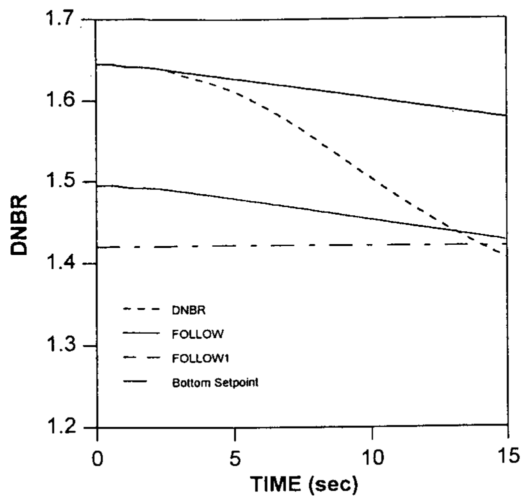

Figure 3. Changes in DNBR and FOLLOW for Excess Feedwater Event

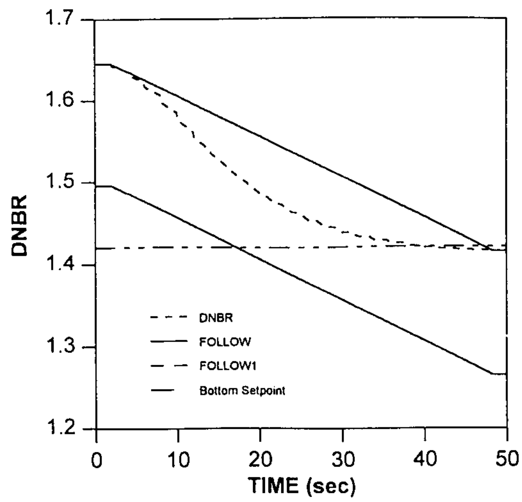

Figure 4. Changes in DNBR and FOLLOW for IOSGADV

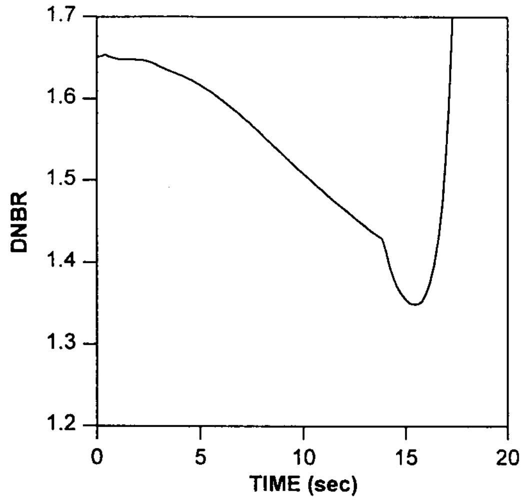

Figure 5. DNBR change due to CPC VLDT for Excess Feedwater Event

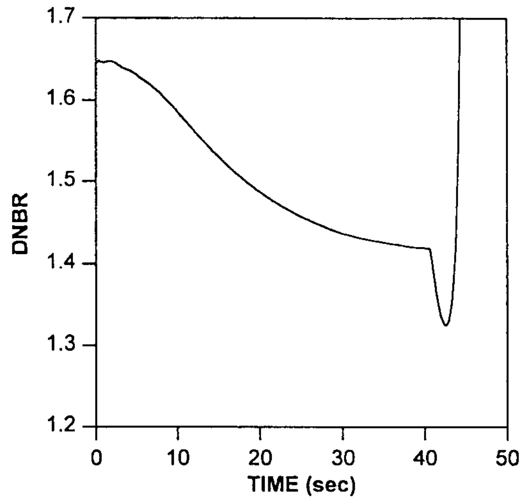

Figure 6. DNBR change due to CPC VLDT for IOSGADV