Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 24-25, 2013

Power Trip Set-points of Reactor Protection System for New Research Reactor

Byeonghee Lee* and Soohyung Yang
Korea Atomic Energy Research Institute, Daedeokdaero 1045, Yuseong, Daejeon, Korea 305-353
*Corresponding author: leebh@kaeri.re.kr

1. Introduction

The reactor protection system (RPS) of new research reactor is designed for safe shutdown of the reactor and preventing the release of radioactive material to environment. The trip set point of RPS is essential for reactor safety, therefore should be determined to mitigate the consequences from accidents. At the same time, the trip set-point should secure margins from normal operational condition to avoid unwanted reactor shutdown.

This paper deals with the trip set-point related to the reactor power considering the reactivity induced accident (RIA) of new research reactor. The possible scenarios of reactivity induced accidents were simulated and the effects of trip set-point on the critical heat flux ratio (CHFR) were calculated. The proper trip set-points which meet the acceptance criterion and guarantee sufficient margins from normal operation were then determined.

2. Reactivity Induced Accidents

Insertion of additional reactivity by experimental apparatus or control absorber rod (CAR) can induce an unexpected power increase of reactor core, causing possible fuel failure by excessive fuel heating [1]. In these cases, the fuel integrity shall be ensured by the adoption of suitable trip parameters, such as core power and log rate. In the new research reactor, the rapid CAR withdrawal inducing continuous reactivity insertion, is analyzed for determining the trip set-points. .

Three independent trip set-points, high power, high log rate and high power level, work for reactor trip in the RIA, depending on the initial power, the reactivity insertion rate. Since the increasing rate of reactor power accelerates with respect to reactivity insertion, the reactor power control becomes more difficult over time. For a safe start-up operation, the power control is separated into two stages depending on the power level, under and over 0.1% of full power (0.1% FP). Under 0.1% FP, the high power level and the high log rate set-point works for reactor trip. Once the reactor power safely reaches at 0.1 % of full power, the operator bypass the high power level signal to increase the reactor power over the level. Over 0.1% FP, the high power and the high log rate set-point works for the reactor trip. Usually, when the initial power is low, the high log rate signal works for reactor trip, whereas the high power signal works when the initial power is high.

3. Analysis Methods and Results

3 different scenarios were considered to determine the trip set-points for RIA. CAR withdrawal during full power operation, under 0.1 % FP, and over 0.1% FP were simulated for various initial conditions and reactivity insertion rates.

For all cases, the CHFR values calculated by Sudo-Kaminaga CHF correlations [2, 3] are checked whether or not they meet the acceptance criterion in new research reactor. The tested range of the high power set points is 17 MW to 22 MW, and that of high log rate is 7%pp/sec to 10%pp/sec. The high power level set point is assumed to be 10%. The delay time of linear and log neutron power meter is assumed to be 0.5 s and the delay between the trip signal and actual CAR drop is assumed as 0.1 s. The Doppler feedback is only considered for the analysis.

Figure 1 shows the CHFR changes over time for different high power set-points on CAR withdrawal accident during full power operation. The reactor is tripped by high power trip set-point rather than the high log rate signal for conservative analysis. The analyses are performed for maximum reactivity insertion rate by CAR withdrawal, 0.4 mK/s, which is selected through the sensitivity analysis of various reactivity insertion rates for various reactivity insertion rates. The high power set-point of 18 MW or 19 MW satisfy the acceptance criterion with margins for the future design change.

Figure 2 shows the CHFR changes for different reactivity insertion rate on CAR withdrawal accident of 0.1% FP with high power set-point of 120% FP. When the reactivity insertion rate is high, the reactor is tripped relatively early by the high log rate set-point, making the consequence is less severe. On the other hands, when the reactivity insertion rate is low, the high log rate set-point does not work and the reactor trip is delayed until the power reaches the high power set-point. The high power at reactor trip makes the consequence severer, nevertheless, still above the acceptance criterion even with the largest high power set-point, 120% FP.

Figure 3 shows the CHFR changes over time for different initial power on CAR withdrawal accident only considering high power level set-point of 10%. The reactivity insertion rate of 0.4 mK/s is used for the analysis since it results in the fastest power increase and the most severe consequence. The smaller initial power results in lower MCHFR value, because the power accelerates further before reach the high power level set-point. As a result, the initial power of 10^{-6} % makes the MCHFR lower than the acceptance criterion. The problem can be resolved either by decreasing the high power level set-point, or adopting the high log rate set-point. When the high log rate of 10% pp/sec is used as a set-point of reactor trip, all the cases show the MCHFR far above the acceptance criterion regardless of the reactivity insertion rate.

Table 1 summarizes the scenarios of RIA, related set-points and whether the MCHFR of the analyses satisfying the acceptance criterion.

4. Conclusions

The three different trip set-points related to the reactor power are determined based on the RIA of new research reactor during FP condition, over 0.1%FP and under 0.1%FP. Under various reactivity insertion rates, the CHFR are calculated and checked whether they meet the acceptance criterion.

For RIA at FP condition, the acceptance criterion can be satisfied even if high power set-point is only used for reactor trip. Since the design of the reactor is still progressing and need a safety margin for possible design changes, 18 MW is recommended as a high power set-point. For RIA at 0.1%FP, high power set-point of 18 MW and high log rate of 10%pp/s works well and acceptance criterion is satisfied. For under 0.1% FP operations, the application of high log rate is necessary for satisfying the acceptance criterion. Considering possible decrease of CHFR margin due to design changes, the high log rate is suggested to be 8%pp/s.

Suggested trip set-points have been identified based on preliminary design data for new research reactor; therefore, these trip set-points will be re-established by considering design progress of the reactor.

Acknowledgement

This work was supported by the National Research Foundation of Korea(NRF) grant funded by the Korea government(MEST) (NRF-2012M2C1A1026916).

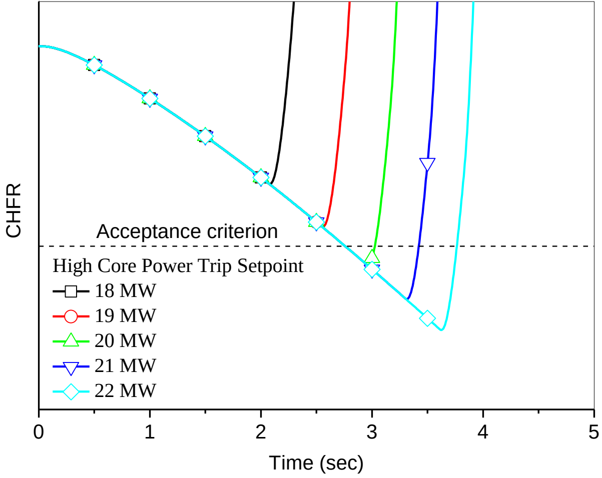

Fig. 1 CHFR changes for different high power set-points on CAR withdrawal accident during full power operation

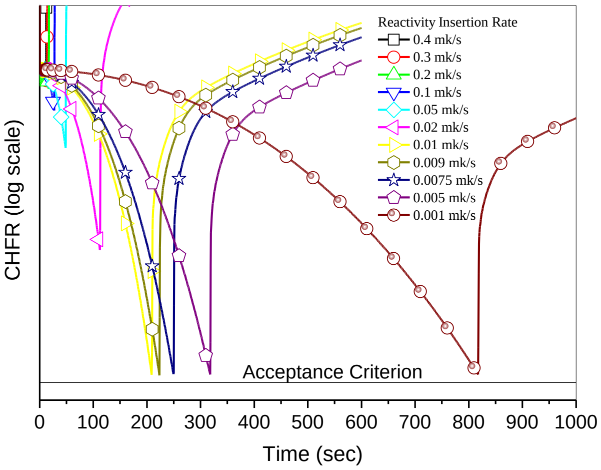

Fig. 2 CHFR changes for different reactivity insertion rate on CAR withdrawal accident of 0.1%FP with high power set-point of 120%

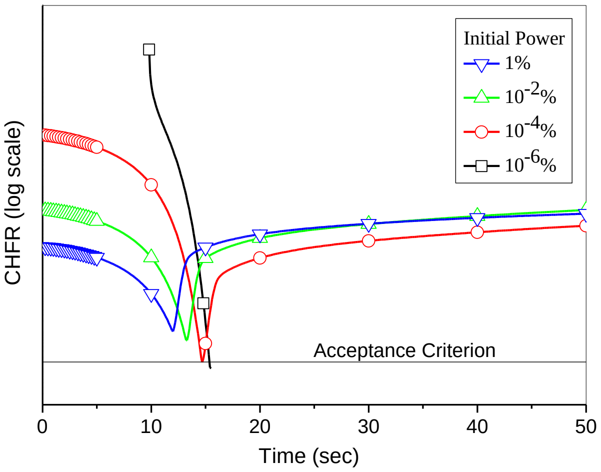

Fig. 3 CHFR changes for different initial power on CAR withdrawal accident with high power level set-point of 10%

Table 1: Summary of trip set-points

Power level	Related set-point	CHFR criterion
FP	High power (18MW, 19MW)	O
Over 0.1% FP	High power (18MW)	O
Under 0.1% FP	High power level only (10% FP)	X
	High log rate (10%pp/s)	O

REFERENCES

[1] IAEA Safety Standards, Safety requirement No. NS-R-4, 2005

[2] Sudo Y. et al., Experimental Study of Differences in DNB Heat Flux between Upflow and Downflow in Vertical Rectangular Channel, Journal of Nuclear Science and Technology, 22 (8), pp. 604-618, 1985

[3] Sudo, Y. and Kaminaga, M., A New CHF Correlation Scheme Proposed for Vertical Rectangular Channels Heated from Both Sides in Nuclear research Reactors, Transaction of the ASME, 115, pp. 426-434, 1993