Turbine Trip Delay System (TTDS) Design in APR1000 I&C

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1. Introduction

In APR1000, the acceptance criteria (Anticipated Operational Occurrence (AOO): No Nucleate Boiling Ratio (DNB) and Design Basis Accident (DBA2): within 10% of fuel damage) is not met due to the reactor coolant flow decrease resulting from the Reactor Coolant Pump (RCP) coastdown due to turbine trip which leads to loss of power to RCP concurrent with reactor trip before decrease in core power resulting from Control Element Assembly (CEA) drop following a reactor trip. In addition, no delay time to turbine trip which leads to loss of power to RCP may cause the decrease in operation margin. The single CEA withdrawal accident is categorized as an AOO and RCP Locked Rotor is categorized as an DBA2 for APR1000. Therefore, the turbine trip delay (TTD) function in APR1000 plant is needed to meet the acceptance criteria and to ensure the operation margin. In this paper, the TTDS design background and the design concept of APR1000 are introduced.

2. Consideration and Implementation

Design of the TTDS in APR1000 requires detailed review of design considerations and backgrounds, as indicated in each sub-clause of this section.

2.1 Safety Classification Requirements

There are some documents to consider for incorporating the TTDS design into APR1000 to suit the needs of European countries. Requirements for safety class are given in Table 8 in [2], which requires designing TTDS as a safety class. The Specific Safety Guide – 2/1 (SSG-2/1) [3] is the top-tier I&C requirements for system designers.

2.2 The needs for TTDS

2.2.1 RCP Locked Rotor

The reactor coolant flow will be decreased due to the RCP coastdown due to turbine trip which leads to loss of power to RCP concurrent with reactor trip before decrease in core power resulting from CEA drop following a reactor trip if there is no TTD function in APR1000 plant.

The safety analysis on the effect of TTD function for RCP rotor seizure accident (categorized as DBA2) has been performed, and verified that the evaluation result can be applied to all DBAs. Figure 1 shows the core flow behavior following RCP rotor seizure accident. As shown in this figure, turbine trip which leads to loss of power to RCP occurs in three (3) seconds after a reactor trip. As a result, the safety margin can be maintained because the additional decrease in reactor coolant flow does not occur for the next three (3) seconds due to the TTD function.

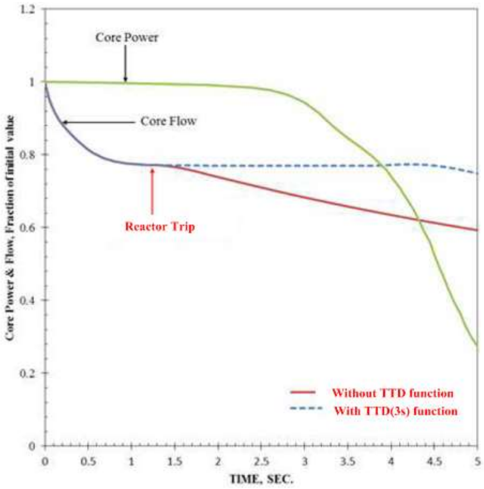

Fig. 2. Core Flow Behavior

2.2.2 Single CEA Withdrawal

The fuel damage is not allowed due to a single CEA withdrawal event (categorized as AOO) and its acceptance criteria cannot be satisfied due to the additionally-decreased DNBR (Departure from Nucleate Boiling Ratio) if there is no TTD function in the APR1000 design.

Figure 2 shows the behavior of minimum DNBR. As shown in this figure, the acceptance criteria is met if three (3)-second TTD function is applied.

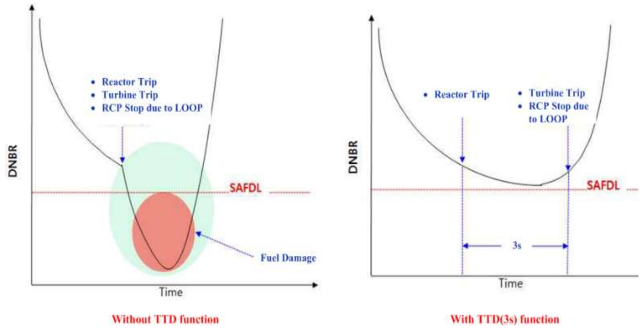

Fig. 2. The behavior of Minimum DNBR
*SAFDL: Specified Acceptable Fuel Design Limit

2.3 Turbine Trip Delay System (TTDS)

The TTDS is part of the RTSS (Reactor Trip Switchgear System). The RTSS consists of four (4) independent channels, each of which includes the CEDM (Control Element Drive Mechanism) phase current monitoring devices and the TTD function circuitry for TTD function.

The three (3)-second TTD signal is generated through the TTD function circuitry in each channelized RTSG cabinet when the status of the phase current monitoring becomes "low" following a reactor trip. The TTD signal is then transmitted to the TCS (Turbine Control System) via the P-CCS (Process – Component Control System) where the 2-out-of-4 logic is performed.

2.3.1 Categorization and Classification

The phase current monitoring devices and TTD circuitry in RTSS are classified as Safety Class 2 (SC-2) in compliance with [2] and [3].

The RTSS equipment including the phase current monitoring devices and TTD function circuitry is classified as Environmental Condition Resistance Level 1 (ECRL 1) and seismically qualified (Seismic Category I).

Power to the CEDM phase current monitoring and the TTD function are provided from 230 Vac ± 10%, 50 Hz ± 5%, single phase, ungrounded and uninterruptible Electrical Class (EC) 1 Vital Bus Power Supply System (VBPSS).

2.3.2 Instrumentation and Control (I&C) System Considerations

The following I&C systems are related to the TTD function as shown in Figure 3.

(1) Reactor Trip Switchgear System (RTSS)
The RTSS consists of four separate RTSG (Reactor Trip Switchgear) cabinets. The three (3)-second TTD signal is generated through the TTD function circuitry in each channelized RTSG cabinet when the status of the phase current monitoring becomes "low" following a reactor trip.

(2) Process – Component Control System (P-CCS)
The P-CCS performs the 2-out-of-4 logic for the TTD signals and then transmits the resulting signals to the TCS.

(3) Turbine Control System (TCS)
The TCS receives the TTD signals from the P-CCS, performs the 1-out-of-2 logic, and actuates turbine trip.

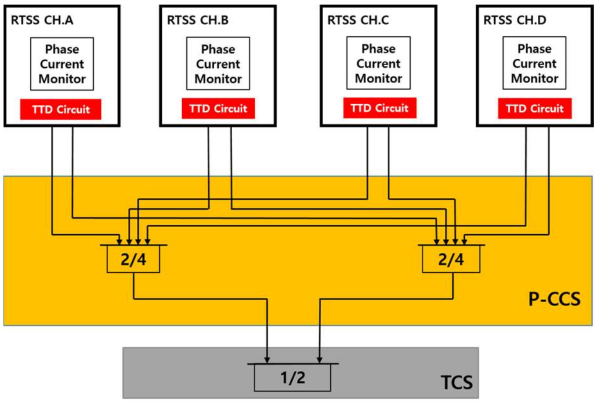

Fig. 3. The Functional Logic Diagram for TTD Function

3. Conclusions

In this paper, the design principles and the needs of TTD function in the APR1000 I&C systems are described. The TTD function is performed by the TTD function circuitry which is in each RTSG cabinet, and it generates turbine trip in three (3) seconds after a reactor trip occurs. Therefore, the TTD function satisfies the acceptance criteria to cope with a single CEA withdrawal event (AOO) and RCP locked rotor (DBA2) in the APR1000 design.

REFERENCES

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