Design Improvement for the Reactor Trip Switchgear System for APR1400 Design Certification

Han Gyu Kim*, Woong Seock Choi, Se Do Sohn
KEPCO E&C, 989-111 Daedeokdaero, Yuseong-gu, Daejeon, 34057
**Corresponding author: KHG46699@kepco-enc.com*

1. Introduction

The Reactor Trip Switchgear System (RTSS) performs the function to open the Reactor Trip Circuit Breaker (RTCB) when the RTSS receives trip signals from the Plant Protection System (PPS).

The RTSS for Shin-Hanul Nuclear Power Plant Units 1 and 2 (SHN 1&2) receives the reactor trip signals from four independent PPS divisions and performs the function to interrupt power from the Motor Generator Set (MG Set) to the Digital Rod Control System (DRCS) as shown in Figure 1. The RTSS for SHN 1&2 consists of four Reactor Trip Switchgears (RTSGs) which form the selective 2-out-of-4 logic. The selective 2-out-of-4 logic generates the reactor trip by the following combinations only : AB, AD, BC, CD.

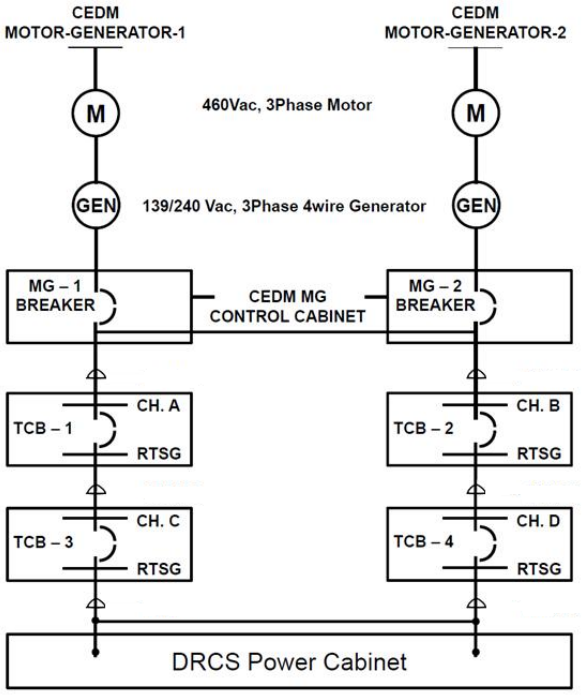

Figure 1. RTSS Diagram for SHN 1&2

On the other hand, the RTSS for APR 1400 Design Certification (DC) consists of two sets of four RTSGs, RTSS 1 and RTSS 2. The configuration has full 2-out-of-4 logic using eight RTSGs that form two RTSSs which include RTSG A-1, B-1, C-1 and D-1 for RTSS 1, and RTSG A-2, B-2, C-2 and D-2 for RTSS 2 respectively as shown in Figure 2. The full 2-out-of-4 logic generates the reactor trip by the following combinations : AB, AC, AD, BC, BD, CD.

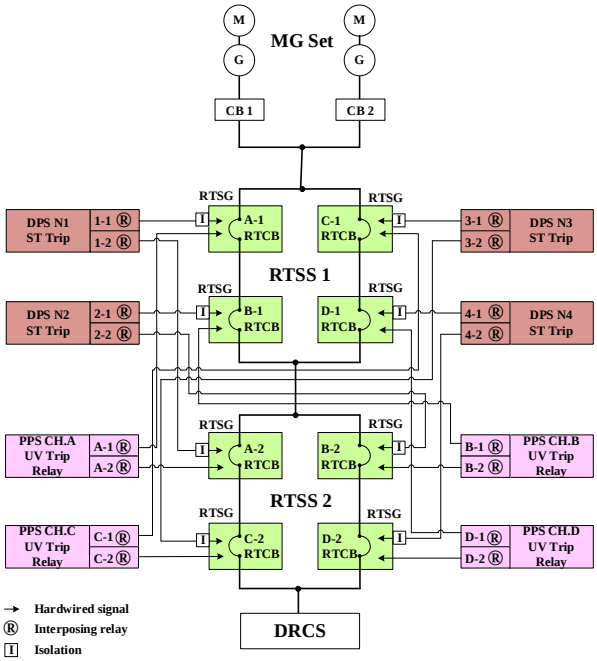

Figure 2. RTSS Diagram for APR 1400 DC

2. Methods and Results

2.1 Design Change Background

The RTSS for SHN 1&2 consists of 4 RTSGs which are connected to selective 2-out-of-4 logic. The RTSG is placed in the trip state when the division is under maintenance or testing. The RTSS for SHN 1&2 meets the minimum single failure criteria because a reactor trip can still occur by the remaining 1-out-of-2 trip output from the other leg during maintenance or testing. Technical Specification section 3.3.4 requires that an RTCB, which is in an inoperable state be opened within one hour, and this requirement is to confirm the RTSG integrity during the periodic testing performed once a month. Even though the RTSS for SHN 1&2 meets the minimum single failure criteria, it does not seem to completely avoid the possibility of spurious reactor trip during maintenance or testing.

The GDC 21 requires that the safety functions remain intact during maintenance or testing. The RTSS for SHN 1&2 satisfies the requirement by complementing through Technical Specification. However, considering the reliability and availability, it is desirable to meet the single failure criteria in any case through redundancy design. Although increasing the quantity of circuit breaker may increase the hardware failure rate and make

maintenance difficult, the design change from selective 2-out-of-4 to full 2-out-of-4 configuration has been applied to enhance the safety system reliability, to follow the trend of the overseas nuclear power plant design, and to minimize the Common Cause Failure (CCF) at the same time.

2.2 Trip Circuit Breaker

Each divisionalized RTSG cabinet includes two RTCBs. The RTSS 1 and RTSS 2 are designed to have diverse design features. The RTCBs for RTSS 1 are supplied by a manufacturer that is different from the manufacturer that supplies RTCBs for RTSS 2. This provides equipment diversity.

Upon a reactor trip condition, each RTCB is opened via the shunt trip and undervoltage trip devices based on the diverse design mechanism. The undervoltage trip device reacts only to a PPS reactor trip condition, whereas the shunt trip device reacts only to a DPS reactor trip condition. A PPS reactor trip de-energizes the undervoltage trip coils of the RTCB to open, while a DPS reactor trip energizes the shunt trip coils of the RTCB to open.

The four reactor trip signals are combined in the PPS to generate two reactor trip signals that are transmitted to the two RTCB undervoltage trip devices (A-1 and A-2) in the respective division (PPS A-1 to RTSS 1 A-1 and PPS A-2 to RTSS 2 A-2), as shown in Figure 2. The reactor trip signal interrupts power to the Control Element Drive Mechanism coils, allowing all Control Element Assemblies to drop into the core by gravity.

2.3 Current Monitoring Devices

The RTSS for SHN 1&2 consists of two parallel legs (A/C leg and B/D leg) as shown in Figure 1. On the other hand, the RTSS for APR 1400 DC consists of two sets of two parallel legs in series (A-1/B-1 leg and C-1/D-1 leg in series with A-2/C-2 leg and B-2/D-2 leg) as shown in Figure 2.

There is one current monitoring device for each phase in RTSG cabinet C-2 and RTSG cabinet D-2 to monitor the current through the RTCBs. Each current monitoring device consists of a current transformer and an electronic package. The current monitoring electronic package and current transformer monitor three phase lines to confirm if the current in the affected current path is removed when the RTCB is opened. The current transformer sends a signal to the low current monitor control unit that is proportional to the load current. If the load current drops below the set level of the control unit, the isolation relay becomes de-energized causing its contacts to change state and provide an open contact.

3. Conclusions

The RTSS design for APR 1400 DC has been changed from selective 2-out-of-4 to full 2-out-of-4 logic by configuring two independent sets of RTSS for diversity. The RTSS with the full 2-out-of-4 logic decreases the chances of generating an inadvertent reactor trip by a failure during maintenance or testing. We expect this design change to contribute to enhancing the plant availability. After all, the quantitative reliability analysis will be necessary to visualize the degree of the plant availability enhancement from the design change described in this paper.

REFERENCES

[1] APR1400-K-X-FS-14002-NP, “APR 1400 Design Control Document Tier 2 Chapter 7”.
[2] APE1400-Z-I-T-12001-P “APR 1400 DC Position Report for Reactor Trip Breaker Configuration”.
[3] 10 CFR 50, Appendix A, GDC 21 “Protection System Reliability and Testability”.
[4] NUREG/CR-6303, “Method for Performing Diversity and Defense-in-Depth Analyses of Reactor Protection Systems”.