Design Characteristics of the APR+ Containment Spray System

Gyu Bong Doh*, Jong Ha Park, Jae Wang Chang
KEPCO Engineering & Construction Co., 257 Yonggudaero, Giheung-gu, Yongin-si, Gyeonggi-do Korea, 446-713
**Corresponding author: gbdoh@kepco-enc.com*

1. Introduction

We, KEPCO E&C, are implementing APR+ design development phase II project, which is owned by the KHNP. The APR+ Containment Spray (CS) System is developed as a four (4) 100%-capacity train system which shares the pumps, heat exchangers, valves, and piping with the Shutdown Cooling (SC) System, meeting the N+2 design concept (capable of satisfying the safety function with a single failure and a concurrent component unavailability due to maintenance) and still maintaining the number and capacity of the system components similar to the APR1400 CS System and SC System combined. The design concept and system configuration of the APR+ CS System are presented.

2. Design Concept and System Configuration

2.1Design Concept

The CS System reduces containment pressure/ temperature and removes airborne radioactive materials during Loss Of Coolant Accident (LOCA) or Main Steam Line Break (MSLB).

The CS System and the SC System of the Shin-Kori 3&4 plants (SKN3&4), the first plants of the APR1400 reactor type, as presented in Figure 1, are two (2) 100%-capacity train systems, respectively, still system availabilities are enhanced by interchangeability of the CS pumps and the SC pumps by adding connection lines between both pump types and designing both pump types with the same design characteristics, such as flow capacity, TDH, etc. [1].

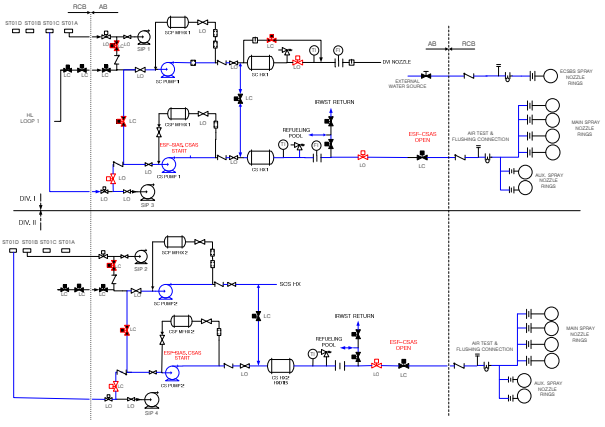

Fig. 1. SKN3&4 CS & SC Systems Configuration

However currently developing Generation III+ nuclear power plants, such as US-APWR and US-EPR generally adopt four (4) train safety systems, meeting the N+2 design concept of the European requirements such as European Utility Requirements (EUR) and Finish regulatory requirements [2, 3, 4, 5]. The N+2 design concept enables on-line maintenance of a safety component because two (2) trains are available under abnormal/accident condition assuming single component failure and concurrent single component maintenance. The N+2 design concept can enhance plant safety and maintainability.

The CS System and the SC System of the APR+ require similar components such as pumps and heat exchangers of similar capacity. The CS function is peaked at the initial phase of LOCA or MSLB, while the SC function is delayed until the Reactor Coolant (RC) System pressure and temperature are reduced to the SC accident entry condition of 380 ^{o}F and 400 psia. Therefore peak capacities of both systems do not overlap each other. The CS System and the SC System can be combined with shared pumps, heat exchangers, valves, and piping, giving priority to the CS function and still enabling the SC function during an accident. Therefore four (4) train CS System and four (4) train SC System are adopted with shared components.

While the US-APWR adopts four (4) 50%-capacity train SC/CS Systems, the APR+ selected four (4) 100%-capacity train SC/CS Systems enabling improved safety and system margin.

In order to implement the four (4) train SC/CS Systems, four (4) emergency diesel generators are installed, and supporting systems such as component cooling water system, essential service water system, auxiliary building controlled area HVAC system, and essential chilled water system have independent four (4) trains, respectively.

The four (4) train SC/CS Systems are implemented with added valves and connection piping, and SC/CS heat exchanger capacity is determined based on the SC function because the SC heat exchange capability requires larger heat removal capacity because of the smaller temperature difference between the SC water and component cooling water during the refueling operation mode.

2.2 System Configuration

As presented in Figure 2, the SC/CS pumps, SC/CS heat exchangers, and SC/CS mini-flow heat exchangers of the APR+ CS System are shared with and belong to

the SC System [6]. The CS System is separated from the SC System by the isolation valves. The spray header rings and spray nozzles form two (2) trains which are shared by trains A/C and trains B/D because the spray header rings and spray nozzles are passive components, and have low probability of component failure, and containment dome has limited space, and four (4) trains, if installed, can interfere each other.

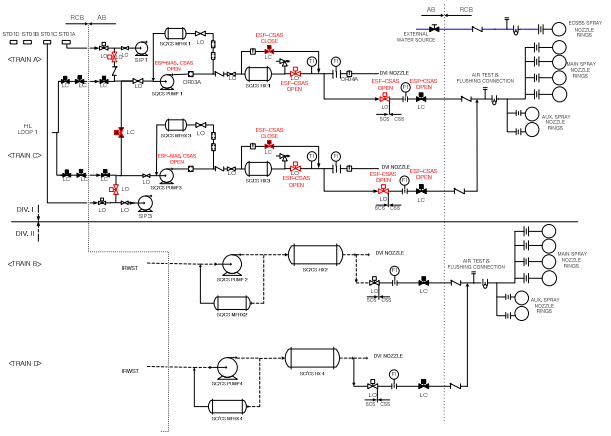

Fig. 2. APR+ SC/CS Systems Configuration.

During power operation, the four (4) SC/CS trains are aligned for CS standby. In case LOCA or MSLB accident occurs during power operation, all four (4) SC/CS trains can automatically supply containment spray upon Containment Spray Actuation Signal (CSAS) and spare trains, more than two (2) trains, will be stopped manually. If the SC function is required during an accident, spare trains, more than two (2) CS operating trains, will be manually aligned for SC operation.

During hot shutdown operation, two (2) SC/CS trains are aligned for SC operation and the others are aligned for CS standby. In case LOCA or MSLB accident occurs during hot shutdown operation, two (2) SC/CS trains among the four (4) SC/CS trains shall be automatically or manually aligned for CS operation. In case one (1) CS/SC train is under maintenance upon LOCA or MSLB accident, one (1) operating SC train shall be aligned to the CS operation manually. In order to verify the capability of a SC operating train as a standby train for CS operation, operator response time for manual switchover without exceeding containment design pressure is under evaluation.

During cold shutdown operation, no CS standby is required due to small heat content of the reactor core and the RC System.

Upon beyond-Design Basis Accident (DBA) of all four (4) DBA CS trains unavailability or IRWST failure, one (1) 100%-capacity train Emergency Containment Spray Backup System (ECSBS) can supply backup spray water using fire engine, independent of Class 1E AC or DC power source, and water source such as reactor makeup water tank, demineralized water storage tank, fresh water storage tank, and raw water tank.

3. Conclusions

The APR+ CS System enhanced system reliability and maintainability in contrast to SKN3&4 by adopting four (4) 100%-capacity SC/CS trains combined with the SC System. The APR+ CS System provides improved and competitive design against competing plants such as US-APWR or US-EPR. Manual switchover of the SC operating train to the CS operation will be further evaluated and developed.

REFERENCES

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