Feasibility Study on New Concept of DHRS in KALIMER-600

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1. Introduction

The new concept of the safety graded decay heat removal system (SGDHRS) is suggested to complement the weakness of the existing passive decay heat removal circuit (PDRC) of KALIMER-600 in the long-term cooling capability. Components of the decay heat removal system in both concepts are the same. The system is operated by natural circulation flow which consists of a DHX (Decay Heat eXchanger), an AHX (Air Heat eXchanger), and piping system connecting two heat exchangers. The DHX of PDRC partly submerged in the cold pool; on the other hand, it is fully submerged in hot pool side. For the comparison of the long-term cooling capability of both systems, a LOOP (Loss Of Offsite Power) of KALIMER-600 reactor was analyzed using two types of DHX's using the MARS-LMR system analysis code [1].

2. Analysis of LOOP

KALIMER-600 is a pool type sodium-cooled fast reactor loaded with metallic fuel of U-TRU-10%Zr for a core [2] and it produces the thermal power of 1538 MW. The plant has an inherent safety characteristic owing to the design to have a negative power reactivity coefficient during all operation modes and it has a passive safety characteristic due to the design of a passive decay heat removal circuit (PDRC).

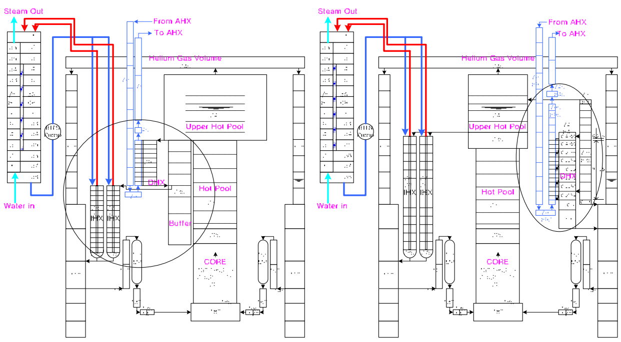

Figure 1. MARS-LMR nodalization for KALIMER 600 MWe

However, PDRC has a weakness which uses the sodium overflow from the hot pool to cold pool to transfer heat produced at the core. The hot pool temperature is dependent on the overflow elevation. Other one is that PDRC becomes unavailable in the case of vessel leak accident because the accident reduces the hot pool level by 1 m. To overcome the weaknesses, a design to submerge the DHX directly into the hot pool is suggested. As shown in the figure 1, while the DHX of PDRC is partly submerged into the cold pool in the normal operation and fully immersed as the cold pool level rise following pump trip in the accident situation, the DHX of new concept is always submerged into the hot pool because it is directly connected with the bottom of upper hot pool node and the cold sodium cooled by DHX is dumped into the cold pool through the IHX (Intermediate Heat eXchanger).

The air damper in the AHX is needed to reduce a heat loss to atmosphere in the new concept DRC because the DHX is always immersed in the hot sodium pool. So the passiveness is slightly decreased due to the active damper.

The figure 1 shows the MARS-LMR nodalization for the system. In the primary system two main pumps take sodium from the pool and discharge it into inlet pipes. Then the flow is entered into the inlet plenum feeding fueled driver subassemblies. The sodium is heated through 7 core regions and mixed in an outlet plenum of the reactor. Then the sodium goes to the IHX inlet through lower hot pool nodes. In the IHX, the sodium transfers its heat to the sodium of the intermediate loop. The primary sodium that leaves the IHX dumps directly back into the cold pool.

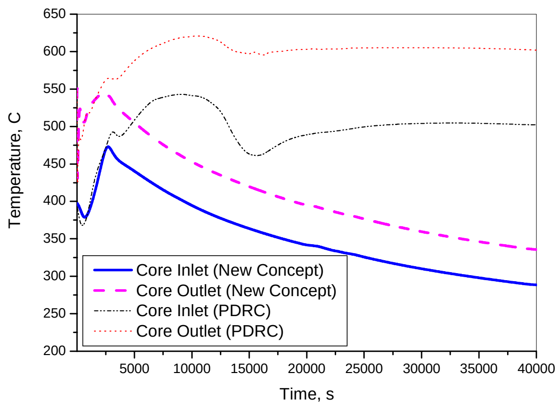

Figure 2. Core I/O temperatures behaviors

The transient calculation results are shown in figures 2 and 3. The accident is caused by a loss of offsite power which brings to trip the reactor and primary pumps simultaneously. In the calculation, the accident is assumed to occur at 10 seconds. So the reactor scram causes at same time as the accident occurrence. It is assumed that the air damper is opened at 1,800 seconds after the accident initiation to consider conservatism of active component.

At the early stage of the accident, the temperatures are goes up because of a loss of heat sinks of steam generators. The operation of PDRC's with overflow of hot pool to cold pool is started from about 7,000 seconds in the KALIMER-600 system with the PDRC. The coolant flow through the global path into DHX, cold pool, and core is activated then. The cold sodium is injected into the inlet plenum and the core temperatures are temporarily dropped, however, the decay power from the reactor is still higher than the heat removed by the PDRC as shown in figure 3. The temperatures go down when the heat removal by the PDRC exceeds the core decay power. The temperatures are again decreased around 32,000 seconds by the excess cooling by the PDRC.

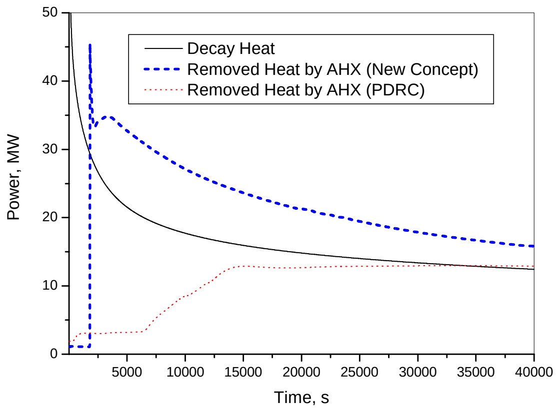

Figure 3. Decay heat removal

On the other hand, the core I/O temperatures in the KALIMER-600 system with the new concept DRC are increased until the heat removal by AHX brisk due to the opening of air damper at 1,800 seconds. Around 2,700 seconds the temperatures start to decrease by much bigger heat removal at the AHX compared to the decay heat. In view of the temperatures of final reached, the accident is mitigated and terminated using the new concept DRC.

3. Conclusion

The feasibility study on the DRC type of KALIMER-600 sodium cooled fast reactor is simply investigated through the calculation of the LOOP accident. The current PDRC design satisfies the safety limit of the temperature of 700 ℃, however, the design has some weaknesses in some accident conditions. Alternatively a new submerged DRC concept was proposed and was calculated satisfactorily.

ACKNOWLEDGMENTS

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REFERENCES

[1] Kwi-Seok Ha et al., "Simulation of the EBR-II Loss-of -Flow tests using the MARS code", *Nuclear Technology*, Vol. 169, No. 2, 2010.

[2] Dohee Hahn et al., "Advanced SFR design concepts and R&D activities", *Nuclear Engineering and Technology*, Vol.41, No.4, 2009.