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Overview of NSSS Fluid System Design of PGSFR

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1. Introduction

PGSFR is a 150MWe Prototype Gen-IV Sodium-cooled Fast Reactor. For the acquisition of specific design approval of PGSFR the conceptual design and pre-specific design with design level 3 for PHTS (Primary Heat Transport System), IHTS (Intermediate Heat Transport System), DHRS (Decay Heat Removal System), and SWRPRS (Sodium-Water Reaction Pressure Relief System) of the PGSFR have been conducted since 2012. Design level 3 represents a preliminary design in which functions and performances of SSCs (Systems, Structures and Components) are fixed.

System concepts and major components design concepts for PHTS, IHTS, DHRS and SWRPRS were developed. Thermal-hydraulic characteristics were analyzed based on CFD simulation. The design bases and concepts for auxiliary systems were also developed.

The upstream design requirements of fluid system such as system design requirements, component design requirements, I&C design requirements, BOP interface design requirements, design guides and P&IDs were produced.

The control logic and computer code for the analysis for operational characteristics is under progress.

In this paper an overview on the NSSS fluid system design of PGSFR is described based on the issued design documents.

2. Fluid System Design

(1) Safety Classification of NSSS SSCs

The safety classifications of major SSCs are decided based on the degree of importance of their roles in plant safety. The safety classification is a systematic attempt to optimize efforts in the design, manufacture, inspection and quality control of SSCs to achieve the desired level of safety. Generally, there are two methods for safety classification such as deterministic and risk informed safety classifications. In Korea, the safety classification of LWR (Light Water Reactor) is made by deterministic way, and is given by regulation [1]. Also, Korean regulatory body, KINS recently has developed preliminary safety classification criteria through the assessment of applicability of LWR criteria to SFR criteria [2]. In the PGSFR, the NSSS SSCs important to safety are classified as Safety Class 1, 2, 3, and non-nuclear safety (NNS) using the intention given in References [1-3].

(2) Design of PHTS

The function of PHTS are: 1) to transfer the heat generated from the reactor core to the IHTS without allowing the reactor to exceed temperature limits, 2) to form a physical barrier against the uncontrolled release of the PHTS sodium and radioactive materials to the environment during normal and accident conditions, and 3) to circulate the PHTS sodium and cover gas for the purpose of maintaining those fluids within prescribed chemistry in conjunction with the Primary Sodium Purification System (PSPS) and the Primary Inert Gas Processing System (PIGPS).

The PHTS pump is a motor-driven centrifugal type mechanical pump and the two PHTS pumps are immersed in the cold pool. The PHTS pump is equipped with a flywheel for the flow coastdown to prevent the fuel temperature from exceeding its design limit following a loss of power to the pump. For the refueling operation with very low PHTS sodium flow rate, a pony motor is utilized to remove the decay heat. Four cylindrical-shaped IHXs are installed inside the reactor vessel. The IHX is shell-and-tube type heat exchanger with counter-current flow heat exchanging mechanism. The schematics of PGSFR configuration is shown in Figure 1.

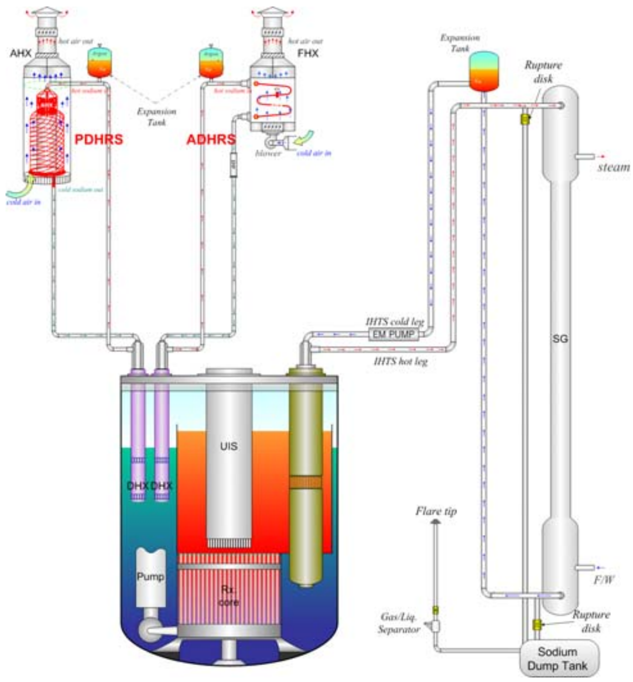

Figure 1 Schematics of PGSFR configuration

(3) Design of IHTS

The IHTS transfers the core heat to the SG through the IHX and the IHTS sodium loops. The IHTS has two loops and each loop consists of two IHXs, one Electromagnetic (EM) pump, one SG, hot/cold legs, and one expansion tank. The IHTS loop is thermally coupled with the PHTS via the IHX and also with the PCS via the SG.

The non-radioactive sodium of the IHTS loop is circulated by the EM pump installed in the cold leg of the loop. The pump is an Annular Linear Induction Pump (ALIP). The flow rate and the head are controlled by varying the voltage and frequency of the EM pump. The SG is single-wall, straight-tube, once-through integrated type and converts subcooled water to superheated steam by transferring heat from the IHTS sodium to water/steam, and provides superheated steam to the turbine. Orifices are provided at each SG tube inlet to prevent flow instability in low feedwater flow condition with two-phase steam-water flow.

(4) Design of DHRS

DHRS provides sufficient cooling capability to bring the plant to safe shutdown condition under post-accident conditions for any event that requires the DHRS. The heat removal capacity of the DHRS is 10 MWt which amounts to about 2.5% of the rated core thermal power. The DHRS is capable of cooling the plant from the temperature of any power operation condition to the hot shutdown temperature within 72 hours after reactor shutdown with a single failure.

The DHRS has four independent loops considering redundancy and diversity. There are two types of DHRS loops. Two Passive DHRS (PDHRS) loops are driven by buoyant head induced by elevation differences and temperature differences between the two heat exchangers and by stack. Two Active DHRS (ADHRS) loops are driven by active components (i.e., a pump and a blower). Additional diversity between the two types of DHRS loops is achieved by different component design (i.e., AHX and FHX) and diverse control systems.

The PDHRS is a safety-grade passive system, which is also comprised of two independent loops with one DHX immersed in the cold pool, one Natural-draft Sodium-to-Air Heat Exchanger (AHX) located in the upper region of the reactor building, four dampers with two dampers in parallel for both AHX inlet and outlet, one expansion tank, cold/hot legs and one stack.

The ADHRS is a safety-grade active system, which is made up of two independent loops with one DHX, one Forced-draft Sodium-to-Air Heat Exchanger (FHX), one EM pump, one blower, four dampers, one expansion tank, cold/hot legs and one stack.

(5) Design of SWRPRS

The SWRPRS is provided to protect the IHTS against excessive pressure. It has been designed to discharge the rapidly increasing SWR products (mainly hydrogen gas) and to relieve the IHTS pressure from a large leak event.

The SWRPRS consists of the Sodium Dump Tank (SDT), gas/liquid separator, rupture disc, backpressure rupture disc, Water Dump Tank (WDT), hydrogen igniter and nitrogen injection system. The rupture discs are installed at the pipes connected to the hot leg and cold leg of the IHTS, which are located at the top and bottom of the SG. Excessive pressure in the IHTS and the SG makes the rupture disc burst, and then sodium coolant and SWR by-products are dumped into the SDT. Gaseous reaction products and some entrained sodium are directed to the gas/liquid separator where the entrained sodium is removed. The gaseous products are then directed to the stack where a hydrogen igniter is installed.

(6) Provision of I&C System

The instrumentations and their functions are preliminarily determined. I&C (Instrumentation and Control) system is composed of PMS (Plant Monitoring System), PCS (Plant Control System) and PPS (Plant Protection System). PMS displays and logs plant process variables for use in determining plant state with respect to operation and safety. PCS provides the means to maintain process variables within their design range during normal operation. PPS provides an automated capability for energizing safety equipment to maintain the plant state within safe limits.

The protection system consists of a safety grade PPS and a non-safety grade DPS (Diverse Protection System). The DPS provides a diverse method to trip the reactor to satisfy the requirements relative to ATWS (Anticipated Transients Without Scram) as well as Defense-In-Depth and Diversity.

Trip by PPS is initiated by 2 out of 4 voting logic, and trip by DPS is initiated by 2 out of 2 voting logic. Provisions for manual initiation from the control room and remote shutdown panel are required on all of the above signals.

3. Acknowledgement

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REFERENCES

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