System Configuration of a SFR Demonstration Plant Developing in KAERI

Lee, Jae-Han [a*] and Kim, Jong-Bum [a]
[a]*Korea Atomic Energy Research Institute, Yuseong-gu, Daejeon, The Republic of Korea*
[*]*jhlee@kaeri.re.kr*

1. Introduction

The one of long-term R&D plans aims to build an advanced SFR (Sodium-cooled Fast Reactor) demonstration plant by 2028. Currently a conceptual design phase (2007~2011) is in progress. The goals of the plant are to verify a transuranics (TRU) burning function and several technical issues.

This paper describes what's different in SFR compared to PWR (Pressurized Water Reactor). The NSSS (Nuclear Steam Supply System) of a SFR has several different design features compared to a PWR because of the use of liquid metal sodium at high temperature environment instead of the use of water as coolant. The sodium coolant is under atmospheric pressure, and the operating temperature is around 500°C. Unlike a PWR, the fuel exchange should be performed in the inert gas environment without opening the reactor head.

2. NSSS Systems of a SFR

The entire system for the SFR plant consists of reactor core, coolant and connection systems, engineered safety equipment, monitoring and control system, auxiliary system, the turbine system, radioactive waste management system, power system, radiation protection system, etc., those are similar with the systems of a pressurized water reactor.

The NSSS of a SFR consists of the following major systems;

- Reactor core ; generates heat by nuclear fission
- Reactor coolant system ; translates the reactor heat to steam generator by circulating of the sodium coolant
- Plant protection system
- Plant control and monitoring system
- Engineering safety facility system ; performs a decay heat removal from reactor coolant system for accidents, and also accident mitigation.
- Auxiliary liquid metal processing system ; controls the impurities of sodium coolant and supplies sodium to the intermediate liquid metal processing line.
- Inert gas processing system ; fills the space above sodium free surface of reactor vessel and steam generator shells, and sodium pumps to prevent the sodium contact with air.
- Fuel Handling System
- Reactor Start-up System

The auxiliary systems of the NSSS and BOP (Balance of Power) of the SFR plant are listed in Figure 1.

There are distinct differences in the auxiliary systems of SFR compared with PWR ; the fuel exchange and storage system, an inert gas supply and processing system, the auxiliary liquid metal processing systems, heating system of piping and equipments, and sodium fire protection system, etc.

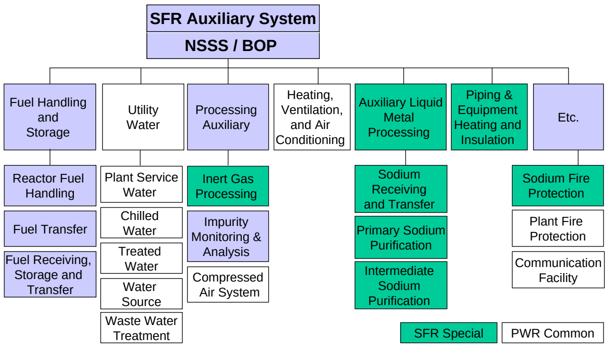

Figure 1 Auxiliary Systems of a Nuclear Plant

The pool-type demonstration reactor has a two-loop system with 2 steam generators, and the electrical capacity is of 600MWe. The system configurations are represented in Figure 2.

The primary components and the intermediate heat transfer systems are actually symmetric. For convenience, steam generators, auxiliary systems and decay heat removal systems are represented by dividing on both sides of the building compartments. In addition, the reactor internal components are expressed differently on both side spaces for convenience.

3. Engineering Safety Equipments

Engineering safety facility systems of the plant are designed to inhibit or prevent a large amount release of radioactive materials due to failed fuel by any damage, or malfunction in nuclear reactors. The engineering safety facilities of PWR usually have two systems of an emergency core cooling systems and a reactor containment system.

First, the emergency core cooling system does not exist in SFR for the following reasons;

(1) The evaporation of a coolant does not occur even when the system pressure becomes lower due to the pipe broken because the boiling point of sodium coolant is so high about 883 ℃ at atmospheric pressure.

(2) The core is easily cooled because the coolant sodium is metallic having a high thermal conductivity.

(3) The large buoyancy force grows natural circulations in reactor because of the large thermal expansion rate of the coolant sodium when heated.

As a result, a secure of sodium free surface and a decay heat removal concept have been adopted for the engineering safety facility of SFR. For the accident like that a crack occurs at the reactor vessel, the secure of sodium free surface will prevent the core to be exposed to the air by limiting a certain amount of sodium leakage into the reactor containment vessel, which encloses the reactor vessel maintaining a certain width. For this reason, injecting additional coolant into the vessel does not be needed.

Because a decay heat removal function is ensured if a sodium free surface covering a reactor core in reactor vessel, a coolant natural circulating circuit, and a decay heat sink are available, the system and components should be arranged to facilitate a natural circulation.

Second, the containment facility for a SFR means containment area and related facilities, like as PWR. In SFR, an intermediate heat transfer system exists between the reactor and steam generator, the steam generators are not included in the containment boundary because a coolant passing through the reactor core does not directly contact to steam generators.

Because SFR coolant sodium has a strong reduction ability of a radioactive iodine, and absorbs most of it, an emission of radioactive iodine into the interior of the containment zone is relatively small. The coolant sodium is also used in lower temperature than a boiling point, the internal pressure of the containment zone does not rise much even if an accident.

Within a reactor vessel, an inert gas is injected to the upper cover of a sodium coolant. As an inert gas, usually argon (AR) gas is used during the operation, but there is a high concentration of radioactivity since radioactive Ar-41, having a half-life of approximately 14 hours, is generated. Therefore, the cover gas system should be located inside of the containment facilities.

In addition, in case of a direct sodium-water reaction accident by a tube break of a steam generator, the installation of the steam opening system for steam generators, and a large vessel that houses the reaction products ensures the accident not to develop into a serious crisis.

A system configuration update considering the distinct features has being performed for a SFR demonstration plant.

ACKNOWLEDGEMENT

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REFERENCES

[1] Lee, Jae-Han, " System Summary Description for a Building Arrangement of a SFR Demonstration Plant," SFR-MS116-SD-01-2011Rev.0," 2011.7.

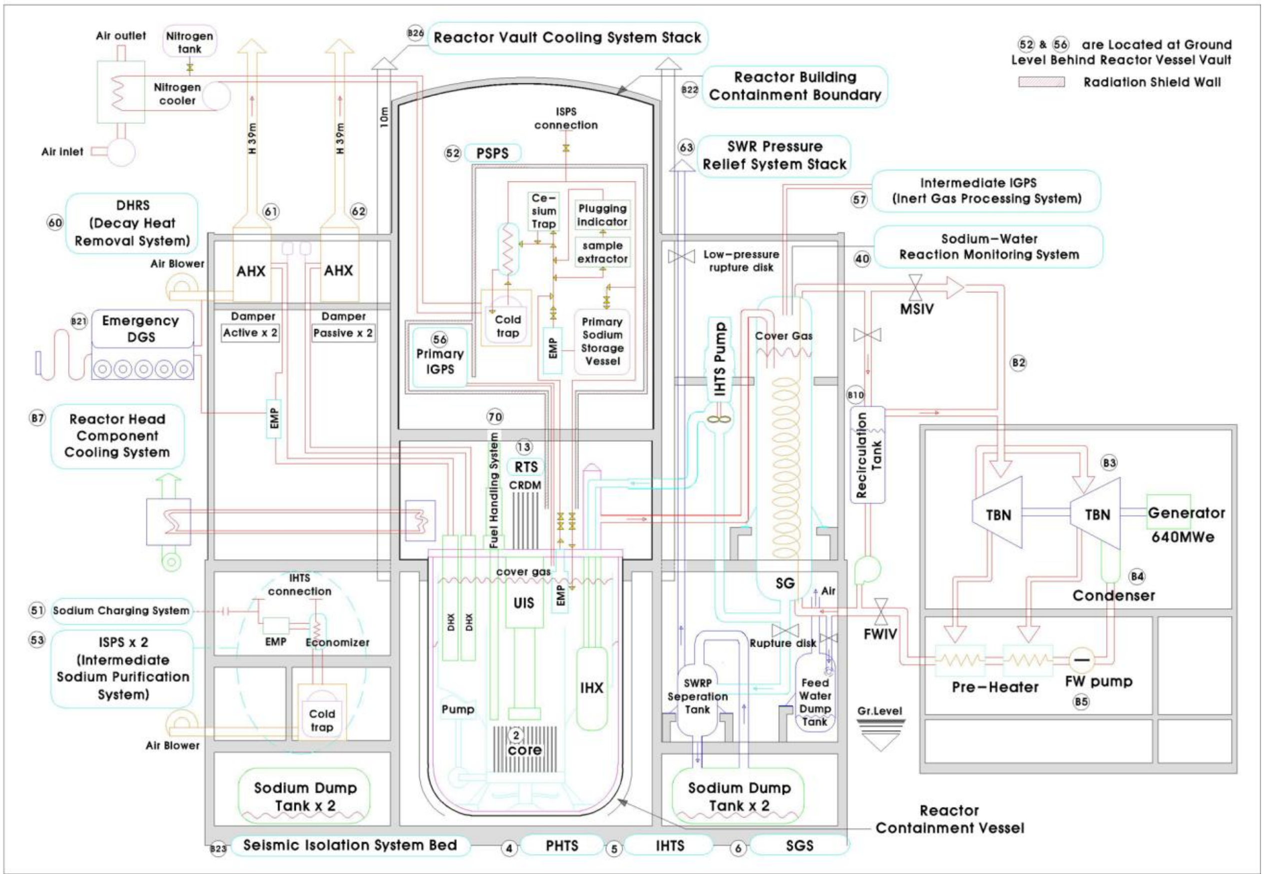

Figure 2 System Configurations of a Pool-Type SFR