Combined Electricity and Heat Generations using SMART

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1. Introduction

Owing to its native characteristics, the application area of the Small and Medium sized Reactors (SMR) can be easily expanded to a non-electricity field such as a sea water desalination and a district heating. SMRs have beneficial advantages of a reactor safety and economics by an easy implementation of advanced design concepts and technology [1]. SMART, a small sized integral type PWR with a rated thermal power of 330 MWt is one of the advanced SMR [2]. The SMART adopts a sensible mixture of new innovative design features and proven technologies aimed at achieving highly enhanced safety and improved economics. Design features contributing to a safety enhancement are basically inherent safety improving features and passive safety features. Fundamental thermal-hydraulic experiments were carried out during the design concept development to assure the fundamental behavior of the major concepts of the SMART systems [2].

A possibility of the combined electricity and heat generations using SMART are evaluated in this study. The conceptual configuration of the cogeneration system is suggested and the transport pipelines using the hot water or the steam are discussed. A heat balance calculation is performed for the quantitative evaluation of cogeneration with the backpressure turbine.

2. Design Features and Safety Systems of the SMART

In order to enhance the safety characteristics, many inherent safety features have been adopted in the SMART system, which are low core power density, negative moderator temperature coefficient, high natural circulation capability and an integral arrangement to eliminate a large break loss of coolant accident, etc. Major components of the reactor coolant system such as the pressurizer, reactor coolant pump, and steam generators are located inside the reactor vessel as shown in Fig. 1. The SMART can fundamentally eliminate the possibility of large break loss of coolant accidents, improve the natural circulation capability, and better accommodate and thus enhance a resistance to a wide range of transients and accidents.

Besides the inherent safety characteristics of SMART, further enhanced safety is accomplished with highly reliable engineered safety systems. Fig. 2 shows the schematic diagram of SMART safety system. Major engineered safety systems function actively or passively on demand, and they consist of a shutdown cooling system, passive residual heat removal system, safety injection system, and reactor overpressure protection system. Under any circumstances, the reactor can be shutdown by inserting control rods or safety injection. Four independent passive residual heat removal systems with 50 % capacity each remove core decay heat by natural circulation at any design bases events, and have capability of keeping the core undamaged for 36 hours without any corrective action by operators. When small break LOCA occurs, core uncovery is prevented by four independent emergency core cooling system with 100 % capacity each which automatically operates by pressurizer pressure set-point signal. The reactor overpressure at the postulated design basis accidents related with a control failure can be reduced through the opening of the pressurizer safety valve. Preliminary safety analysis on the SMART design shows that it remains in a safe condition with proper response of the safety systems to major design bases events [3].

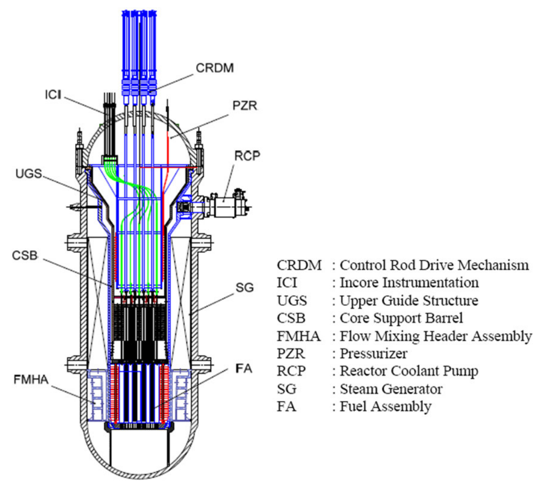

Fig. 1. SMART Reactor Assembly

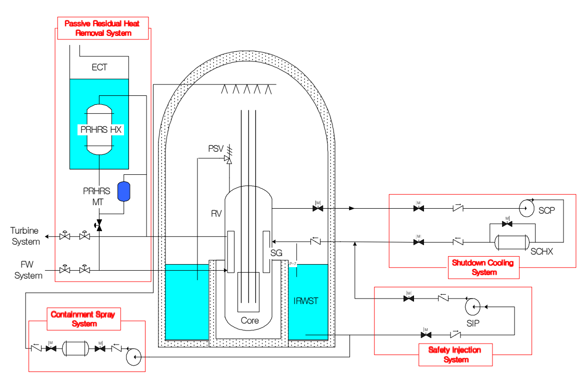

Fig. 2. Schematic Diagram of the SMART Safety System

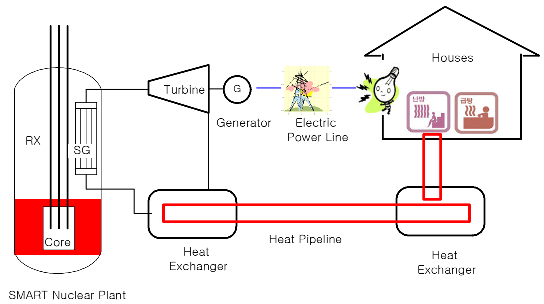

Fig. 3. Schematic diagram of the cogeneration system using the SMART

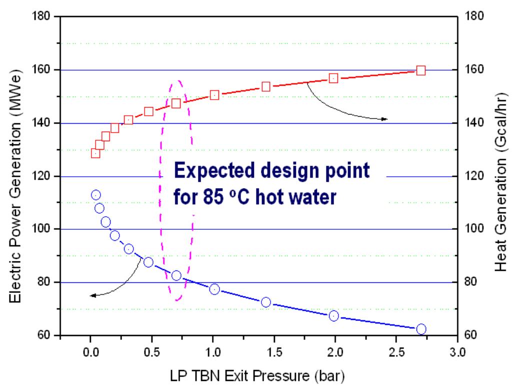

Fig. 4. Cogeneration Capacity of SMART

3. Quantitative Evaluation of Cogeneration using the SMART

The basic BOP system is based on the five-stage regenerative system with two low pressure preheaters, one deaerator, and two high pressure preheaters. The usual exhaust temperature from the low pressure turbine for the electric power generation is about 33 °C, which is too lower for the purpose of cogeneration. The backpressure turbine is introduced with less final turbine stages. The condenser is substituted to the heat exchanger as shown Fig. 3. The figure also shows the schematic flow diagram of the hot-water pipeline system. The heat was extracted from the heat exchanger and the hot water is supplied by the pipeline for the long distance. The hot-water pipeline of Beznau nuclear power plant was known to be able to supply hot-water with 1 °C decrease by 5 km distance [4]. For the heat balance calculation, the important design parameters of the BOP components for the thermal efficiency such as turbine isentropic efficiency, and pump efficiency were determined on the basis of the former study [5].

Fig. 4 shows the cogeneration capacity of SMART with the varying low pressure turbine exit pressure. As the exit pressure increases, more heat is generated with less electric power. If we fix the expected hot water temperature at the 85 °C, it is estimated that 82MW of electricity and 147 Gcal/h of heat can be supplied to the local grids as shown in Figure 4. These amounts of delivered electricity and heat are quite sufficient to meet the demand of more than 60,000~70,000 population assuming that the usage of electricity and heat per 10,000 persons reaches ~10MW and 25 Gcal/h, respectively.

4. Conclusions

SMART has beneficial advantages of a reactor safety and economics by an easy implementation of advanced design concepts and technology. The SMART can be easily applicable not only to a small scale electricity generation but also to non-electricity applications such as the district heating. The cogeneration system with a modified secondary system was evaluated to deliver sufficient electricity and heat to meet the demand of more than a 60,000~70,000 population.

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