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Assessment of SMART Capability for Multiple Applications

Han-Ok Kang*, Young-In Kim, Keung Koo Kim, Sung-Kyun Zee
Korea Atomic Energy Research Institute, 1045 Daeduk-daero, Yuseong-Gu, Daejeon 305-353, Republic of Korea
**Corresponding author: hanokang@kaeri.re.kr*

1. Introduction

Current thermal efficiencies of nuclear power plants are rather low, about 33%, since the rest of the energy is dissipated to the environment as heat. Multiple applications of nuclear energy can significantly increase the overall plant efficiency and make nuclear power as a more viable option. Cogeneration is the simultaneous sequential production of electrical and thermal energy. Cogeneration has become an attractive for a wide range of non-electric application, including seawater desalination, district heating, district cooling, and other industrial process heat applications [1, 2].

From 2009 to 2012, the SMART Technology Validation and the Standard Design Approval Project was carried out. After one and half years of intensive licensing review, the SDA for SMART was officially issued on July 4th, 2012 by the NSSC, in compliance with Article 12 of the Nuclear Safety Act. This is the first license for an integral reactor in the world [3].

SMART has beneficial advantages of a reactor safety and economics by an easy implementation of advanced design concepts and technology. Owing to its native characteristics, the SMART can be easily applicable not only to a small scale electricity generation but also to non-electricity applications such as sea water desalination and a district heating. The capability of SMART for the application of sea water desalination and a district heating are assessed through modifying the existing secondary system for electricity generation in this study.

2. SMART Design Characteristics

SMART (System-integrated Modular Advanced ReacTor) is a promising advanced small nuclear power reactor. It is an integral type reactor with a sensible mixture of proven technologies and advanced design features. SMART aims at achieving enhanced safety and improved economics; the enhancement of safety and reliability is realized by incorporating inherent safety improving features and reliable passive safety systems.

SMART is an integral-type reactor containing major components within a single reactor pressure vessel, as shown in Fig. 1. Eight (8) modular type once-through steam generators produce superheated steam under normal operating conditions. Four (4) reactor coolant pumps with a canned motor inherently prevent a loss of coolant associated with a pump seal failure. The major fluid systems of SMART are the reactor coolant system, a chemical and volume control system, a passive residual heat removal system, and a safety injection system together with a shutdown cooling system. There also a variety of auxiliary systems as well.

The integral configuration of the reactor coolant system, which eliminates large breaks in the primary pipes, provides an improved natural circulation a large volume of coolant. Design characteristics contributing to the safety enhancement are basically inherent safety features such as the integral configuration of the reactor coolant system and improved natural circulation capability. By introducing a passive residual heat removal system and an advanced LOCA mitigation system, significant safety enhancement is achieved.

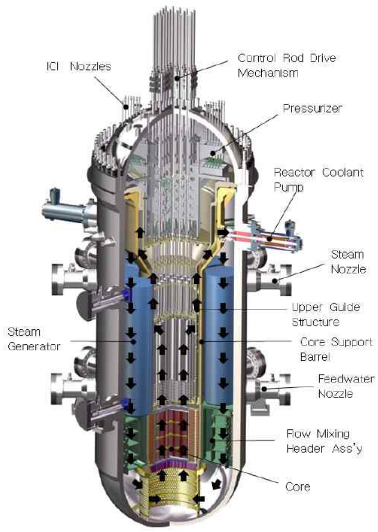

Fig. 1. SMART Reactor Vessel Assembly

Since the Fukushima accident, mitigation measures to cope with a sever accident have become key safety issues. This shows that maintaining continuous core-cooling capability is essential. In a series of realistic simulations, the passive residual heat removal system of SMART effectively removed decay heat, maintaining the reactor in a stable condition for 20 days without external power sources or operator actions. With regard to aircraft crash resistance, the containment and auxiliary buildings of SMART were designed to withstand an aircraft collision (Boeing 767) without damage to the reactor or spent fuel pool.

3. SMART Multiple Applications

The capability of SMART for the application of sea water desalination and a district heating are evaluated through modifying the existing secondary system for electricity generation. The desalination process and the coupling method are determined through the thermodynamic analysis for the several evaporation processes. The MED-TVC desalination process is selected for the co-generation of distillated water and electricity, and steam transformer is introduced to minimize the possibility of product water contamination. Fig.2 shows the MED-TVC desalination plant. One significant advantage of the MED-TVC is its ability to use the pressure energy in the steam. Thermal vapor compression is very effective when the steam is available at higher temperature and pressure conditions than required in the evaporator.

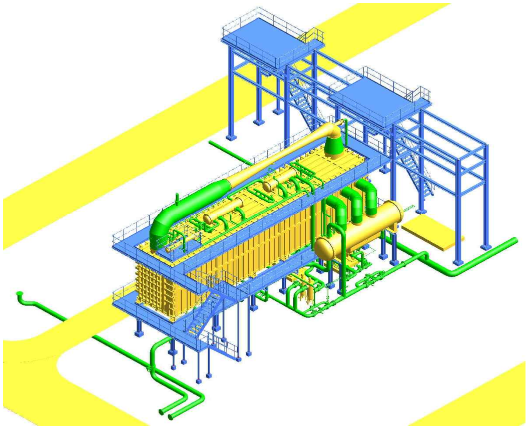

Fig. 2. MED-TVC Desalination Plant

A possibility of the combined electricity and heat generations using SMART is also evaluated in this study. 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 ^{o}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. A heat balance calculation is performed for the quantitative evaluation of cogeneration with the backpressure turbine. When SMART is utilized for a cogeneration purpose, i.e. electricity generation and district heating, it is estimated that 82MW of electricity and 147 Gcal/h of heat can be supplied to the local grids as shown in Figure 3. The amount of delivered electricity and heat (~85°C hot water) is 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.

Additional systems such as desalination system and district heating can have adverse effects on CDF (Core Damage Frequency) and LERF (Large Early Release Frequency). Desalination system is connected to conventional BOP through the steam transformer. As there is no direct connection between reactor system and desalination system, the coupling doesn't introduce additional concern related to the LOCA. Probable events related to the desalination system are secondary heat removal increase due to steam flow surge to desalination system and turbine trip due to operational disturbance related to desalination system. Bounding approaches for the desalination plant safety concerns shows that the desalination system doesn't have adverse effect on reactor safety.

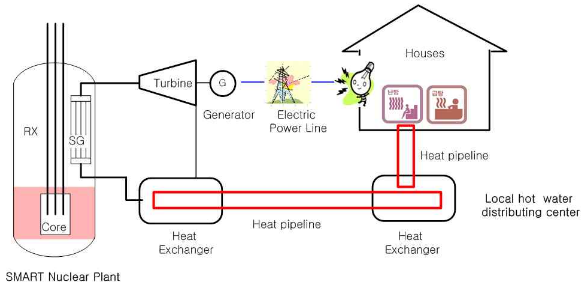

Fig. 3. District Heating Configuration using SMART

4. Conclusions

SMART can be a good engine for seawater desalination and district heating. Power generation system can be safely and effectively coupled with MED-TVC desalination system using steam transformer. District heating application will increase the cycle efficiency of SMART significantly. Introduction of desalination system doesn't have adverse effect on reactor safety.

REFERENCES

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