6–1 Toward a Demonstration of the HTGR Cogeneration System

— Completion of Component Design and Preliminary Safety Assessment for the HTTR-GT/H_2 Plant —

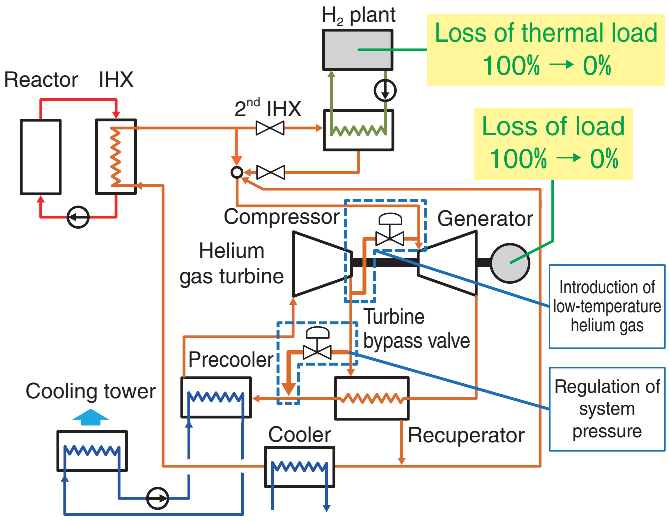

Fig.6-2 Mitigation system for the HTTR-GT/H_2 plant
System pressure is regulated to suppress turbine over-speed during loss of generator load. Low-temperature helium gas is introduced to the turbine inlet to mitigate the temperature increase in reactor coolant against loss of thermal load in an H_2 plant.

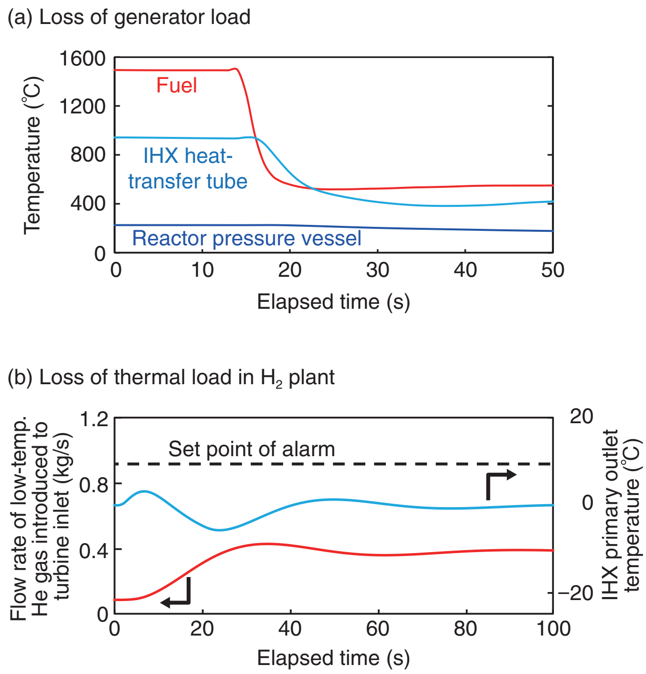

Fig.6-3 Plant dynamics of HTTR-GT/H_2 plant
The integrity of the plant and stable operation of the reactor can be maintained by the same mitigation systems used in commercial HTGR cogeneration systems.

High Temperature Gas-cooled Reactors (HTGRs) are expected to extend the use of nuclear energy for heat applications such as hydrogen (H_2) production owing to their inherently safe characteristics and high-temperature heat-supply capabilities. We are planning a demonstration program for carbon-dioxide-emission-free cogeneration of electricity and H_2 using the High Temperature engineering Test Reactor (HTTR).

The program aims to demonstrate heat-application technologies for HTGR and to obtain a first-of-a-kind license for coupling chemical plants to nuclear reactors. We have been conducting system and component design for the HTTR gas-turbine cogeneration plant (HTTR-GT/H_2 plant) since 2015. As a result, we have completed pre-licensing of the basic design with a power output of 1 MW and a H_2-production rate of 30 Nm^3/h.

In addition, we have performed preliminary analysis to ensure reactor safety during abnormal events in the heat-application system. First, we selected two new events—loss of generator load and loss of thermal load in an H_2 plant—which must be evaluated under coupling of a helium-gas turbine and an H_2 plant to the HTTR. Then, the plant dynamics of selected events are evaluated by RELAP5 code, a system-analysis code. We employed the same mitigation systems as commercial HTGR-cogeneration systems for demonstration of system-design technologies. As for the loss of generator load, a turbine-bypass control valve is devised to suppress turbine over-speed by regulating system pressure. Regarding the loss of the thermal load in an H_2 plant, a turbine-inlet-temperature-control valve is installed to introduce low-temperature helium gas from compressor inlet to the turbine inlet to suppress the temperature increase in the reactor coolant (Fig.6-2).

The simulation results demonstrate that loss of the generator load does not impact the temperature of fuel or the reactor-coolant-pressure boundary and that the integrity of the plant is maintained even if control-system failure is assumed and conservative conditions for measurement errors and operational fluctuations based on the HTTR design are applied. In addition, the results demonstrate that the transients did not trip the alarm and that stable operation of reactors can be achieved during loss-of-thermal-load events in H_2 plants (Fig.6-3).

Toward the realization of the HTTR demonstration test, it is important to share construction cost with foreign entities utilizing international collaboration. A further direction of study is to investigate a detailed test plan with countries interested in the demonstration program.

Reference

Sato, H. et al., System Analysis for HTTR-GT/H_2 Plant - Safety Analysis of HTTR for Coupling Helium Gas Turbine and H_2 Plant -, JAEA-Technology 2017-020, 2017, 23p. (in Japanese).