SFR Control Logic and Performance Evaluation for a Large Load Rejection Event

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Introduction

· In the case of LWR, if a sudden change in power is detected on the BOP, the reactor power is rapidly reduced by RPCS and the surplus steam bypasses the turbine by SBCS to balance the power between the reactor and the BOP to prevent the reactor trip.

· The Reactor Power Cutback System(RPCS) and Steam Bypass Control System (SBCS) of the SFR can improve both structural reliability and availability by reducing the emergency shutdown of the reactor at sudden power transient on the BOP.

· In this study, the control logic for load runback operation is set for PGSFR, and the plant operation performance is evaluated in case of sudden transient.

Control logics of RPCS and SBCS

· Clinch River Breeder Reactor (CRBR)

- In the event of a turbine trip, the turbine bypass valve is fully opened within 3 seconds, allowing 80% capacity heat to be removed from the steam generator

- CRBR reduces the power at a rate of 3%/min by the general reactor control system, not the RPCS

- The reactor power is reduced to 90% after 200 seconds, and then equilibrated with the heat removal of the steam bypass system at the new operating condition

· Prototype Fast Breeder Reactor (PFBR)

- When the steam pressure rises at the turbine or generator trips and rises above the set pressure, the turbine bypass valve is opened to bypass steam flow.

- If the pressure continues to rise and becomes above the set pressure, the atmospheric release valve is opened.

- The atmospheric release valve generates a reactor cutback signal and the control rod starts to be inserted and reducing the reactor power

- If the steam pressure is restored to the set value, the atmospheric release valve is closed, and the power between the reactor and the BOP becomes to balanced states.

· Light Water Reactors

- When a large load transient such as a turbine trip occurs, the light water reactor opens the turbine bypass valve from SBCS and sends a Reactor Power Cutback (RPC) signal for RPCS

- The capacity of the light water reactor's steam bypass system is 55% of rated power, which is allocated 40% to the condenser exhaust and 15% to the atmospheric dump

- The reactor power is to cutback the core power by the RPCS, and maintain the reactor power between 20% and 75% with the Reactor Regulating System (RRS)

· PGSFR

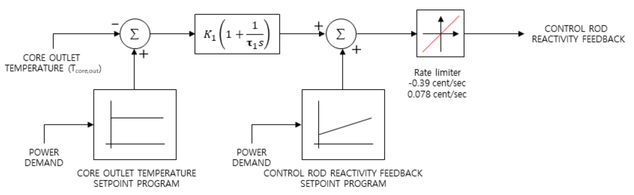

Fig.1 Reactor Regulating System

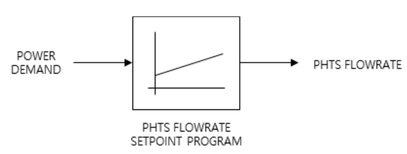

Fig.2 Primary Sodium Flow Control System

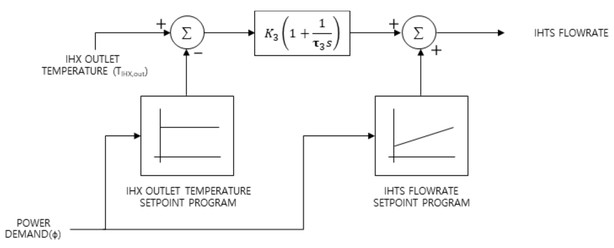

Fig.3 Intermediate Sodium Flow Control System

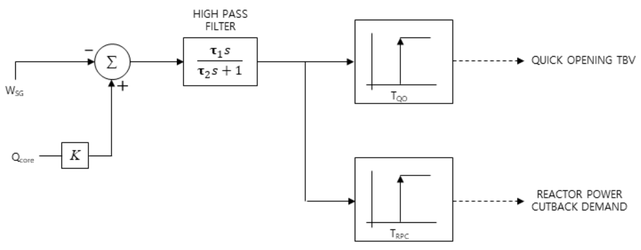

Fig.4 Control logic of steam bypass control system for PGSFR

- Since PGSFR is a pool type, the heat capacity of the hot/cold pool is very large, therefore, the power that can be absorbed by the system is also very large compared to the light water reactor. Therefore, even if the control rod subgroup is not dropped as in the case of light water reactors, it is expected that the large load transient can be accommodated by the reactor regulating system and the SBCS.

- The bias signal of the reactor power and the steam flow rate passes through the high-pass filter to derive the degree of sudden change as an output signal (Fig. 4)

- If this output signal exceeds the setpoint of the quick opening of the Turbine Bypass Valve (TBV), a demand signal for quick opening of the TBV is generated

- The setpoint of reactor power is set to 55% and the reactor power is reduced as quickly as possible by RRS (Fig.1)

- The primary system flow rate is reduced to a flow rate corresponding to the core power, and the intermediate system flow rate is controlled to maintain the cold pool temperature at a set point (Fig.2)

- The primary system flow rate is reduced to a flow rate corresponding to the core power, and the intermediate system flow rate is controlled to maintain the cold pool temperature at a set point (Fig.3)

Performance evaluation of control systems

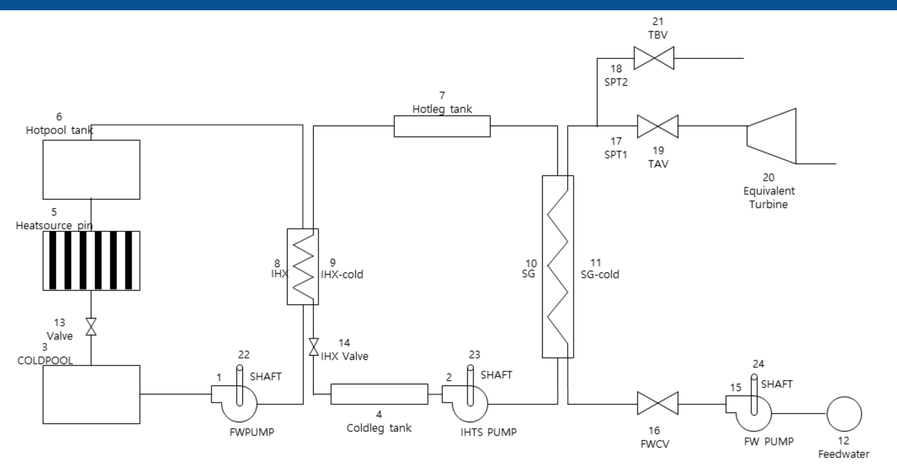

Fig.5 Network model for GPASS code

- The control performance analysis was performed using GPASS code which is developed by Argonne National Laboratory that can analyze the plant dynamic behavior of SFR

- In the event of a full load rejection, the turbine system rapidly reduces the power and operates in a house load(20% of rated power). The steam flow rate through the turbine is reduced at a rate of 1%/sec

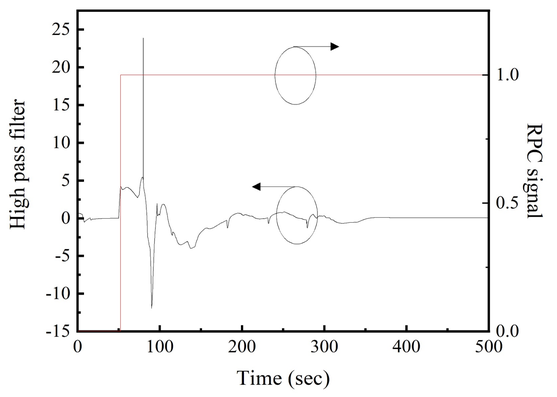

Fig.6 Transient behavior of high pass filter and reactor power cutback signal

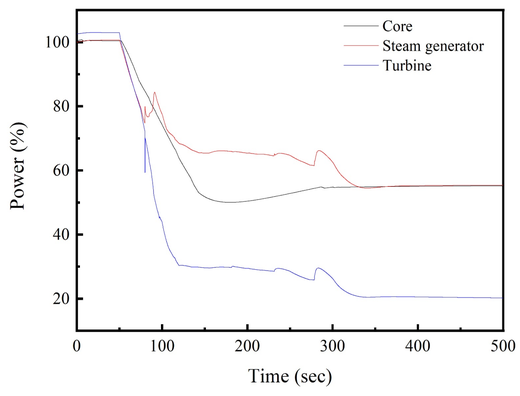

Fig.7 Transient behavior of power of core, SG and turbine

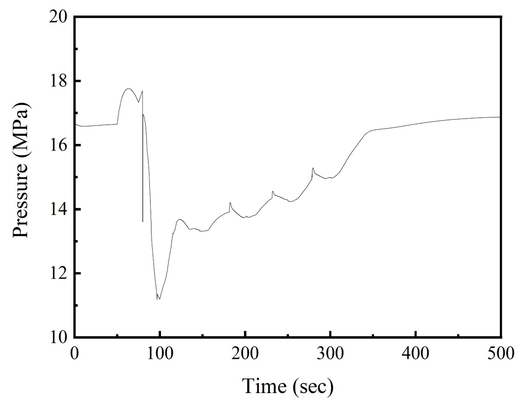

Fig.8 Transient behavior of SG outlet pressure

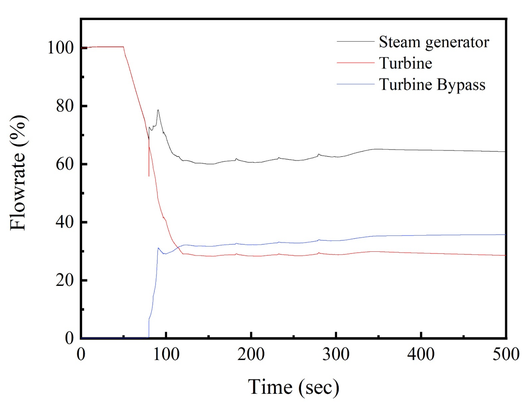

Fig.9 Transient behavior of flowrate of steam generator, turbine and turbine bypass line

- In the event of a full load rejection, the bias signal increases sharply between the reactor power and the main steam flow rate, and such a sudden change passes through the high pass filter and increases the amplitude of the signal rapidly. It can be confirmed that the RPC signal occurs approximately 2 seconds after the event

- The power of the reactor and steam generator decreases rapidly after the occurrence of a full load rejection and converges to 55% power. It can be seen that the turbine power is reduced to 20% which is excluding the amount of SBCS by 35% removed from steam generator of 55%

- The main steam pressure increases rapidly for a certain period due to a rapid decrease in the flow rate on the turbine side after the event. The steam pressure is rapidly relieved by opening the TBV by the quick open mode of steam bypass line

- After the event, the main steam flow rate rapidly decreased due to the closing of the turbine control valve and then increased again for a certain period due to the quick opening of the TBV. It can be seen that about 35% and 20% flow rates are formed to the steam bypass system and the turbine side, respectively

Conclusions

· The control logic of PGSFR in reactor power cutback was set and the control performance was evaluated at full load rejection event

· It was confirmed that the RPCS and the quick opening of the TBV valve were activated after 2 seconds. After the event, the reactor and turbine power were stabilized at 55% and 20%, respectively

· It was confirmed that the main process parameters were well controlled within the operating limit conditions