Dynamic Simulation of Startup in PGSFR

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1. Introduction

Plant startup usually covers the operations that take the reactor plant from refueling conditions to the 30% reactor thermal power operating conditions in PGSFR. During startup the operating constraints are to be met to protect various systems and components in the plant.

In this paper, the transient responses of systems and components during startup are evaluated by using dynamic simulation code GPASS[1]. Representative results of the model calculations and a possible good startup policy are presented.

2. Methods and Results

2.1 Modeling of PGSFR

The models of the PGSFR are presented in Fig. 1. Heat generated in the core is transferred by the primary sodium pumps. This heat is transferred to intermediate secondary sodium circuit through intermediate heat exchangers. Heat from intermediate sodium circuit is transferred to steam water system to produce superheated steam in SG. In this model, the BOP side is not modeled, because the system dynamics does not give the significant effect on the NSSS side. The boundary conditions are given at SG inlet and outlet. Nuclear fission in the core is not modeled, but heat source is given at present study.

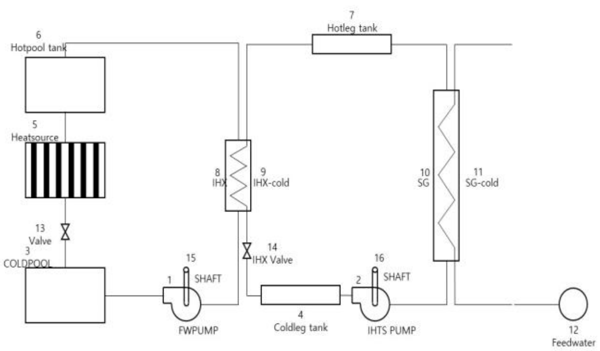
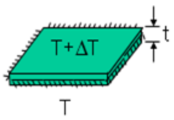


Fig. 1. Modeling of the PGSFR heat transport system.

2.2 Operating Constraints

Presently there is no published operating constraints in PGSFR. Limiting temperature difference on the cold tube sheet end of the IHX and SG can be roughly estimated by a following thermal bending stress formula[2].



$$\sigma = \pm \frac{\alpha E \Delta T}{2(1-\nu)}; \; 2-D \; Plate, \; Max \; Bending$$

,where σ=288 MPa, α=0.0000116, E=188,000 MPa, ν=0.3 at 300 ℃, G91 steels.

As the principal material of IHX and SG in PGSFR is G91 steels, the limiting temperature difference will be about 184 ℃.

During the power raising operation it is necessary to keep the heating up rate of hot pool below 20 ℃/hr to avoid thermal shocks to components. In addition during all startup as well as shutdown operations the heat transport systems will be performed above 200 ℃, and feedwater temperature be above 150 ℃ to preclude the possibility of sodium freezing.

2.3 Results

The existing schedule[3] of flow and pressure VS reactor power is shown in Fig. 2. During startup the flow arte of PHTS, IHTS and feedwater are fixed at 30%, 23% and 26.7% of the rate respectively.

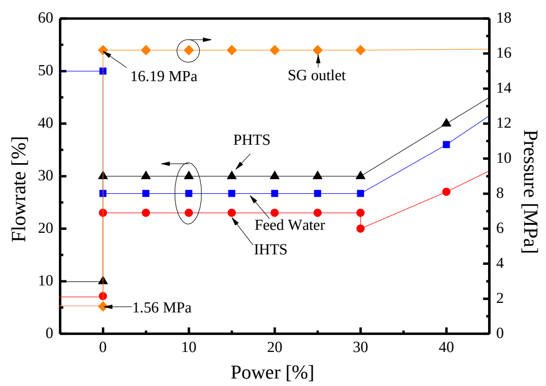


Fig. 2. Schedule of flow and pressure VS reactor power during startup.

Fig. 3 shows sodium temperature of heat transport systems goes below 200℃ in the early stage of startup. Therefore the startup policy should be modified not to violate operating constraints.

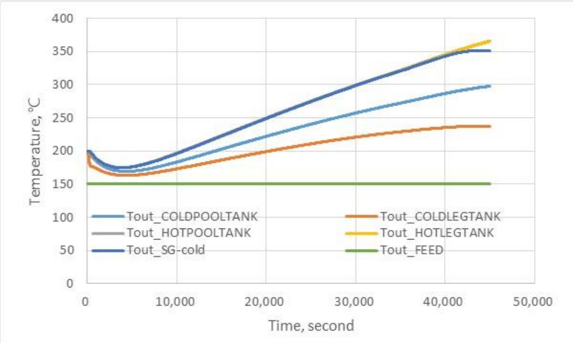


Fig. 3. Temperature response of the PGSFR heat transport system.

Fig. 4 shows heat transfer rate of the heat source, IHX and SG. Fig. 5 shows feed water and steam flow rate. The initial feed water flow through SG should be limited to a low value 1.1 % to avoid the cool down of sodium system below 200℃. This value is derived such that the heat removal through SG matches with the net heat added due to the running of sodium pumps and decay heat(0.089% of rated core power) 60 days after shutdown, and all heat losses through sodium purification system, standby mode of DHRS, roof cooling system and reactor vault cooling system. Feedwater is raised from 1.1%, 3%, 10% to 15% in stepwise manner. The minimum flow of operation of feed water controller is 15%. The PHTS and IHTS sodium pumps are operating at 30%, 23% flow condition.

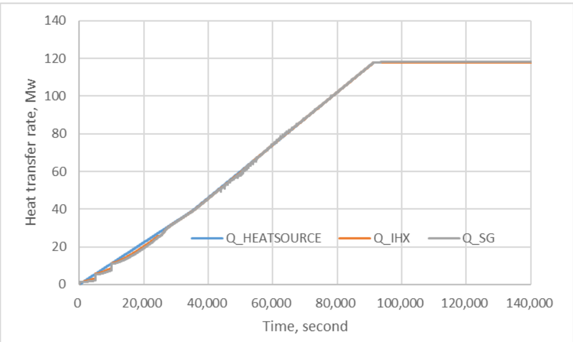


Fig. 4. Heat transfer rate of the heat source, IHX and SG.

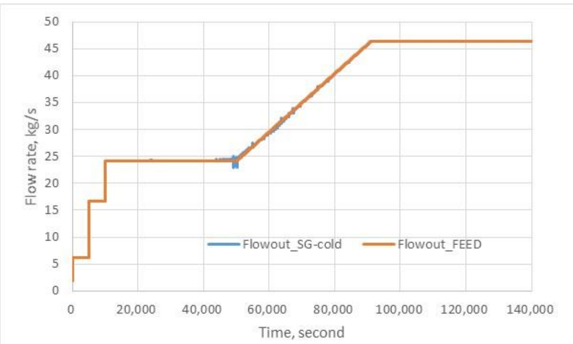


Fig. 5. Feedwater and steam flowrate.

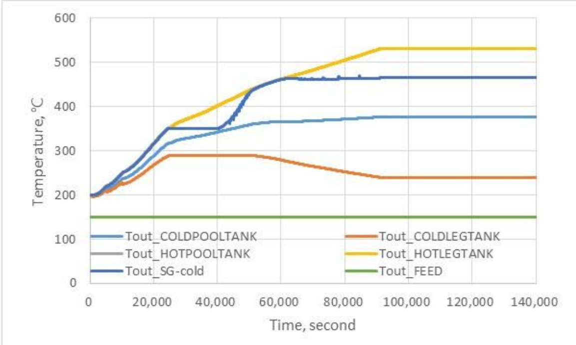


Fig. 6. Temperature response of the heat transport system.

Fig. 6 shows temperature response of the heat transport system. The temperature of the PHTS increases from 200℃ to 532℃ in 92,400 second. The overall heating up rate of hot pool is about 13 ℃/hr, which are less than the permissible rate. Maximum temperature differences on the cold tube sheet end of the IHX and SG are 138℃, 139℃, which are below the constraint. The steam-water mixture flow is at 15% of feed water flow, which is satisfying the requirement on the moisture separator tank design (usually 20% of rated feed flow).

3. Conclusions

The transient responses of systems during startup depending on the existing PGSFR startup schedule shows that heat transport systems violate operating constraints in the early stage. The startup policy has been modified such that all the requirements are met. This results can be used for the study of the system response with core reactivity model.

ACKNOWLEDGEMENT

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