Combined Cycle Power Plant

Power Industry

Challenge: This case study demonstrates the modeling of a Combined Cycle (CC) power plant of a High Temperature Gas-Cooled Reactor (HTGR).

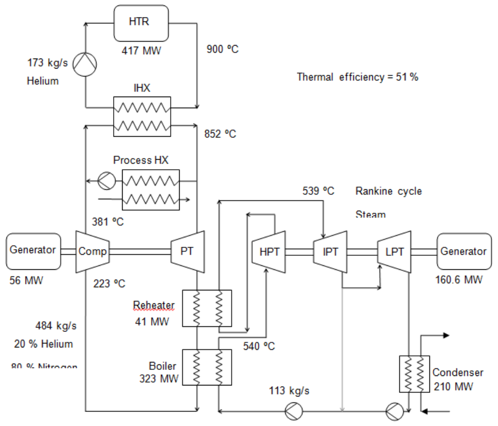
The objective of the example is twofold. Firstly it is to predict the steady-state performance of the plant and secondly it is to investigate the behavior of the plant in a situation where the mass flow through the process heat exchanger changes from 0 to 70 kg/s during a 35 second period.

Benefits:

- Multiple fluid networks in a single simulation including pure gasses, gas mixtures and two-phase fluid.
- Validate and implement control system philosophies.
- Interaction between various networks, i.e. Heat Exchangers.

Solution: Flownex was used to simulate a complex combined cycle power plant that produces both electricity and process heat. It was shown that with the appropriate control system the plant will operate stably as the mass flow through the process heat exchanger is increased from 0 to 70 kg/s.

This case study also demonstrated Flownex's ability handle a network with different types of fluids i.e. pure gasses, gas mixtures and two-phase fluid.



Power Industry

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Introduction

This case study demonstrates the modeling of a Combined Cycle (CC) power plant of a High Temperature Gas-Cooled Reactor (HTGR). The nuclear reactor is not modeled in detail as the focus of this case study is not on the reactor but on the CC Power Conversion Unit (PCU).

System Description

The lay-out of the system is shown in Figure 1.

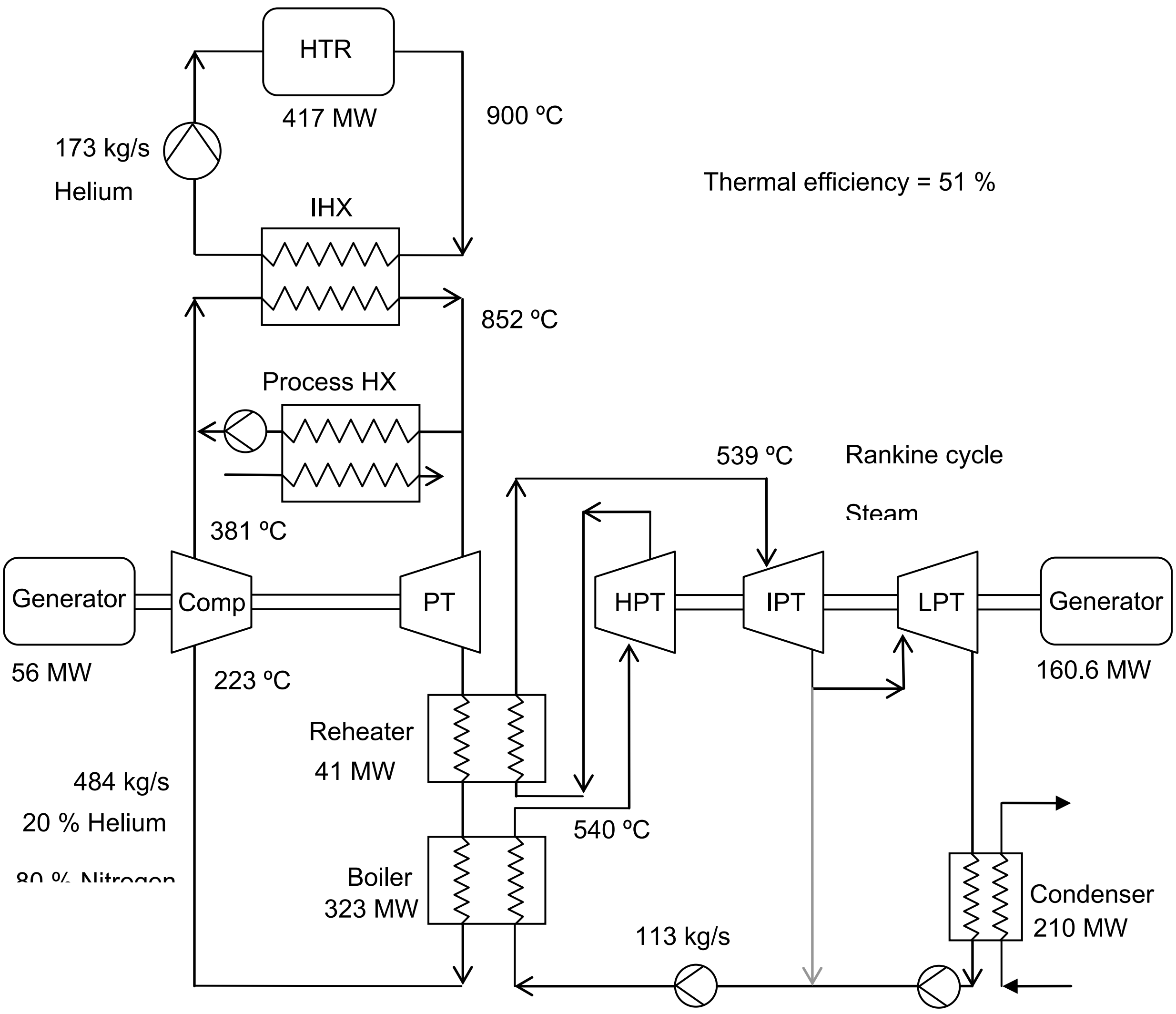

Figure 1: Layout of combined cycle power plant.

The plant consists of three closed loops that are connected through two heat exchangers. The first loop is a helium loop that consists of a blower, a High Temperature Gas-Cooled Reactor (HTGR) and an intermediate heat exchanger (IHX).

The second is a Brayton cycle that consists of a compressor, a turbine, an IHX and a steam generator. The working fluid for the Brayton cycle is a mixture of 20 percent helium and 80 percent nitrogen. In parallel over the IHX is another heat exchanger called the process heat exchanger that can supply heat to e.g. a sulphur iodine hydrogen production plant.

The third is a bottoming Rankine cycle that consists of the following components: a steam generator, three steam turbines (high pressure, intermediate pressure and low pressure), condenser and two condensate pumps.

Objective of simulation

The objective of the example is twofold. Firstly it is to predict the steady-state performance of the plant and secondly it is to investigate the behavior of the plant in a situation where the mass flow through the process heat exchanger changes from 0 to 70 kg/s during a 35 second period.

Flownex model

The Flownex model of the system is shown in Figure 2.

The reactor is modeled as a pipe with a specified constant exit temperature of 900 ºC. The reason why the reactor is not modeled in detail is that the focus of the simulation, as mentioned earlier, is not on the reactor but on the on the CC PCU.

Three controllers are used to control the speed of the helium blower and the two condensate pumps that form part of the Rankine cycle. The blower speed controller senses the IHX exit temperature and controls the speed so as to keep this temperature constant. The controller on the high pressure condensate pump attempts to keep the boiler exit temperature constant while the controller on the low pressure condensate pump attempts to keep the mass source at node 1 zero.

Description of simulation

First a steady-state simulation was done and the results of this simulation was then used as initial conditions for a transient simulation. With the transient simulation the mass flow through the IHX was ramped up from 0 to 70 kg/s over a 35 second period.

Results

Figure 3 shows the variation in mass flow through the IHX, the helium loop and in the Rankine cycle with time.

Interesting to note is that the mass flow in the helium loop increases as the IHX mass flow increases. The mass flow in the steam cycle, however, stays constant.

Figure 4 shows the variation in temperature at a few positions in the plant with time. The temperature stays mostly constant except at the exit of the IHX where the temperature increases drastically as the mass flow through the IHX increases. This is as expected.

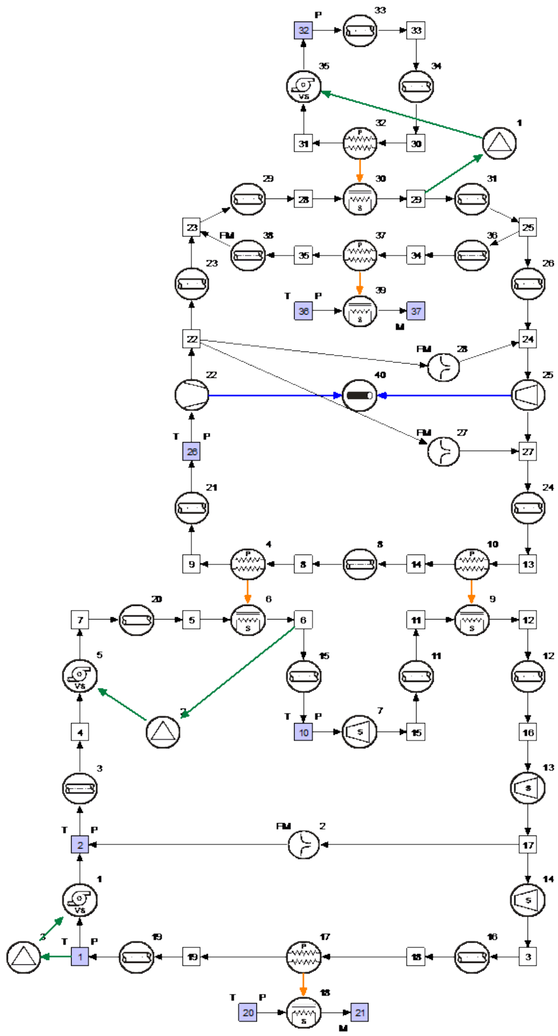

Figure 2: **Flownex model of the Combined Cycle High Temperature Reactor Gas-Cooled Nuclear Power Plant.**

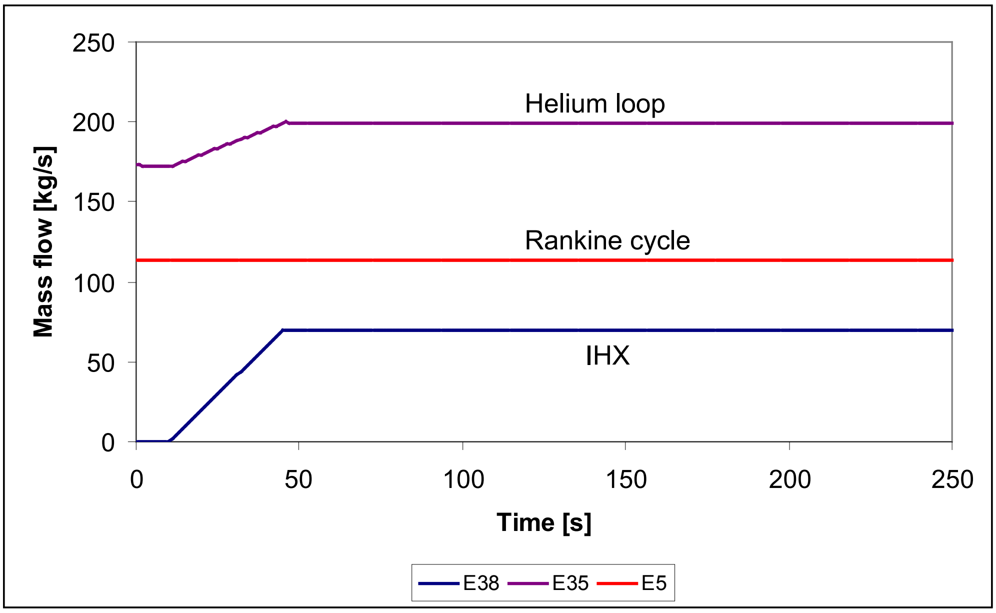

Figure 3: **Variation in mass flow with time.**

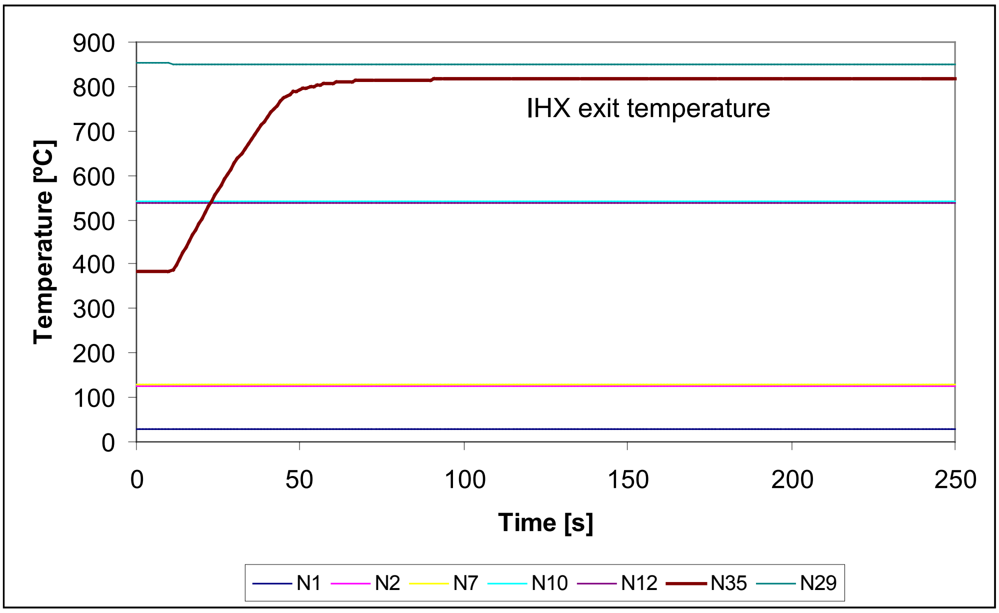

Figure 4: **Variation in temperature at a few positions in the plant with time.**

Conclusion

Flownex was used to simulate a complex combined cycle power plant that produces both electricity and process heat. It was shown that with the appropriate control system the plant will operate stably as the mass flow through the process heat exchanger is increased from 0 to 70 kg/s.

This case study also demonstrated Flownex's ability do handle a network with different types of fluids i.e. pure gasses, gas mixtures and two-phase fluid.