District heating cycle

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6.1 Introduction

As the sixth example an advanced system of district heating has been chosen. This example shows how a complicated scheme with several cycles influencing each other can be modelled. In addition an example is given of the use of user subroutines. The scheme is set out in Figure 6-1.

6.2 System description

Figure 6-1 shows the calculation scheme for a STAG installation with steam extraction for a district heating network. The scheme consists of four closed and one open cycle. The pipes and apparatuses are numbered per cycle by starting each cycle at a hundred.

In the open cycle (apparatuses 1 to 12 and pipes 1 to 11) natural gas is burned in combustor 4/13. The hot flue gases drive turbine 7 and are then used to provide energy to the water/steam cycle via heat exchangers 8 to 10.

In the water/steam cycle (apparatuses 101 to 116, pipes 101 to 122) the steam produced in heat exchangers 8 to 10 and superheated drives turbine 101. The steam is then divided via

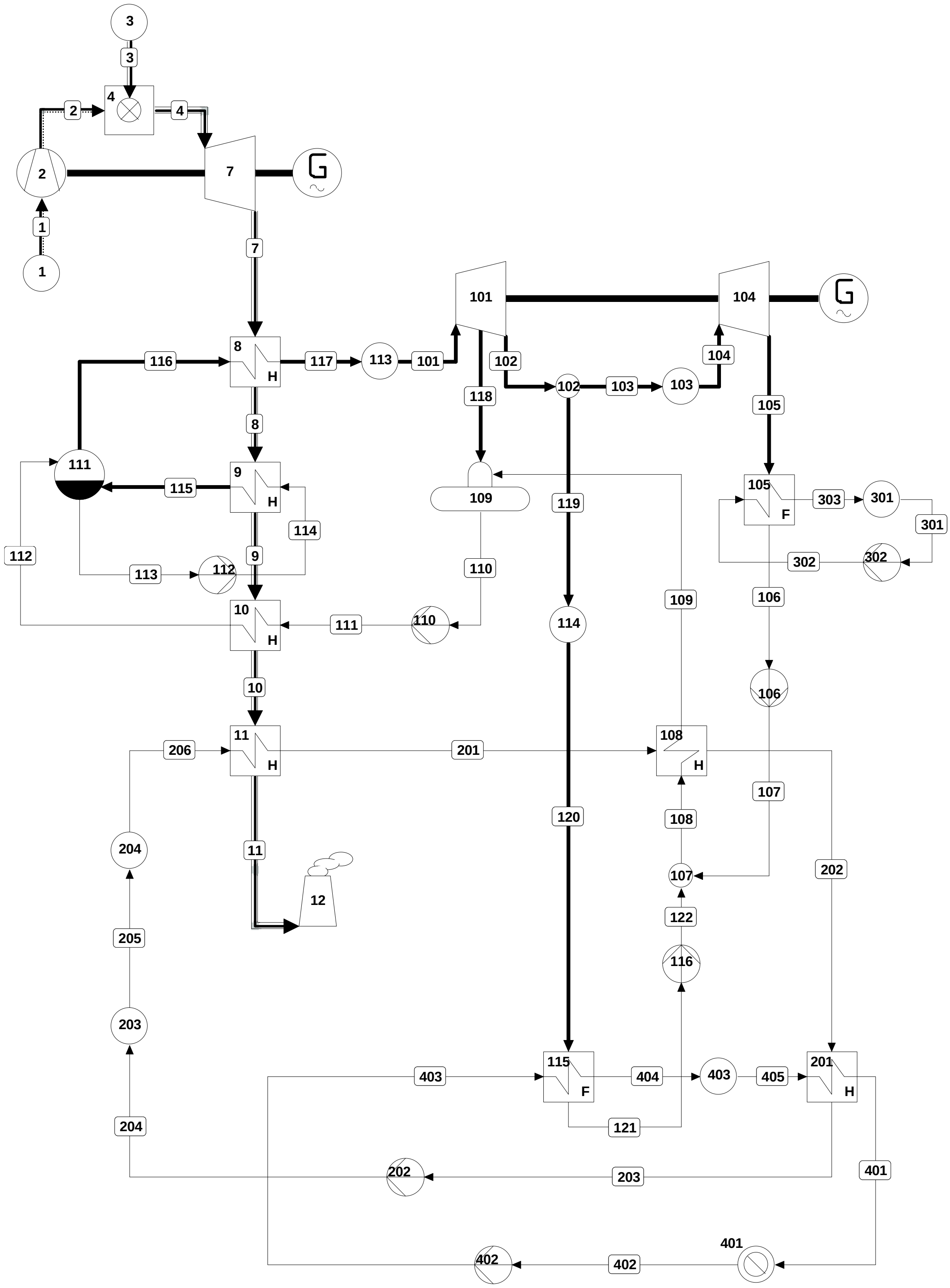

Figure 6-1: District heating cycle

junction 102 between turbine 104 and heat exchanger 115, which supplies energy to the district heating cycle. After turbine 104 the steam is condensed in heat exchanger 105, by the cooling water cycle (apparatuses 301 to 302, pipes 301 to 303). In junction 107 the two mass flows come back together. The water is preheated in heat exchanger 108, after which it goes to the deaerator and is pumped on to heat exchanger 10.

The district heating cycle (apparatuses 401 to 403, pipes 401 to 405) receives its energy from the water/steam and the hot water cycle (apparatuses 201 to 204, pipes 201 to 206). The latter gets its energy from the flue gases via heat exchanger 11.

6.3 Summary of calculations

For this system various calculations are performed.

Design calculations

Calculation 1	*Maximum electricity production* In heat exchanger 115 no energy is given off and all the steam goes through turbine 104.
Calculation 2	*Maximum heat production* Turbine 104 only gets a minimum quantity of steam, and also as much energy as possible goes to heat exchanger 115.

From these two design calculations the input data for the off-design calculations are formulated.

Off-design calculations

Calculation 3	*Off-design maximum electricity production* In fact the same calculation as calculation 1, but with relevant apparatuses operating in off-design mode.

Calculation 4 *Off-design maximum heat production*

In fact the same calculation as calculation 2, but with relevant apparatuses operating in off-design mode.

Calculation 5 *Off-design, average heat production*

The heat production is determined from the average of the heat given off in the district heating network from calculations 3 and 4.

6.4 Starting points for the calculation

For each calculation the energy supply is kept the same. This is done via a production function, in which the power which the generator of turbine 7 supplies, is set at 100 MW (specified for the shaft as Surplus Power).

The steam from the HP-turbine (101) can be divided via junction 102 between turbine 104 and the district heating network (sink 401) by heat exchanger (115). Water is supplied to this district heating network at a temperature of 75 °C. This returns at a temperature of 55 °C. The pressures in the cycle are also given, hence by specifying the quantity of energy to be discharged in apparatus 401, the mass flow in the district heating network is determined.

Variables which relate to conditions outside the system (inlet temperatures and pressures of air, fuel and cooling water and the outlet pressure of the stack (sink 12)) are also the same for each calculation.
To make the individual calculations possible the type of some apparatus is changed for a particular calculation:

- Apparatus 203 is a dummy sink in the design calculations, but a valve in the off-design calculations (type 14), in order to determine the mass flow.
- Apparatus 11 is type 12 in the design calculations, but of type 6 in the off-design calculations, as for the latter the outlet temperature of the stack is not given, but in place of it the mass flow of the hot water cycle is determined.
- Apparatus 102 is a valve in calculations 2 and 4, maximum heat production, (type 14), in order to determine the mass flow to turbine 104. In the other calculations it is a junction of type 9.

- Heat exchanger 201 uses EEQCOD = 1 in calculations 1 and 3, since in these cases the heat supply of apparatus 201 determines the mass flow in the district heating network; in the other calculations it uses EEQCOD = 2.

In the off-design calculations the mass flow in the cooling water cycle is specified and the variables which must be altered to achieve this: ’TIN’ of apparatus 301. In the data for sink 301 an initial estimate must be specified for TIN. The accuracy of this estimate can be very finely adjusted and the wrong estimate can sometimes result in the failure of a calculation.

6.5 Use of temperature estimates

In all the calculations apart from calculation 1 dummies of apparatus type 10 are used for temperature estimates to enable the program to start the iterative calculation process.

Initial estimates for the temperatures in pipes 404 and 206 are specified in the input window of apparatus 403 and 204, respectively. For apparatus 403 parameter ESTTIN is specified, for apparatus 204 parameter ESTTOU.
The passing-on of temperatures is necessary for the calculation. In order for example to calculate the temperature of pipe 404 that of pipe 405 must be known. But, to calculate the temperature of pipe 405, that of pipe 202 must be known. The circle continues via pipes 108, 122 and 121, and returns for pipe 404, for which the temperature must be known. The dummies are used to supply the program with initial estimates, which will be automatically overwritten by the calculated values during the iteration process.

The following temperature estimates are specified:

Calculation 2:	ESTTIN at apparatus 403 to pass the calculated temperature of pipe 405 to pipe 404 in succeeding iterations.
Calculation 3:	ESTTOU at apparatus 204 to pass the calculated temperature of pipe 205 to pipe 206 in succeeding iterations.
Calculation 4 and 5:	ESTTIN at apparatus 403 to pass the calculated temperature of pipe 405 to pipe 404 in succeeding iterations. ESTTOU at apparatus 204 to pass the calculated temperature of pipe 205 to pipe 206 in succeeding iterations.

6.6 Results of the calculations

As the full calculation results are outside the bounds of this manual, there follows below just a few calculation results.

Temperature estimates:
Pipes 404 and 405 have in fact obtained the same ultimate temperature in calculations 2, 4 and 5, in which the temperature of pipe 405 is transmitted to pipe 404. For pipes 206 and 205 in calculations 3, 4 and 5 the same applies.

An extra condition is specified for pipe 301. There it is stated that the inlet temperature (TIN) of apparatus 301 (APNO = 301) must be adjusted to a prescribed mass flow (MASFLO). Hence a sort of iterative procedure is set in operation. If we look in calculations 4 and 5 at the ultimate mass flow in the cooling water cycle, then we see that this does not differ much from the mass flow specified.

In the situation of maximum heat production virtually no steam goes to the low-pressure turbine. Some steam supply is however necessary to remove the friction heat developed in the low-pressure turbine. The steam velocity at the outlet of the turbine is however so low that this falls outside the validity range of the relations used and the program warns of this. The enthalpy calculated from extrapolation is probably too low. As this is also a relatively small mass flow, this error has a negligible effect on the total heat balance. Only the heat discharge in the condenser will, in percentage terms, have a large error; in addition the results are very useful.