STAG-unit with back-pressure steam turbine

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4.1 Introduction

In this chapter a simple example of a STAG unit is shown. This example contains three ‘independent’ cycles, namely a gas turbine cycle, a water/steam cycle and a district heating cycle.

The diagram is shown in Figure 4-1.

4.2 System description

In this example natural gas is fed to the gas turbine via source 1 and air via source 2. The gas turbine consists of compressor 3, combustor 4 and turbine 5. The flue gases from the turbine are passed to stack 6 via surface heat exchangers 18, 17, 14 and 32.

The flue gases are used to heat the water/steam in the water/steam cycle to an inlet temperature for steam turbine 10 of 450 °C. The steam then expands in the turbine and the heat is transferred via condenser 33 to the district heating system. Via pump 11, deaerator 12 and pump 13 the steam condensed to water is passed back to the waste heat boiler (heat exchangers 18, 17, 14 and drum 15) where steam is again produced.

The water from the district heating system is heated in condenser 33 and in an extra heat exchanger 32 in the gas turbine cycle. The heated district heating system is represented by
heat sink 30.
The electric power is supplied by generators which are driven by the gas and steam turbine.

Figure 4-1: STAG-unit with back-pressure steam turbine
4.3 Starting points for the calculation

The most important starting points are:

**Gas turbine**

- fuel: standard Slochteren natural gas (specified for pipe 1)
- oxidant: standard air (specified for pipe 2)
- inlet temperature air: \( T_{OUT} = 290 \, ^\circ C \) (see compressor 3/8)
- isentropic efficiency: \( \eta_{THAI} = 0.85 \)
- inlet pressure turbine 5/3: \( P_{IN} = 8.9 \) bars
- outlet temperature turbine 5/3: \( T_{OUT} = 530 \, ^\circ C \)
- power: \( S_{URPMW} = 30 \, MW \) (specified for the shaft)

**Steam turbine 10**

- inlet pressure: \( P_{IN} = 40 \) bars
- inlet temperature: \( T_{IN} = 450 \, ^\circ C \)

**Pump 11**

- isentropic efficiency: \( \eta_{THAI} = 0.85 \)

**Deaerator 12**

- inlet pressure: \( P_{IN} = 2 \) bars

**Pump 13**

- isentropic efficiency: \( \eta_{THAI} = 0.85 \)

**Heat exchanger 14**

- pressure drop primary side: \( D_{ELP1} = 3 \) bars
- pressure drop secondary side: \( D_{ELP2} = 0 \) bar
- temperature difference at high-temperature side: \( D_{ELTH} = 20 \, K \)

**Pump 16**

- isentropic efficiency: \( \eta_{THAI} = 0.85 \)
Heat exchanger 17
pressure drop primary side: \( \text{DELP}_1 = 1 \text{ bar} \)
presure drop secondary side: \( \text{DELP}_2 = 0.005 \text{ bar} \)
temperature difference at low-temperature side: \( \text{DELT}_L = 16 \text{ K} \)

Heat exchanger 18
pressure drop primary side: \( \text{DELP}_1 = 2 \text{ bars} \)
presure drop secondary side: \( \text{DELP}_2 = 0.005 \text{ bar} \)

District heating system 30
outlet pressure: \( \text{POUT} = 2 \text{ bars} \)
outlet temperature: \( \text{TOUT} = 70 \text{ °C} \)

Pump 31
outlet pressure: \( \text{POUT} = 15.0 \text{ bars} \)
isentropic efficiency: \( \text{ETHAI} = 0.85 \)

Heat exchanger 32
pressure drop primary side: \( \text{DELP}_1 = 2 \text{ bars} \)
presure drop secondary side: \( \text{DELP}_2 = 0.005 \text{ bar} \)
outlet temperature secondary side: \( \text{TOUT}_2 = 100 \text{ °C} \)

Condenser 33
pressure drop primary side: \( \text{DELP}_1 = 1 \text{ bar} \)
presure drop secondary side: \( \text{DELP}_2 = 0 \text{ bar} \)
outlet temperature primary side: \( \text{TOUT}_1 = 110 \text{ °C} \)
temperature difference at high-temperature side: \( \text{DELT}_H = 3 \text{ K} \)

Generators
efficiency (both): \( \text{ETAGEN} = 0.975 \)

Pipe data
Pipe 13: pressure drop \( \text{DELP} = 0.1 \text{ bar} \)