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P095

Investigating indirect evaporative coolers for ORC condenser cooling

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CONTEXT

Organic Rankine Cycle (ORC) condenser cooling is most of the time achieved by air or water. In the latter case, provided the water loop is closed, it is connected to a dry cooler (DC) or wet cooling tower (CT). Using a wet cooling tower allows to exploit the latent energy associated with air humidification, which boosts the performance of cooling but yields a water consumption. Whatever the condenser cooling solution, fans and pumps introduce auxiliary consumptions that significantly impact the ORC net efficiency.

This work aims to investigate the potential of IEC to further decrease the condensing temperature and pressure, over the more conventional cooling techniques previously mentioned. Indirect evaporative coolers (IEC) are a variant of wet cooling towers, where air is pre-cooled at the inlet of the cooling tower by a fraction of chilled water leaving the latter one. Such a system theoretically allows cooling the water down to the ambient air dew point temperature rather than the wet bulb temperature. However, the introduction of an additional heat exchanger as well as the increase of the air/water flow rate trough the cooling tower (for a given net water flow rate through the condenser) increases auxiliary electrical consumption.

To compare the energy performance of IEC over DC and CT, a 2.2 MWe ORC model implemented in Python is coupled to models of the previously mentioned technologies, implemented in Matlab. Cooling by air is also simulated in order to provide an exhaustive comparison.

The first part of this work describes the models of the ORC and cooling systems used. The methodology and boundary conditions set for the comparison between the different cooling strategies are presented afterwards. The first results are shown and discussed in terms of ORC net efficiency, auxiliary consumption and condensing temperature and pressure conditions.

MODELS DESCRIPTION

The ORC model implemented in python uses the superheat and sub-cooling of the cycle as input parameters. The turbine is modelled as an expander with constant efficiency. The LMTD method is used in the condenser and evaporator models to calculate the required transfer areas when subdividing the heat exchangers in sub-cooled, two phase and super-heated zones. This allows to iterate the evaporating and condensing pressures until the areas calculated for the evaporator and condenser are equal to the total area of the heat exchanger.

The CT model uses the nominal heat flow to be dissipated and the air conditions (dry bulb temperature, relative humidity) as input to size the CT. It is assumed that the CT is an air-water heat exchanger in which the humid air is replaced by a fictitious perfect gas; afterwards, a water flow control strategy is used to obtain, among others, the auxiliaries electrical power consumption.

METHODOLOGY

Four cases are proposed to evaluate the differences between the cooling options as shown in Fig. 1:

- **Case 0**: ORC condenser cooled by air loop. It corresponds to the original case study and allows to calibrate the ORC model and obtain the sizing parameters for the desired operation conditions. The condensing temperature and pressure are 59 [°C] and 0.78 [bar] for air an inlet temperature of 12.5 [°C].
- **Case 1**: ORC condenser cooled by water loop, cooled in turn by a DC. The sizing of the dry cooler is based on the ORC sizing done in Case 0 and an iso-bar hypothesis for the condensing pressure. The main output is the dry cooler electrical power consumption.
- **Case 2**: ORC condenser cooled by water loop and a wet Cooling Tower. The cooling tower is sized and operated based on iso-auxiliaries electrical power consumption with respect to Case 1.
- **Case 3**: ORC condenser cooled by a water loop, cooled in turn by an Indirect Evaporative Cooling Tower. The indirect cooling tower is sized and operated based on iso-auxiliaries electrical power consumption with respect to Case 1. This configuration is shown in Fig.3.

The weather data used corresponds to the location of Třinec, in Czech Republic, for 2022 [*Meteorological data: PVGIS, European Commission*]. Simulations are made for the daily average dry bulb temperature, for three relative humidities (50%, 70% and 90%).

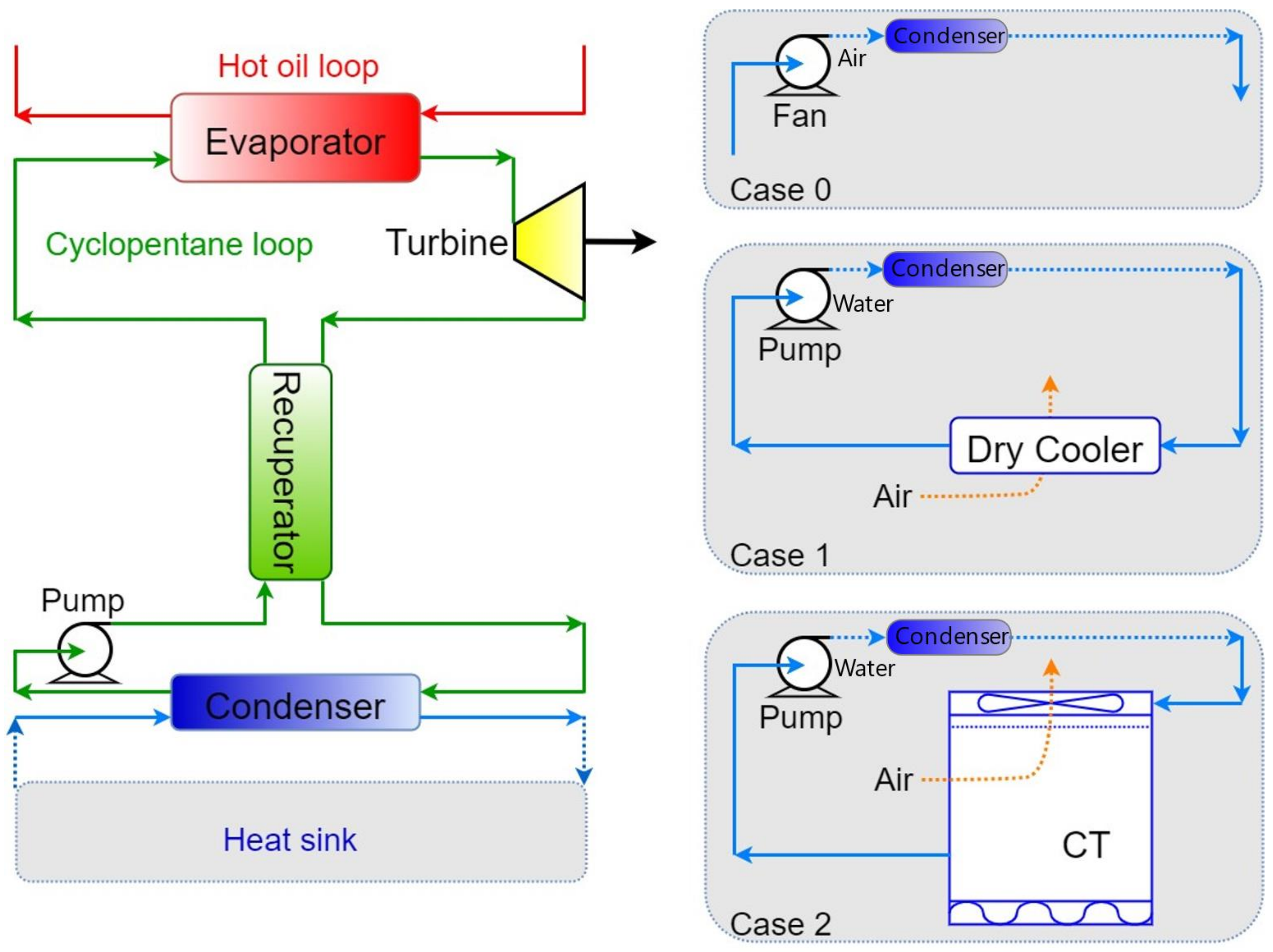

Fig. 1. ORC modeled system. Case 0: ORC condenser cooled by air loop; Case 1: ORC condenser cooled by Dry Cooler; Case 2: ORC condenser cooled by Cooling Tower

Results

The results presented in Fig. 2. show that the condensing temperature of the ORC decreases when the water loop is chilled by the CT instead of the DC; in both cases, the results are lower than the original case study conditions (Case 0). The effect of the relative humidity is also observed and has a higher impact for higher dry bulb air temperatures. The same can be seen in the condensing pressure results, where the results for air dry bulb temperature supply have the same order of magnitude than Case 0.

In terms of system efficiency, the results of obtained for the CT are better than the DC ones, increasing the ORC performance by about 1%.

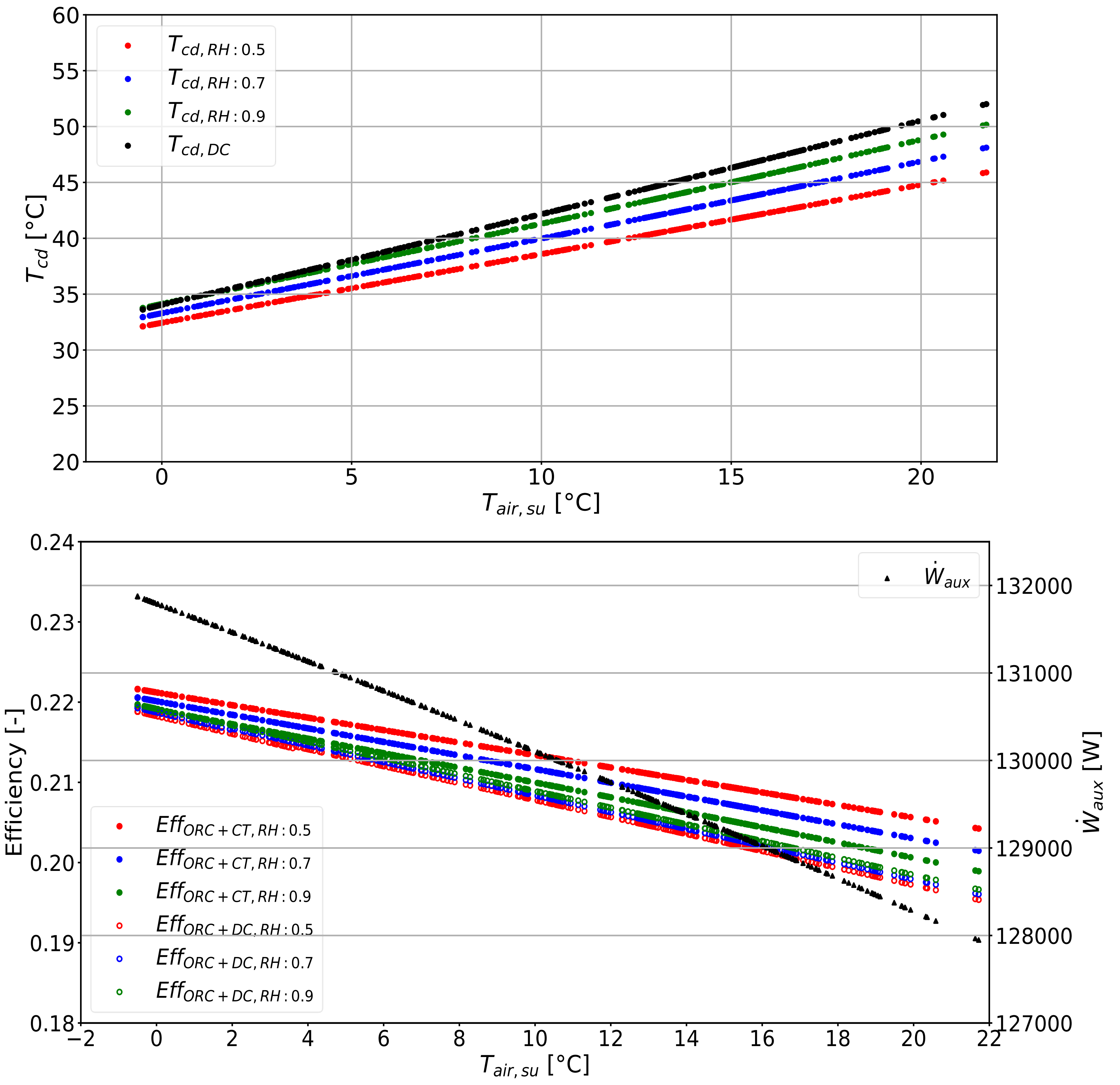

Fig. 2. Results for condensing pressure and temperature from the ORC and CT models coupling for different supply air conditions versus the reference DC case results (Top); Results for efficiency for CT and DC cooling for different supply air conditions versus auxiliaries electrical power consumption (Bottom)

Conclusions and perspectives

In a CT, the minimum water temperature that could be reached is the wet bulb temperature of the outdoor air. To further decrease the chilled water temperature, an air-water fin and tube heat exchanger can be used to pre-cool the outdoor air that enters the CT by using part of the chilled water as shown in Fig.3 (left). Results for this configuration (Case 3), is still work in progress.

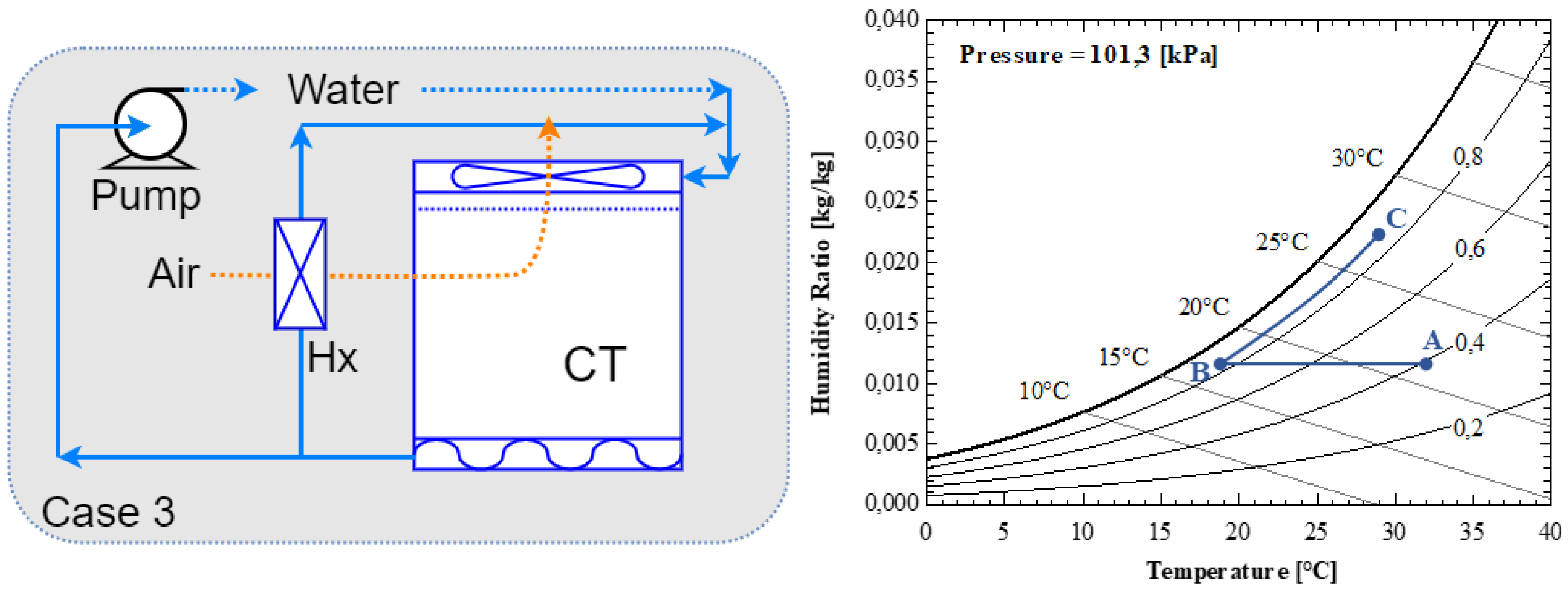

Fig. 3.Case 3 system scheme (left); Representation of the IEC process on a psychrometric chart

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