Impact of the turbine performance on the series and parallel CHP plants

Deep-geothermal energy is a renewable energy source which has large potential around the world. However, in northwest Europe, the brine (geothermal water) temperatures typically are low. Together with the high drilling costs, a pure electrical power plant fed by low-temperature geothermal energy is often not economically feasible. Combined Heat-and-Power (CHP) plants which produce, both, electricity and useful heat are a way to improve the economics of a geothermal project. In this work, we investigate the series and parallel CHP configurations of an Organic Rankine Cycle (ORC – electrical power) and a district heating (DH - thermal power) system. A typical DH system with supply and return temperatures of 75°C and 50°C is considered, and the brine has a temperature of 130°C.

For low heat demands, the parallel configuration is the most appropriate, whereas for high heat demands, the series configuration performs better. In case of a series configuration, the ORC outlet temperature is constrained by the supply temperature of the DH system such that a recuperated ORC generates more electrical power than the basic ORC. Therefore a recuperated ORC is considered in the series implementation. On the contrary, for the parallel configuration, the ORC performance is independent of the DH system requirements. Therefore, a basic ORC is considered for the parallel configuration. A recuperated cycle would give the same electrical power output but introduces an extra cost.

The parallel and series configurations are investigated for a heat demand of 7.3MW, where they perform equally well - for the higher mentioned brine and DH temperatures. The influence of the turbine performance on the overall plant efficiency will be discussed based on a second-law analysis.

Since the turbine is generally a high-cost component and bears a large share of the overall irreversibilities, a good turbine is of the utmost importance for good plant efficiency. For both, the parallel and series configurations, the net electrical power output is more than 50% lower when using a bad turbine (isentropic efficiency of 50%) in comparison with a good turbine (isentropic efficiency of 90%). In general, the implementation of a worse-performing turbine results in a higher turbine outlet temperature and hence requires more cooling power. In case of the recuperated cycle, the effect is less than for the basic ORC because more heat can be internally recuperated. Therefore, the effect of a worse-performing turbine is less in case of the series configuration compared to the parallel configuration.