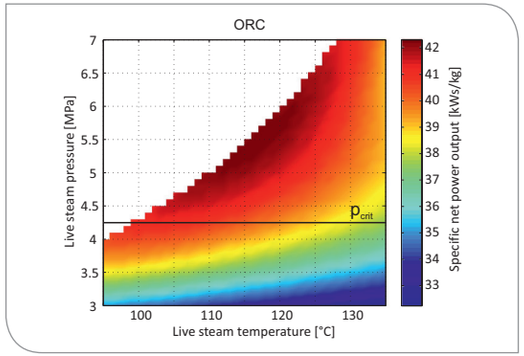
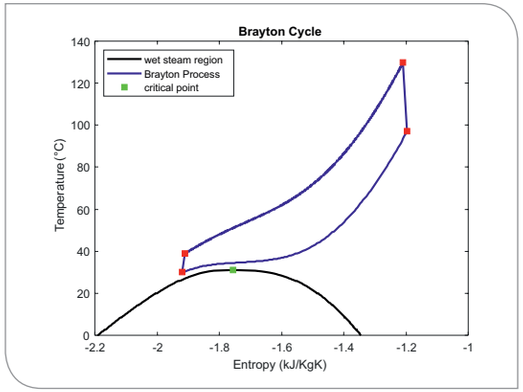
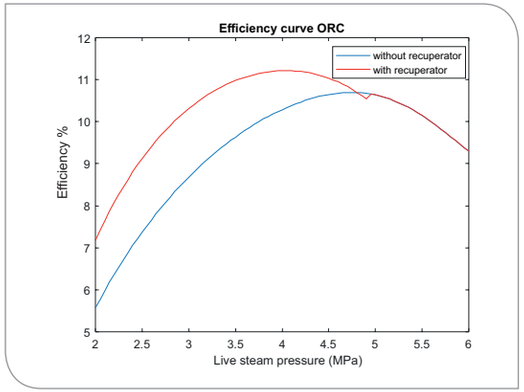
- Inlet and outlet temperature difference of the heat exchanger, condenser, recuperator
- Release heat to cooling fluid, outlet temperature and mass flow of cooling fluid.







Applications of GeSi

- Thermodynamic investigation of the stationary and part load behavior of ORC circuits at different operating conditions.
- Characterization and optimization of components.
- Generation of validation data for code development and simulation.
- Examining different cycles and ORC applications.
- Basic design tool
- Feasibility study tool

Outlook of further development

- Design and cost optimization of ORC.
- Implementation of different thermodynamic property databases.
- Use of new solver (GA).

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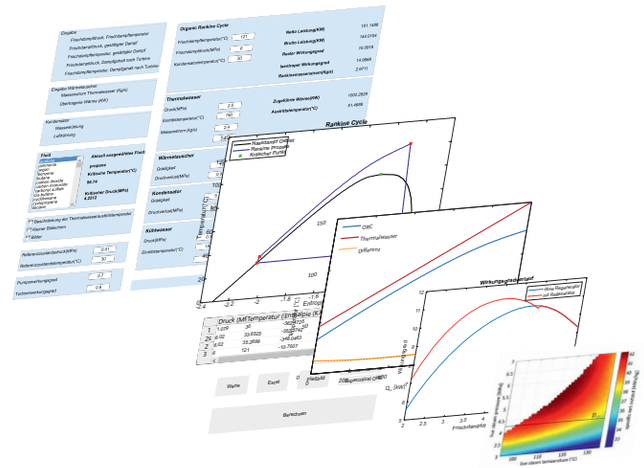
Karlsruhe Institute of Technology

GeSi
Geothermal Simulation

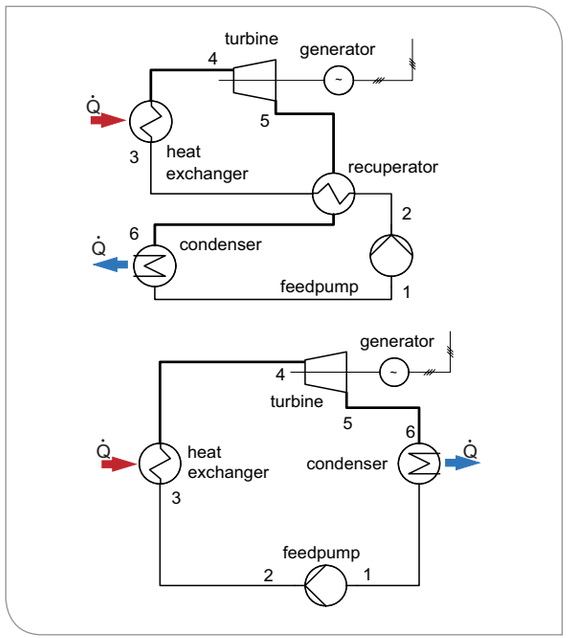
Stationary thermodynamic simulation and optimization of Organic Rankine Cycle (ORC) power plants

INSTITUTE FOR NUCLEAR AND ENERGY TECHNOLOGIES
EVT ENERGY AND PROCESS ENGINEERING



Introduction

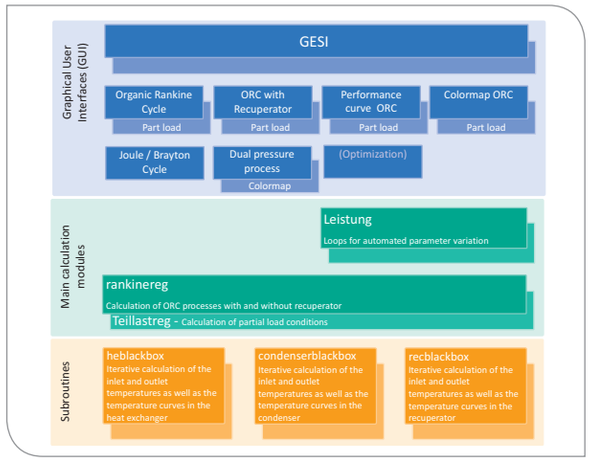
The Clausius Rankine process is the most efficient way of generating electricity through the conversion of thermal energy.
It is used in coal-fired and nuclear power plants as well as in gas and steam power plants.
For the utilization of low-temperature heat in smaller plants, this process is however, unsuitable, since high pressures and associated high evaporation temperatures for efficient conversion are required.



Instead of water, the so-called Organic Rankine Cycle (ORC) is applied. The ORC uses organic liquids as a working medium. These fluids differ from water in lower evaporation temperatures and pressures.
The figure shows two simplified process diagrams of such an ORC. A recuperator can be included, in order to increase the process efficiency in case of retrograde fluids.

Structure of GeSi

The simulation program Geothermal Simulation (GeSi for short) is a code developed in Matlab® for stationary, zero-dimensional calculation of Organic Rankine Cycle Processes (ORC). The GeSi software allows the thermodynamic optimization of ORC with different boundary conditions and workings fluids.
Depending on the external constrains, calculations for local or integral cycle data can be determined. This makes it easy to analyze the sensitivity of influencing variables.



GeSi release 2.3.6d has up to 12 different cycle input GUI´s which differ mainly in the available input variables and cycle configurations e.g. with or without recuperation or selection of cooling fluid.
It is also possible to vary only one variable p, T or q (steam quality) and keep the other inputs constant. This decreases the calculation time compared to the colormap module in which p and T are varied simultaneously.
Futhermore, GeSi is able to simulate part load conditions of ORC, two pressure cyles and Brayton Cycles.
The subroutines “blackbox” included in GeSi calculate the heat transfer of heat exchanger (HX), condenser and recuperator with an iterative bisection process with a standard discretization number of 200.

The calculation of the required substance properties of the working fluid and of the thermal water is provided by using the REFPROP fluid data of the National Institute of Standards and Technology (NIST).

Features of GeSi

The in house code GeSi (Geothermal Simulation) is able to simulate standard ORC cycles with the following inputs:

- Simulation mode p,T / p(tot.) / T(tot.) / p,x / T,x
- Heat transfer (mass flow or transferred heat)
- Condenser (water-cooling or air-cooling)
- Workings fluids (111 organic and inorganic compounds)
- Reference state p,T
- Pump and turbine isentropic efficiency
- Live steam conditions p,T
- Condensation temperature
- Thermal water p, T, (mass flow), (max. reinjection temperature)
- Heat exchanger min. temperature difference / pressure loss
- Condenser min. temperature difference / pressure loss
- Recuperator min. temperature difference / pressure loss
- Heat sink (water p,T / air p,T,Phi)

The GUI will show directly the result in a T,s diagram and a table with all the necessary data of the cycle. Additionally the following results are delivered:

- Net power output
- Gross power output
- Real efficiency
- Isentropic efficiency
- ORC mass flow
- Transferred heat
- Reinjection temperature of thermal water