ORC Turbogenerators

Turboden experience from R&D to industrial projects

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What We Do

Turboden designs, develops and maintains turbogenerators based on the Organic Rankine Cycle (ORC), a technology for the combined generation of electric power and heat from various renewable sources, particularly suitable for distributed generation.

➢ *Turboden solutions* from 200 kW to 15 MW electric per single unit
**Cycle** it is a thermodynamic cycle

**Rankine** it is theoretically given by 2 isobar and 2 adiabatic thermodynamic transformations

**Organic** it exploits an organic working fluid

**The principle** is based on a turbo-generator working as a normal steam turbine to transform thermal energy into mechanical energy and finally into electric energy through an electric generator. **Instead of** the water steam, the ORC system **vaporizes an organic fluid**, characterized by a molecular mass higher than water, which **leads to a slower rotation** of the turbine and **lower pressure and erosion** of the metallic parts and blades

**Efficiency:** 98% of incoming thermal power is transformed, into **electric power** (around 20%) and **heat** (78%), with extremely limited thermal leaks, only 2% due to thermal isolation, radiance and losses in the generator; the electric efficiency obtained in **non-cogeneration** cases is much higher (more than 24% of the thermal input)
Early Demonstration Projects

Location: Kapisha, Zambia
Year: 1988
Heat source: Geothermal fluid at 88°C
Total electric power: 2 x 100 kW

Location: Castelnuovo di Val di Cecina, Italy
Plant type: geothermal – experimental for Enel
Year: 1992
Heat source: Geothermal fluid at 114°C (return at 102°C)
Cooling source: water/air
Total electric power: 1.3 MW
Net electric efficiency: 9%
### EU Funded Demonstration Projects

<table>
<thead>
<tr>
<th>Location</th>
<th>Plant type</th>
<th>Started up</th>
<th>Heat source</th>
<th>Cooling source</th>
<th>Design electric power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marktgemeinde, Altheim, Austria</td>
<td>geothermal low enthalpy, coupled with a geothermal district heating system</td>
<td>March 2001</td>
<td>hot water at 106°C</td>
<td>cold water from a nearby river (cooling temperature 10/18°C)</td>
<td>1 MW (normally operated by the owner at ~ 500 kW)</td>
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<tr>
<td>Soultz-sous-Forêts, Alsace, France</td>
<td>geothermal, 1st EU operating plant on EGS (Enhanced Geothermal System)</td>
<td>June 2008</td>
<td>hot water at 180°C</td>
<td>air</td>
<td>1.5 MW</td>
</tr>
<tr>
<td>Simbach–Braunau, Germany/Austria</td>
<td>geothermal low enthalpy, coupled with a geothermal district heating system</td>
<td>August 2009</td>
<td>air/water at 80°C</td>
<td>water</td>
<td>200 kW</td>
</tr>
</tbody>
</table>

- **FP4-NNE-THERMIE C**
- **FP6 - SUSTDEV**
- **LOW-BIN GEOTHERMAL POWER**
Sauerlach, Bavaria, Germany
Plant type: Two level cycle geothermal unit
Started-up: February 2013
Heat source: geothermal fluid at 140°C  Cooling device: air condensers
Total electric power: 5+ MW_e plus 4 MW_th decoupling for district heating
Working fluid: refrigerant 245fa (non flammable)

Dürrnhaar, München, Germany
Heat source: geothermal fluid at 138°C
Total electric power: 5,600 kW
Started-up: December 2012
Scope of supply: EPC contract for the complete ORC unit, including the Air Cooled Condenser and the geothermal balance of plant

Kirchstockach, München, Germany
Heat source: geothermal fluid at 138°C
Total electric power: 5,600 kW
Started-up: March 2013
Scope of supply: EPC contract for the complete ORC unit, including the Air Cooled Condenser and the geothermal balance of plant

Traunreut, Bavaria, Germany
Heat source: geothermal fluid at 118°C
Total electric power: 4,100 kW
Total thermal power: 12,000 kW (to the District Heating)
Scope of supply: Supply of the complete ORC unit, including the Air Cooled Condenser and control system of geothermal site
ORC technology and the grid

✔️ **High predictable** - small seasonal and daily trends

   Power produced is slightly depending only on ambient temperature: at least **60% of the nominal load is always available** (+/- 20% in winter/summer case)

✔️ **Flexible** - different possible regulations

   **Power Control with quick reaction time** - ready for grid balance

✔️ Zero emissions - binary cycle with total reinjection

✔️ Different possibilities for coupling with district heating
Grid Balance Concept

[Diagram showing supply and demand with frequency control]

www.regelleistung.net
Consentec GmbH
Grid Balance

1) Directly control the Producers*

Smart Grid control
Grid Balance

1) Directly control the Producers*

2) Directly control the Consumers  
... when possible!
Grid Balance

1) Directly control the Producers*

2) Directly control the Consumers … when possible!

3) Store the Power

Efficiency?

Battery Life Cycle balance?
Grid Balance

Smart Grid control

1) Directly control the Producers*

2) Directly control the Consumers … when possible!

3) Store the Power

New concept: producer availability →
Power Availability examples

F.V.

Windmill

Geothermal ORC
The Geothermal Turboden’s ORC Experience in Germany

The Power can be reduced from 100% to 30% in 15 seconds and goes back to 100% in 15 seconds.
Next steps

- R&D was important and is still crucial for Turboden developments...
  more than 300 ORC plants in 32 countries represents an EU excellence

- GEOTHERMAL development:
  - the first 5 MW plant commissioned in Japan - summer ’15
  - further large scale geothermal projects foreseen in the future in EU
  - several projects currently under evaluation in Asia, US, LAM, ...

- R&D further efforts are strongly recommended in order to
  - reduce costs
  - increase performances
  - develop supply chain ... and compete in the global market
Thanks for your attention!

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35 Years of Experience

- **’60-’70**
  - Prof. Mario Gaia makes experience in the field of ORC within his research group at Politecnico di Milano

- **1980-1999**
  - 1976 – First prototype of a solar thermodynamic ORC
  - 1980 – Prof. Mario Gaia founds Turboden to design and manufacture ORC turbogenerators
  - Turboden develops research projects in solar, geothermal and heat recovery applications
  - 1998 – First ORC biomass plant in Switzerland (300 kW)

- **2000-2009**
  - Turboden installs ORC biomass plants, especially in Austria, Germany and Italy
  - Turboden plans to enter new markets, with focus on North America
  - First heat recovery applications

- **2009-2013**
  - 2009 – Turboden achieves 100 plants sold
  - 2013 - MHI acquires the majority of Turboden. Italian quotaholders stay in charge of management

- **2015…**
  - Today - Over 300 ORC plants in the world, over 240 in operation
  - 2009 – United Technologies Corp. (UTC) acquires the majority of Turboden’s quota. PW Power Systems supports Turboden in new markets beyond Europe
  - UTC exits the power market forming strategic alliance with Mitsubishi Heavy Industries
  - PW Power Systems becomes an MHI group company

- **2015…**
  - 2009 – United Technologies Corp. (UTC) acquires the majority of Turboden’s quota. PW Power Systems supports Turboden in new markets beyond Europe
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Turboden ORC Plants in the World

Turboden ORC plants in the world

AUSTRALIA 1
- biomass 1
- geothermal 1
- heat recovery 1

AUSTRIA 29
- biomass 29
- geothermal 1
- heat recovery 1

BELARUS 4
- biomass 4
- geothermal 1
- heat recovery 1

BELGIUM 1
- biomass 1
- geothermal 1
- heat recovery 1

BULGARIA 1
- biomass 1
- geothermal 1
- heat recovery 1

CANADA 2
- biomass 2
- geothermal 1
- heat recovery 1

CROATIA 1
- biomass 1
- geothermal 1
- heat recovery 1

CZECH REP 1
- biomass 1
- geothermal 1
- heat recovery 1

DENMARK 2
- biomass 2
- geothermal 1
- heat recovery 1

ESTONIA 1
- biomass 1
- geothermal 1
- heat recovery 1

FINLAND 1
- biomass 1
- geothermal 1
- heat recovery 1

FRANCE 1
- biomass 1
- geothermal 1
- heat recovery 1

GERMANY 4
- biomass 4
- geothermal 1
- heat recovery 1

GREECE 1
- biomass 1
- geothermal 1
- heat recovery 1

INDONESIA 1
- biomass 1
- geothermal 1
- heat recovery 1

ITALY 70
- biomass 1
- geothermal 10
- heat recovery 2
- waste to energy 3
- solar thermal power 1

JAPAN 15
- biomass 15
- geothermal 1
- heat recovery 1

LATVIA 1
- biomass 1
- geothermal 1
- heat recovery 1

MOROCCO 1
- biomass 1
- geothermal 1
- heat recovery 1

NETHERLANDS 1
- biomass 1
- geothermal 1
- heat recovery 1

POLAND 11
- biomass 11
- geothermal 1
- heat recovery 1

ROMANIA 2
- biomass 2
- geothermal 1
- heat recovery 1

RUSSIA 5
- biomass 5
- geothermal 1
- heat recovery 1

SINGAPORE 1
- biomass 1
- geothermal 1
- heat recovery 1

SLOVAKIA 1
- biomass 1
- geothermal 1
- heat recovery 1

SLOVENIA 1
- biomass 1
- geothermal 1
- heat recovery 1

SPAIN 7
- biomass 7
- geothermal 1
- heat recovery 1

SWEDEN 1
- biomass 1
- geothermal 1
- heat recovery 1

SWITZERLAND 8
- biomass 8
- geothermal 1
- heat recovery 1

TURKEY 2
- biomass 2
- geothermal 1
- heat recovery 1

UNITED KINGDOM 4
- biomass 4
- geothermal 1
- heat recovery 1

U.S. AMERICA 1
- biomass 1
- geothermal 1
- heat recovery 1

BIOMASS
- in operation: 218
- under construction: 43
- total: 261

GEOTHERMAL
- in operation: 5
- under construction: 4
- total: 9

HEAT RECOVERY
- in operation: 16
- under construction: 7
- total: 23

WASTE TO ENERGY
- in operation: 7
- under construction: 2
- total: 9

SOLAR
- in operation: 4
- under construction: 4
- total: 4

TOTAL PLANTS
- in operation: 246
- under construction: 60
- total: 306

*Hybrid Heat Recovery and Solar Thermal Power plant

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a group company of MITSUBISHI HEAVY INDUSTRIES, LTD.