ASME ORC 2013 2nd International Seminar on ORC Power Systems

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FIELD OPERATIONAL ANALYSIS OF AN EXISTING SMALL SIZE BIOMASS-FIRED ORC UNIT

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- Introduction
- CHP system description
- Operation data analysis
- ORC model definition
- Conclusions







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Biomass fired CHP in Italy



Current situation in Italy:

- about 200 existing power and CHP plants fired with solid biomass (*December* 2012)
- about 100 plants under construction
- about 3% of electricity production from renewables is generated by solid biomass power plants (*December* 2011)



from: GSE data, December 2012



CHP system location



The CHP system **BIOGENERA** is in the company **Fratelli Boscaro S.r.I.**, located in Vigliano Biellese (BI), a small town near Biella, in the Northwest of Italy.

The system is connected to a boiler fired with **wood biomass by-products**, resulting from the activities of green management in the surroundings.







Wood biomass by-products





The low biomass quality causes a difficult boiler design, together with the need of frequent maintenance operations (cleaning of the heat exchangers) and the low operating temperature of the superheated water.



District heating network





About **50.000** m³ of buildings currently supplied by the DH grid:

- residential buildings
- commercial/industrial buildings







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CHP system layout









Biomass feeding



Biomass boiler



Heat storage system

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- Heterogeneous input biomass, high moisture content (up to 50%), poor quality (average Hi 2,2 kWh/kg);
- **150 m³** silos with biomass pre-heating (heat recovery from ORC condensers).
- Superheated water boiler (nominal conditions: **150°C** and **5 bar**);
- Net heat output of 2.088 kW_{th};
- Boiler nominal efficiency of 85,8%

- Two heat storage systems of **110** m³ each;
- Water temperature of 80° C.



ORC specifics



ORC units



- Two ORC units of 125 kW_{el} each (GE Cleancycle 125)
- Organic Fluid: R-245fa
- Nominal gross ORC cycle efficiency: 12.8%
- High-speed turbine expander (26,500 rpm)
- Turbine design input conditions: 122° C and 15,5 bar







ORC units











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Available operation data





The **heat supplied** to the ORC system is not available through direct measurement, and it has been calculated from other available data.

RC13 Evaporator operation temperatures





The operation temperatures are much lower than design values.









ORC units gross power





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- The low temperatures of saturated water have a direct influence of the evaporation temperature of the working fluid.
- As a consequence, the fluid has a **lower pressure at the turbine inlet**, causing the cycle efficiency to be lower.
- The units show a good efficiency at partial load, which remains comparable to full load operation.







The annual operation of the units is limited by the **availability of the input heat from the boiler.** The need of significant maintenance operation for the cleaning of exchangers limits the annual hours of operation.







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- A stationary model has been defined starting from the experimental data, leading to the complete calculation of the points of the cycle.
- The model has been developed with the software EES (Engineering Equation Solver), considering a thermodynamic analysis of the components of the system.
- The model has been validated on all the available operation data, with an average relative error on gross power output of 0,5%.



13 Relative error on gross power output











Results of the model calculations on a specific hour of operation.







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- The operation of the biomass system showed a good availability, generally higher than 7,600 h/y;
- The variable power output is strongly related to the available water conditions from the boiler, which are related to the biomass heterogeneity, low quality and high moisture content;
- The match with **biomass boiler operation data** (not yet available) could lead to a more comprehensive analysis of the CHP system.





- Need of biomass boiler operation data for a more complete analysis of the CHP system performance;
- Application of the model to different configurations in order to analyse the variation of cycle efficiency and other parameters;

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Thank you for your attention.



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