EDGaR Energy Delta Gas Research

Decentralized (bio)gas storage design with small scale MTT/CAES/TES (C5, WP2)

M. de Rooij, F. Koopman, H. van Weerden (Hanze), R. de Boer (ECN), C. Pelletier (Hanze)

Introduction

The increase in renewable energy sources will require an increase in the operational flexibility of the grid, due to the intermittent nature of these sources. This can be achieved for the gas and the electricity grid, which are integrated by means of power-to-gas and vice versa, by applying gas and other energy storages. Because renewables are applied on a decentralized scale level and syngas and biogas are produced at relatively low pressures, we study the application of a decentralized (bio)gas storage system combined with Micro Turbine Technology (MTT), Compressed Air Energy Storage (CAES) and Thermal Energy Storage (TES) units, which are designed to optimize energy efficiency.
In this study we answer the following research questions:

a. What is the techno-economical feasibilty of applying a decentralized (bio)gas storage with a MTT/CAES/TES system to balance the integrated renewable energy network?
b. How should the decentralized (bio)gas storage with MTT/CAES/TES system be designed, so that the energy efficient application in such networks is optimized?

Note that:

c. We verify the calculations for the small scale MTT unit with measurements on our proof-of-principle set-up of part of the system that includes two MTTs in parallel.

Method

a. Techno-economical system analysis

The integrated grid with a decentralized (bio)gas storage with MTT/CAES/TES system is modeled based on linear programming[1]. We obtain the dimensions of this energy network so that the costs (CAPEX and OPEX) are minimized. The primary energy sources (wind, solar and biomass) are balanced with the energy consumption of average Dutch household neighbourhoods in Eelde (Figure 1).

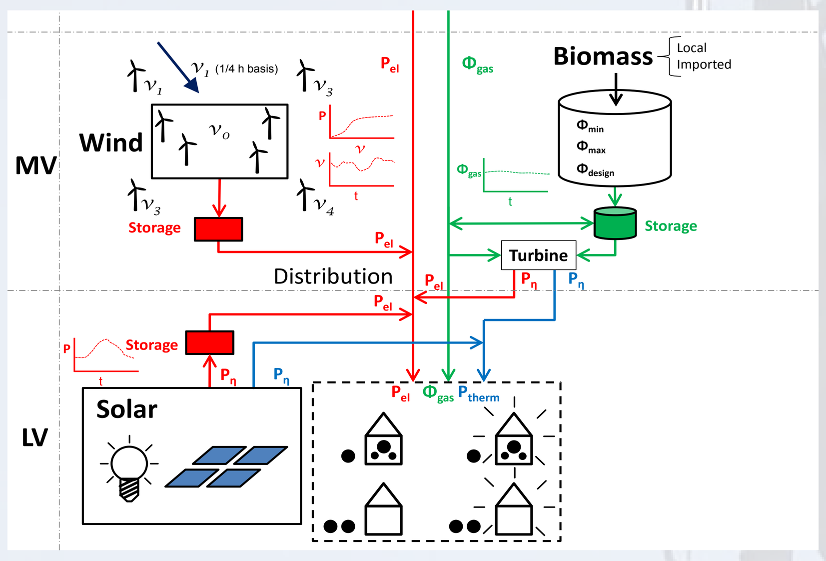

Figure 1.The integrated grid with decentralized (bio)gas storage is modeled with conversion and energy storages.

b. Thermodynamical system analysis

The thermodynamic model consists of components of a decentralized (bio)gas storage with MTT/CAES/TES system (Figure 2). Calculations are based on:
- System dimensions obtained from answering a.
- System functions for the system, units, components
- Energy functions for the system, units, components
- Mathematical thermal optimization equation

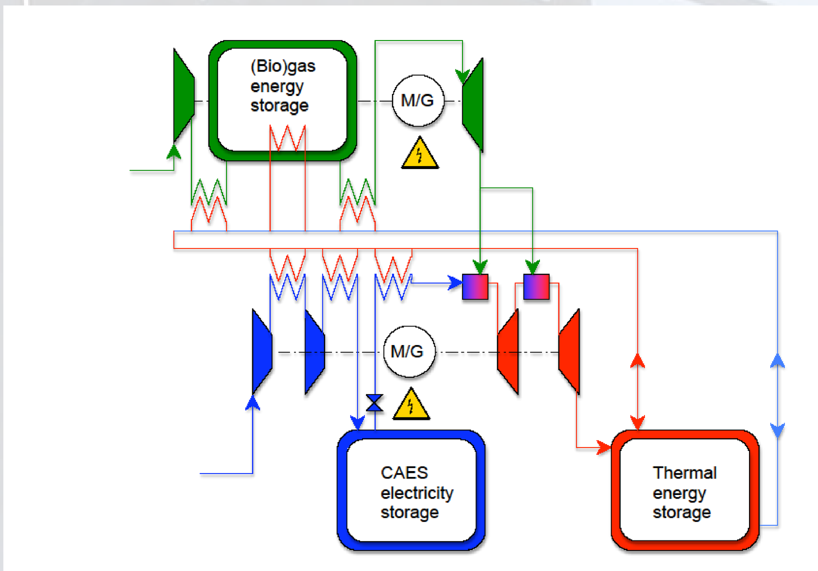

Figure 2.The decentralized (bio)gas storage with MTT/CAES/TES system consists of various units.

c. Thermodynamic MTT measurements

To verify the thermodynamic calculations for the MTT system[2], we build a proof-of-principle set-up that consists of 2 MTTs in parallel with a cooling system to discharge the heat (Figure 3).
The recuperated MTT produces 1.2-3 kWe and 7-15 kWth at an efficiency that is reported to be 87% maximum, depending on the water conditions.

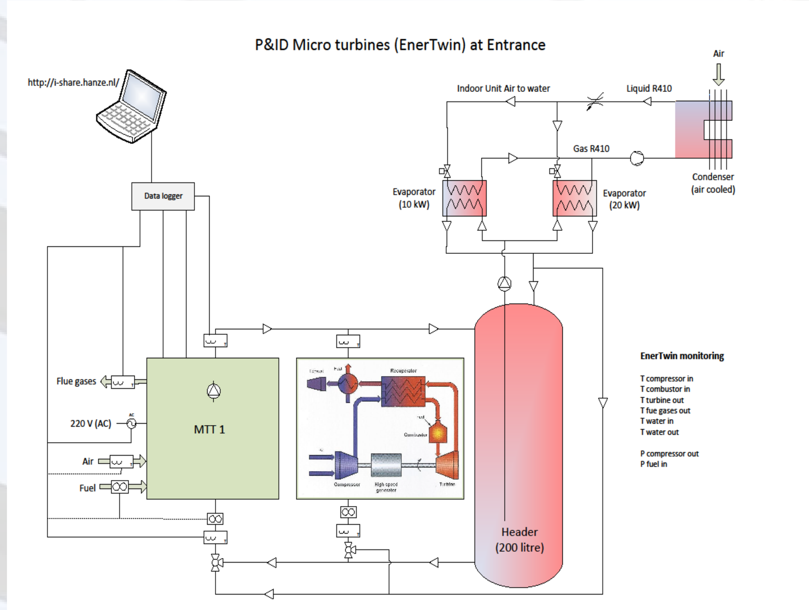

Figure 3.The P&D of the proof-of-principle MTT set-up with a cooling system to discharge the heat.

Preliminary Results

a. Techno-economical system analysis

As an example, we studied a case that consists of 100 households with a yearly demand of 3500 KWhe and 40 GJh each. We assumed the yearly electricity demand to be supplied by wind energy (30%), solar energy (20%) and biogas (50%).
The hourly supply and demand were supposed to be balanced by a CHP (Figure 4). However, because the heat demand, which is met by a supply of 85,000 Nm3 biogas via the CHP, is dominant in The Netherlands, there is a continuous over production of electricity.

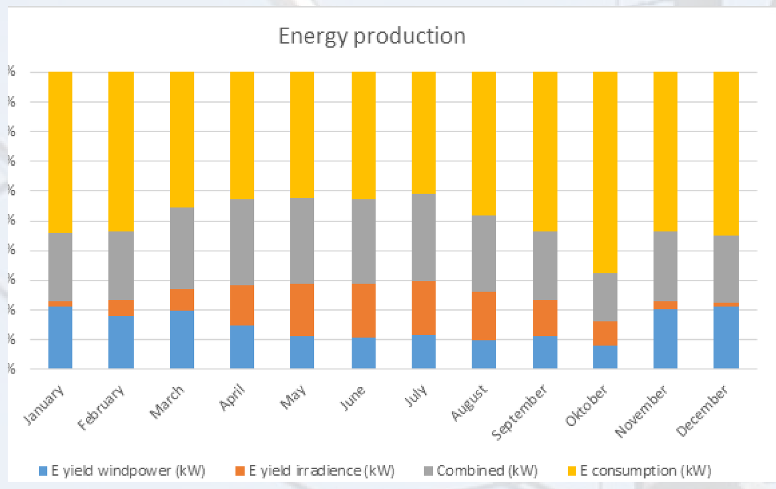

Figure 4.Energy production from various renewable energy sources. The supply and demand is matched with biogas combustion in a CHP.

b. Thermodynamical system analysis

The 85,000 m3 of biogas that is required for the heating demand is obtained from a (bio)gas storage system. Out of 4 different storage technologies (CNG, ANG, LNG and NGH), LNG scored the highest on volume reduction, energy efficiency and simplicity.
The continuous overproduction of electricity due to the dominant heat demand does not leave any room for CAES. Therefore, we performed a thermodynamic analysis of a CAES unit for the electricity grid only(Figure 5).

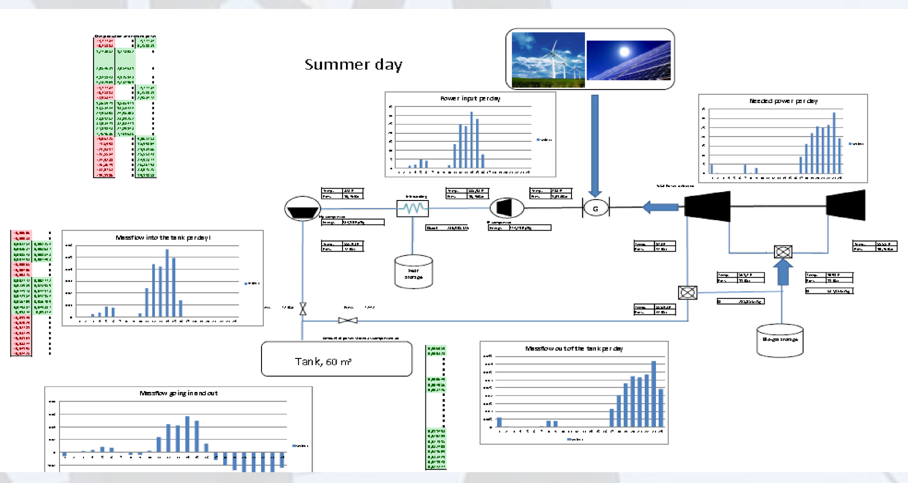

Figure 5.The thermodynamic results of a downscaled CAES unit which is part of an all electric renewable energy network.

c. Thermodynamic MTT measurements

Due to the dominant heat demand in the Netherlands, the CHP with a P/Q ratio = 2/3 causes a constant overproduction of electricity. This does not leave any room for additional renewabel energy sources on the grid. Small scale MTT offers a solution with its P/Q ratio = 1/5. We measured the temperatures and pressures for the MTT gasturbine cycle and the water heat exchanger which are given in a system layout in Figure 6.

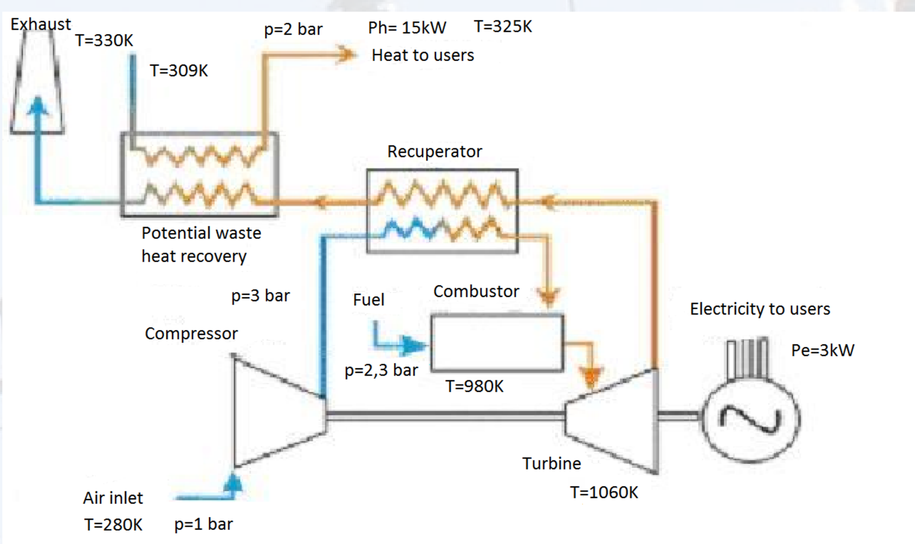

Figure 6.The thermodynamic data of a recuperated MTT under full load conditions (2.5 kWe and 15 kWth)

Preliminary conclusions and future research

Based on wind speed, irradiance patterns and electricity and heat demand patterns for a case of 100 households, we found the optimum dimensions for the decentralized (bio)gas storage based on guaranteed supply. We concluded that a decentralized (bio)gas storage of 85 000 Nm3 was needed to provide the heat demand. LNG was the most energy efficient storage technology for such dimensions.

The use of (bio)gas directly in a CHP (P/Q ratio = 2/3) that was mainly heat driven, resulted in a continuous overproduction of electricity due to the dominant heat demand of the 100 households in the Netherlands.This does not leave any room for the increase in the application of PV and wind generators, nor is there a purpose for electricity storage.
For that reason we will further investigate the application of a decentralized (bio)gas storage with MTT/CAES/TES as a solution to balance a renewable integrated network. Using an MTT in the system offers a more useful P/Q ratio for households of 1/5.

References

[1] Ramakumar R., Sudhakara Shetty P., Ashenayi K., 1986, A linear programming approach to the design of integrated renewable energy systems for developing countries, IEEE Transactions on Energy Conversion, Vol. EC-1, No. 4, December 1986
[2] W. P. J. Visser, S. Shakariyants, M.T.L. de Later, A. Haj Ayed, K. Kusterer, 2012, Performance optimization of a 3 kW microturbine for CHP applications, Proceedings of ASME Turbo Expo 2012, GT2012-68686

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