Project Submission Form 2012

Team Name	Thermal squad
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Level: capstone or others (specify)	Technology readiness level 4 - Basic R&D. Technological development initiated, components are being integrated to establish that they will work together.
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Title	*Thermal Battery: A concept enabling 100% renewable energy systems*
Number of student participants	*3*
Project duration	*4320 hours*
Industry collaboration, if any	*Alfalaval, Danfoss, Embraco, Nilan A/S*
Description:	*Atthaced*

Thermal Battery: A concept enabling 100% renewable energy systems

The future of the world has always evolved in response to human necessities. Change frequently requires energy and now more than ever before in the history of our planet new generations look for safer, healthier, greener and more efficient ways to obtain it. One expressive example reflecting this are policies around the world for replacing fossil fuels with renewable energy sources such as wind and solar power, e.g. in Denmark that aims at achieving 50 % renewables in electricity supply by 2020. The successful implementation of such policies is critical to the welfare of future generations and societies.

As renewables encompass a larger fraction of energy generation, power grid integration must be resolved to balance the essential energy supply-demand relationship. In order to balance intermittent renewable supply and consumer energy demand it is generally recognized that large-scale integration of wind and solar power leads to a need for new energy storage technology. Energy storage allows ‘smoothing’ in power delivery, absorbing production peaks and filling troughs, hence reaching higher renewable penetration levels. This strategy involves balancing both electrical grid supply and demand in an intelligent manner, often referred to as the “Smart Grid concept” [5].

Most research on smart grids and intelligent energy systems focuses on the power grid and on electro-chemical and mechanical storage technologies.

However, our group research finds that it will be far more cost-effective to focus on the ability to smart-grid-enable the provision of thermal energy services, which at the same time is resulting in state-of-the-art resource efficiencies [2], [3].

To further investigate our hypothesis, we have designed, modeled, and built a concept that combines hot and cold thermal storages with a transcritical CO_2 heat pump for combined, yet flexible supply of useful heat and cooling. Figure 1 illustrates our Thermal Battery (TB) concept [4], which consists of a transcritical heat pump and two water storages. The TB simultaneously produces heated water stored in a hot storage that can be used for space heating and/or hot tap water, and chilled water stored in a cold storage that can be used for space cooling and/or refrigeration.

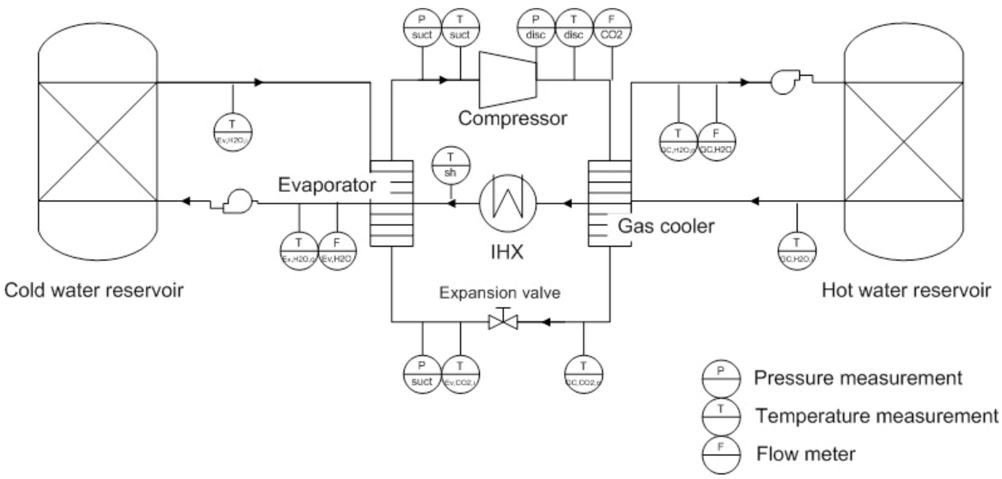

Figure 1 Schematic layout of the Thermal Battery concept [1]

We have developed a thermodynamic model that identifies the optimal operational modes for the specific application, leading to state-of-the-art conversion efficiencies and allowing an increase of renewable penetration levels in the electrical grid.

Our model simulates the heat pump performance by changing the inlet and outlet water temperatures and the water mass flow rates considered both for the gas cooler and the evaporator. The model was validated with experimental results found in the literature and lead to encouraging conclusions regarding the potential of the TB concept for household applications. Findings from this research will be presented at the collaborated 21st International Compressor Conference, the 14th International Refrigeration and Air Conditioning Conference, and the 2nd International High Performance Buildings Conference, to be held at Purdue University in July 2012 [1].

Furthermore, a thermodynamic model that predicts the temperature distribution of the tanks was developed to study the influence of CO_2 heat pump and a solar thermal collector as heat providers on performance of the thermal storage for domestic applications. The model is validated with results from experiments carried out on an experimental setup that we designed and built for the purpose with a full-scale storage tank at Aalborg University.

We have subsequently designed and built a test facility for a transcritical CO_2 heat pump, including a state-of-the-art climate box for creating a controlled ambient environment for the air-to-gas evaporator at Aalborg University as well as a TB incorporating two water storage tanks, built in a partnership between Aalborg University, the University of California (UCSC and UCD) and Purdue University.

Figure 2 Picture showing the actual status of the experimental setup [6]

This new knowledge will provide a significant research-based lift to visions towards 100% renewable energy systems. At the same time, the applications would benefit manufacturers that intend to bring new Smart-Grid-Ready products to consumer and industry markets, and will thus also be supporting the creation of new green businesses and jobs.

The research project involves a team of young talents who already possess cutting-edge knowledge of the field and who are eager to be part of the engineers that make the world change for the better. Our group is proudly committed to this project and we look forward to sharing our experience as a group working towards new energy-generation ideas for a better future.

References

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