Determination of the energy content in hot water storage tanks

Algorithms for estimating quantities that are not directly measurable

1 Project goal

In order to provide the desired room climate, heating, ventilation and air conditioning systems are widely used in apartments and buildings. As a consequence today a large part of the total energy consumption of buildings is directly attributable to room heating and hot water systems. In order to reduce the overall energy consumption, such systems should be designed and operated in such a manner that energy consumption is as low as possible without impairing the comfort of the residents.

Developing heating systems that use an intelligent control strategy and thereby reduce overall energy consumption is today quite difficult for several reasons. One reason for this is that, compared to the complexity of the task only very few sensors are normally installed in a building that are capable to monitor the underlying room climate and the heating system. This means that only a limited view of the current status of the heating system is available based on the possible sensor data.

From a data processing point of view, the greatest challenge is that the heat exchangers of the solar collector and the burner feed an unknown amount of energy into the system. In addition, residents produce events like hot water extraction which creates additional challenges to the system. Finally cooling down of the building reduce the energy content. In addition, the temperature is only monitored by a few sensors, which are located on the heat exchanger of the solar collector and in the middle and top of the water tank.

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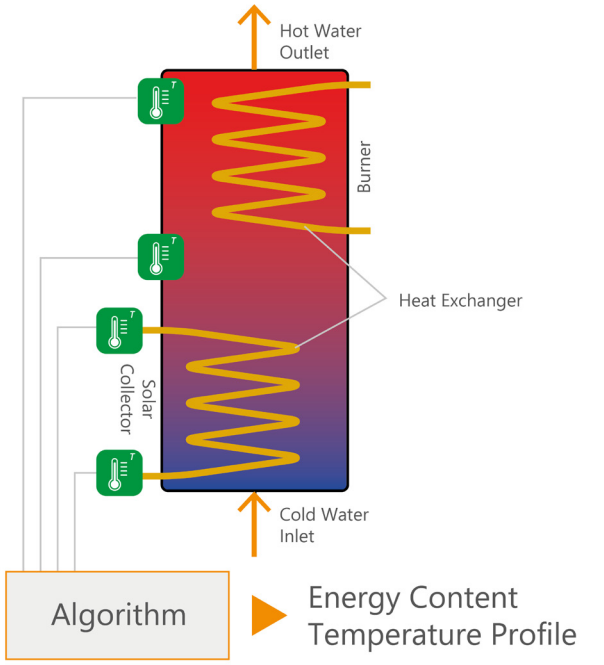
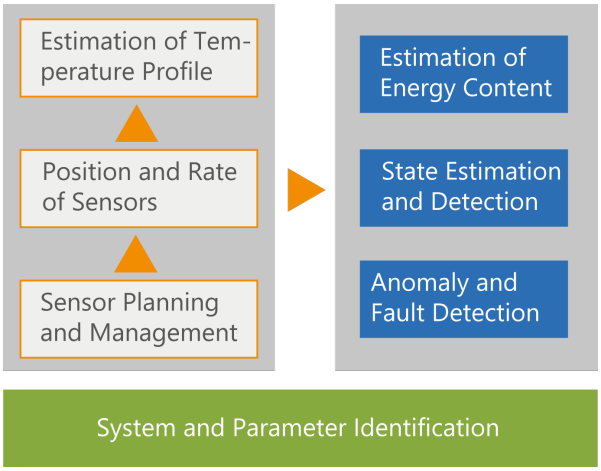
The aim of this project was to develop different algorithms for the state detection, the estimation of the energy content and the temperature profile in hot water storage tanks. The main objective was to estimate the energy content based on the few sensor data and to control the hot water storage tank in such a manner that the overall energy consumption can be reduced as well as that peak loads can be minimized. This makes it possible to provide the end customer with additional functions for needs-based hot water preparation.



Hot water tank diagram. An intelligent algorithm integrated in a control system permanently calculates the energy content and the temperature profile of a hot water storage tank based on temperature sensors.

2 Development approach

- Selection of a model-based approach to take the physical conditions into account.
- Modeling of the heat propagation over time and place in combination with the energy inflows and outflows, as well as the heat exchangers (heat transport) including also the inflows and outflows of water (mass transport).
- Estimation of the temperature profile in the hot water tank for each measurement.
- Compensation of measurement disturbances.
- Realization of the algorithm development in a rapid prototyping language like Python.
- Implementation of final qualified and product ready software development in C on embedded microcontrollers and integration into the customer's target system.
- The algorithm and software development took place in very close coordination with the customer.



Estimation of quantities that cannot be measured directly. Based on temperature sensors that are attached to a few places on the hot water tank, quantities that cannot be measured directly can be estimated using intelligent algorithms. Examples: (a) temperature profile and energy content in the storage tank, (b) status of the hot water storage tank, (c) energy flow from the solar collector, (d) hot water taps by users and (e) anomaly detection.

3 Result and benefit

- Thanks to its good configurability, the developed software product has been expanded to include several product families and integrated very well into the product range.
- The procedure developed by Knowtion only requires approx. 5 kByte of memory.

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- The end user receives further information obtained from the temperature measurements, such as a detailed temperature profile, energy levels, energy balances and the time and volume of hot water taps.
- The realized solution will enable the consumption of fossil fuels to be reduced in the future and to achive in combination with the use of solar energy an optimized energy utilization.

Reduction of energy consumption in buildings and apartments

Reduction of energy consumption. The algorithm enables new functionalities that provide the end customer with needs-based hot water preparation. This helps to reduce energy consumption in buildings and apartments.

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