Validation of predictive models for smart control of thermal and electrical energy storage

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A transition of today's energy system towards renewable resources, requires solutions to match renewable energy generation with demand over time. These solutions include smart grids, demand-side management and energy storage. Energy can be stored during moments of overproduction of renewable energy and used from the storage during moments of insufficient production. Allocation in real time of generated energy towards controlled appliances or storage chargers, is done by a smart control system which makes decisions based on predictions (of upcoming generation and demand) and information of the actual condition of storages.
Algorithms used for smart energy control systems therefore contain a model which describes the amount of stored energy within a thermal or electrical storage. A simple model which is frequently applied is given by Equation 1.

$$E_t = E_{t-1} + G_t - D_t \tag{1}$$

In which E_t the average stored energy during a time interval {t-1,t}, with t being the present time interval and $t-1$ the previous time interval. Further, G_t the average generation and D_t the average demand during the present time interval. The model assumes that there are no losses related to energy storage. In practice, significant energy losses can occur during standstill or charging and discharging processes. The paper investigates these losses for common types of thermal storages and batteries.

The paper reviews more detailed simulation models, such as the stratified layer model for a thermal storage, and experimental models containing physical parameters for batteries. Various experiments are carried out, involving two types of thermal storage and two types of batteries. With the results of these experiments, accuracy of the detailed simulation models is validated.

Lastly, the paper validates accuracy of the simple energy model to describe charging and discharging cycles. The paper shows that the simple energy model is accurate but only to a certain minimum discharge level of the storage. An example of this is shown in figure 1. The figure shows results of measurements, the "ideal model" or simple energy model and a more detailed node or stratified layer model, for which 7 layer temperatures are shown in the upper graph. The figure shows that the ideal or simple model is reasonably accurate until a discharging temperature of 40°C is reached. From that discharge level, the inaccuracies become more significant. The paper shows more figures for thermal storage and batteries. We conclude that the loss of accuracy is more prominent for the investigated types of thermal storage than for the batteries. The paper introduces a possible correction method to increase accuracy of the simple model over a wider range, which is the paper's main contribution. Finally, the paper shows results of a realistic smart energy control case to demonstrate the importance of the correction method.

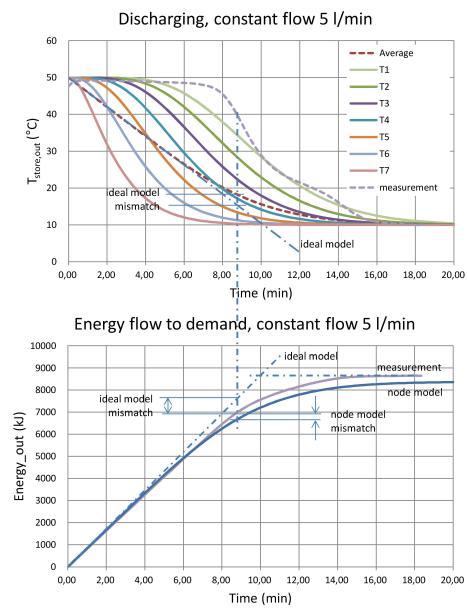

Fig. 1. Temperature and energy flow to demand for a thermal storage