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Auxiliary Energy Saving Potential of Solar Thermal Systems with Predictive Controls

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1. Introduction

Solar thermal (ST) systems are generally equipped with two-level controllers. Auxiliary heating divides the storage volume (V_S) into two parts; Fig. 1. The lower, reserved for ST heat supply only and the upper (V_{aux}) available for ST and auxiliary heat supply, to guarantee the compliance of set temperatures on the load side of the storage.

A two-level controller enabling the auxiliary heating has no information on actual or expected solar radiation. This might lead to interference of the auxiliary heating with ST heat supply, reducing the share of ST energy fed into the storage.

A smart model predictive control (MPC) concept, incorporating weather forecast data might be able to overcome this shortcoming.

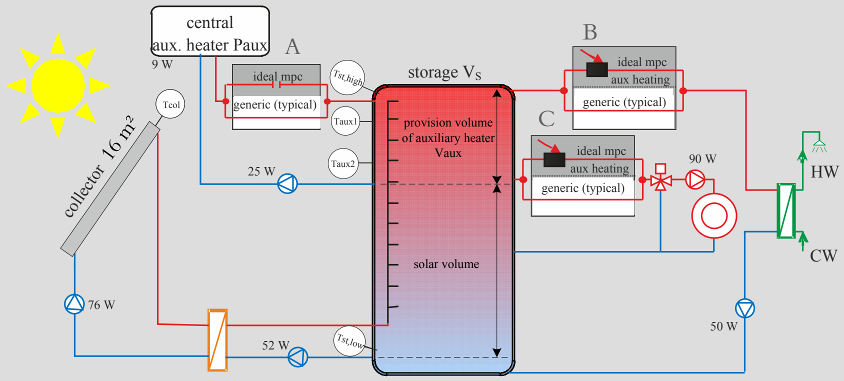

Fig.1: System hydraulics, principal sketch with two exclusive options for auxiliary heating.

2. Methodology

The maximum theoretical potential of an intelligent MPC is investigated by means of comparing simulation results from a *generic* (white area) and an altered (grey area) hydraulic scheme shown in Fig. 1 in the boxes A, B and C, respectively. The altered scheme – *ideal mpc* – essentially mimics an ideally operating mpc.

The scheme in Fig. 1, A_{Col} = 16 m², V_S = 1.2 m³, Meteonorm data for Strasbourg and a load profile for a single family house (SFH45) – taken from the IEA SHC Task 44 – form the main ingredients to obtain annual TRNSYS simulation results.

Solar fractions (F_S) are calculated according to eq.1; eq.2 is defined to characterize the relative change of F_s for a given relative solar volume.

$$F_S = \frac{\sum_i \dot{Q}_{HXsolar}(t_i)}{\sum_i \dot{Q}_{HXsolar}(t_i) + P_{aux}(t_i)} \quad \text{(eq. 1)}$$

$$\Delta f_S := \frac{(F_{S,ideal\ mpc} - F_{S,generic})/F_{S,generic}}{(V_S - V_{aux})/V_S} \quad \text{(eq. 2)}$$

3. Results

Generic base case results are listed in Tab.1. Fig. 2 depicts solar inputs and storage losses for five different storage volumes (V_S). The heights of the white bars show the solar input for the *generic* case. Gray extensions indicate the potential improvement for ideal mpc. Annual solar input is up to 308 kWh higher for ideal mpc and the losses are approximately 12% lower, compared to the generic case, shown by the very right bars above the label Year. Ideal mpc requires 409 kWh less auxiliary energy for the base case than generic.

The behavior of Δf_S for increasing relative solar volume is shown in Fig. 3.

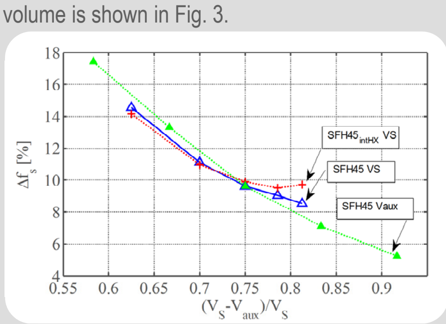

Fig.3: Relative change of F_s; ideal mpc compared to the generic case as a function of the relative solar volume

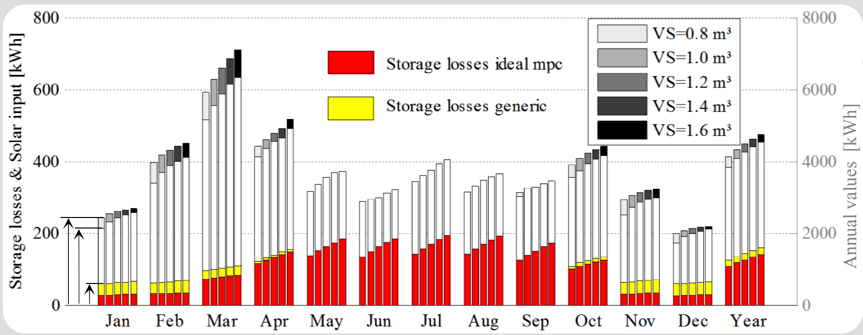

Fig.2: Storage losses and solar input for generic (white bars) and ideal mpc case (grey extension) for variation of V_S for SFH45; each color coded bar is drawn from zero level, left axis relates to months, right axis relates to the Year bars.

Tab.1: Annual generic base case results in [kWh] for SFH45, space heating load 45 kWh/(m² a), hot water 2133 kWh/a

FS [-]	Operation [h]	DHW demand	Heating demand	Solar input	Aux. Input	Storage losses	Aux. electr.
0.43	1586	2132	6476	4276	5776	1440	654

During summer the improvement potential is nearly zero due to the relatively low load compared to the available solar input. Operation conditions as for the outstanding months are viable to drastically increase the annual improvement potential. In addition ideal mpc is favorable as the relative storage volume decreases.

In a more extended MPC control concept, the MPC would also strive to operate the collector at maximum efficiency if reasonable, which was not considered herein.

A real application requires accurate weather forecast data and a receding horizon control algorithm, which is currently investigated.

4. Conclusion

The annual auxiliary energy saving potential for the base case originates from 226 kWh more solar input and 173 kWh less losses. The improvement is less than expected, however, in certain months an increase of F_s by 0.12 or 30% is possible.

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