Balancing Residential Energy Consumption and End-User Comfort

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With the currently growing trends in residential electricity consumption, maintaining the desired reliability of the energy system is of utmost importance. The stress on the grid can be diminished by inducing lower energy use during the peak-load hours In practice, it can be done by means of controllers that limit energy consumption of individual consumers. However, an ill-conceived disconnection of residential loads can have dramatic implications on end-user comfort. Impossibility to operate domestic devices and the need to alter consumption patterns might significantly deteriorate consumers' satisfaction with an energy provider. Thus, in case of on-site electrical water heating loads, cut-off of electric energy during the periods of hot water usage might result in the increased user thermal discomfort and the following complaints to the utility company. To avoid these situations, there is a need for solutions that allow to balance energy consumption and consumers' comfort.

In this paper we demonstrate how such balancing can be achieved on the level of a single domestic device. We consider a scenario wherein the energy consumption of an electrical tank water heater (WH) is scheduled along a daily timescale to minimize its impact on the energy system while respecting the user comfort. To formulate this problem, we use an LPI-optimization approach and a discrete time model with a daily time horizon. The first objective function f_1 represents a possible user thermal discomfort that (s)he can experience due to electricity cut and that has to be minimized. Our thermal comfort model incorporates parameters such as the water temperature, duration of water usage and personal tolerance to cold water temperature. The second objective f_2 is a daily energy consumption of the WH to be minimized subject to a user-acceptable thermal discomfort (f_1) and some WH's engineering constraints. Given a daily hot water usage profile (e.g., from a forecast), we solve the problem for different comfort levels, which yields Pareto front where each individual solution corresponds to a certain daily plan of heat injections into the tank (energy consumption) and the associated user thermal comfort.

Simulation results for various water usage profiles reveal possible trade-offs between the electric energy reduction and the consumers' thermal comfort. The proposed approach lets utility companies exercise reliability measures more cautiously with awareness of consumer comfort. While consumers can benefit from energy (money [3]) savings and can get an insight about their electricity consumption habits.

[3] Belov, A., Kartak, V. et al.:Load shifting of domestic water heaters under double price tariffs: Bringing together money savings and comfort. IEEE ISGT-Europe Conference, 2016.