A residential load behavior model to analyze Demand Response and end-use tariffs

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Overview

There is a growing awareness of the importance of Demand Side Management (DSM) on residential electricity consumption to improve system operation efficiency and reduce grid and generation capacity investments. In particular, price-driven Demand Response (DR) mechanisms are gaining interest because they are believed to have a great potential to reduce demand peaks or flatten the overall demand curve by making electricity tariffs for end-consumers more closely reflect the time variation of marginal electricity prices. However, most existing tariff structures consist of an average flat charge preventing residential consumers from actively participating in energy markets, in spite of their significant contribution to peak demand.

DR measures involve the deployment of smart metering equipment and intelligent appliances, as well as communication technologies and new network management requirements. A cost-benefit analysis is necessary prior to the implementation of any DR program in order to evaluate their convenience and to ensure that the obtained benefits exceed the costs incurred. The major difficulty of this assessment lies on the estimation of the reaction capacity of consumers regarding their flexibility to change their load patterns. Even though numerous pilot programs and field tests are being conducted, how households enabled with these technologies will react to time-based tariffs remains to be researched more extensively. Therefore, a validated customer response model that captures both the behavioral and engineering aspects of power consumption becomes very useful to make this assessment.

Among the different modeling approaches for residential electricity demand that can be found, bottom-up models create or characterize load profiles of individual customers, or even appliances and individuals, and aggregate or extrapolate their results to larger regions. Some examples of the use of bottom-up load models to synthetically generate representative profiles with high time resolution are (Walker and Pokoski, 1985; Capasso et al., 1994; Armstrong et al., 2009). They are based on the probabilistic influence of factors that affect energy usage, such as occupants' availability, home activities, power limits, appliance use cycles and mode of operation. Specific application of similar models to DSM can be found in (Paatero and Lund, 2006) or in (Gottwalt et al., 2011), where demand response to hourly electricity prices is analyzed. In contrast to the mentioned references, this paper proposes a load behavior model that does not generate load profiles but fits appliance usage to historic load profiles taken from individual households that are exposed to flat tariffs, as in (Conchado and Linares, 2010), and estimates the reaction to different tariff schemes according to technological constraints and customer preferences. The objective is to assess the impact of different tariff schemes on household consumption and discuss the convenience of investing on residential DR measures.

Methods

A bottom-up model that characterizes the electricity demand of an individual household and simulates their reaction to the variation of electricity prices will be presented. It will be applied to a representative set of load profiles belonging to different customer categories and built form real data of individual households exposed to a flat regulated tariff. The model will obtain expected new load profiles in response to different time-based electricity tariffs, such as day-ahead hourly time of Use (TOU) tariffs or more simple structures with lower time resolution or day-to-day variation.

The model is structured in two modules. Based on socioeconomic factors and a basic set of appliance characteristics and comprehensive rules that link the use of appliances, the first module identifies the most probable distribution of appliance usage in a given profile. The second module is an optimization program that manages loads so as to minimize the total energy cost in response to time-dependent tariff. The final optimal load schedule is limited both by technical constraints, behavioral rules and consumer predisposition to change consumption patterns reflected in demand-price elasticities that are taken from real experiences.

Expected results

The application of the model to available consumption profiles of several household categories will enable us to quantify the expected impact of various tariff designs on the final energy consumption, the modification of the load pattern and the economic benefits for consumers. The results will allow us to discuss the convenience of a sophisticated tariff system versus a simple average flat tariff on regular residential customers and shed some light on the trade-off between economic efficiency and simplicity in end-use electricity tariff design.

References

Armstrong, M.M., Swinton, M.C., Ribberink, H., Beausoleil-Morrison, I., Millette, J., 2009. Synthetically derived profiles for representing occupant-driven electric loads in Canadian housing. Journal of Building Performance Simulation 2, 15–30.

Capasso, A., Grattieri, W., Lamedica, R., Prudenzi, A., 1994. A bottom-up approach to residential load modeling. IEEE Transactions on Power Systems 9, 957 –964.

Conchado, A., Linares, P., 2010. Gestión activa de la demanda eléctrica doméstica: beneficios y costes. Presented at the V Congreso de la Asociación Española para la Economía Energética (AEEE), Vigo, Spain.

Gottwalt, S., Ketter, W., Block, C., Collins, J., Weinhardt, C., 2011. Demand side management—A simulation of household behavior under variable prices. Energy Policy 39, 8163–8174.

Paatero, J.V., Lund, P.D., 2006. A model for generating household electricity load profiles. International Journal of Energy Research 30, 273–290.

Walker, C.F., Pokoski, J.L., 1985. Residential Load Shape Modelling Based on Customer Behavior. IEEE Transactions on Power Apparatus and Systems PAS-104, 1703 –1711.