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Demand response for renewable energy integration

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Abstract: Short term mismatches between production and consumption leads to deviations in the grid frequency. Here, two collaborations from Uppsala University on new approaches in renewable energy integration are presented. The contribution of cooling appliances in the frequency regulation has been studied. Electric Energy Time-shift requires some sort of energy storage with slow dynamics. HSLU in Switzerland is investigating the use of electric water heaters as a thermal energy storage system to balance wind power production. Uppsala University contributed with the analysis of hot water consumption profiles for system sizing.

Refrigerators for primary frequency reserves

The idea of using domestic cooling appliances to stabilize grid frequency dates back to the 1980s, but it is only recently that communication systems made it possible to implement the idea. Some projects has been developed in USA with air conditioning [1].

ETH has developed a stochastic control system that allows the connection and disconnection of refrigerators to participate in the frequency regulation. The method prevents synchronization of appliances and only requires communication in one direction with the same value for all appliances in the system [2].

Would you allow your electric utility to disconnect your fridge during peak hours? For how much?

Uppsala has collaborated in the development of the refrigerator model, introducing the door opening in the model and discovering that the potential contribution to the regulation in higher at peak loads in the consumption.

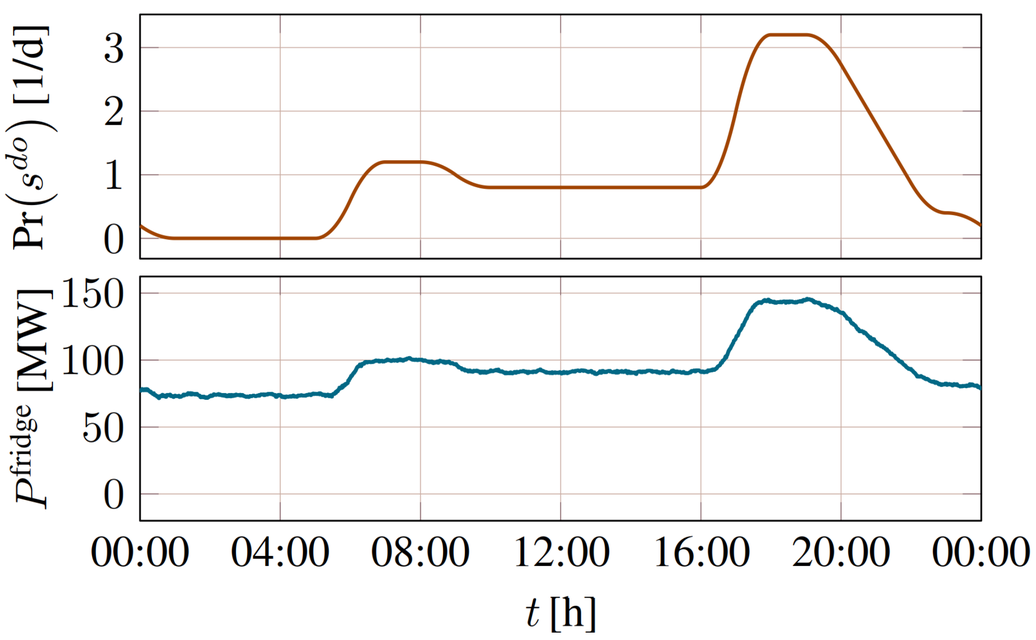

Figure: Probability distribution function of the door opening in a fridge and the consumtion of an agregation of refrigerators during a day.

Domestic hot water as an energy storage system

Electric heaters are common in Swiss domestic hot water systems. There are plans to increase efficiency by replacing old systems with heat pumps. HSLU in Lucerne is analyzing the impact in the electric system of a characteristic residential multistory buildings in Switzerland with average 6-8 dwellings per building. A centralized heat pump would allow frequency regulation, and increase efficiency. The high thermal capacity allows also to time-shift the power demand in different time scales, including night-day shift.

Uppsala University has contributed to the first step in the project with the statistical analysis of the hot water consumption registered in four dwellings during a whole year [3].

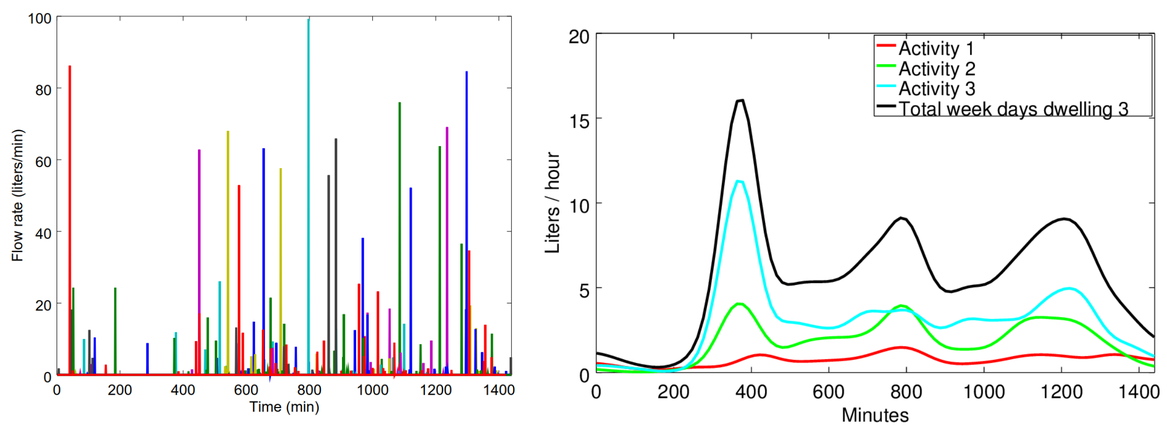

Figure: 10 geneated hot water consumption profiles show. It is possible to determine sensitive information shuch as the client's sleeping or cooking patterns. Agregated data is very similar to the electricity market.

References

[1] https://www.clearlyenergy.com/residential-demand-response-programs
[2] T. S. Borsche, J. de Santiago, G. Andersson, Stochastic control of cooling appliances under disturbances for primary frequency reserves, Sustainable Energy, Grids and Networks, vol. 7, 2016.
[3] J. de Santiago, B. Sicre, O. Rodriguez-Villalon, The Generation of Domestic Hot Water Load Profiles in Swiss Residential Buildings through Statistical Predictions, Energy and Buildings, 2017.

Conclusions

- **Demand response has already been implemented in some markets.**
- **Loads with thermal inertia have great potential for frequency regulation and even for time-shift.**
- **Thermal loads are evaluated with the same top-down and bottom-up models as in electric systems.**
- **Ethical aspects of measurement data should be considered as it is for smart meters. It is possible to identify sensitive information like sleeping patterns and house activities.**

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