Technology Strategy Board
Driving Innovation

Knowledge Transfer Network
Industrial Mathematics

Smart power for homes

MERGING ELECTRICITY MARKETS WITH DOMESTIC STORAGE

IBM UK Ltd / University of Manchester

The need

As the UK pushes towards its 2020 carbon emission targets, domestic demand for energy must be managed more effectively. Total demand must be reduced, and this load must be shaped in order to match increasingly variable supply due to intermittent energy sources such as wind which are an increasing proportion of the UK's energy mix.

For electricity suppliers, real-time pricing to shape demand is made possible by the current generation of smart meters. However, vulnerable and price-sensitive consumers may not be comfortable with real-time electricity pricing. Domestic electricity storage with a smart controller could protect such consumers, and provide an acceptable solution for both supplier and consumer.

The outcomes

Our research found that for an individual household under real-time electricity pricing, smart electricity storage can reduce expected spend. We are able to quantify both the value of the storage facility, and the best control strategy for a smart controller.

The best control strategy was not a simple target price for electricity, where electricity is only bought below a fixed price. The best strategy was in fact a variable target price, which depends on the amount of electricity which is already in the store.

We investigated the implications of these findings at the community or area level. As expected, load shaping occurred, so that high prices tended to induce lower demand and vice versa. An unexpected additional finding was that ramp rate control also emerged, so that changes in load tended to occur at a controlled rate. This feature depended on the amount of diversity, or randomness, in the amounts of electricity stored by different members of the community.

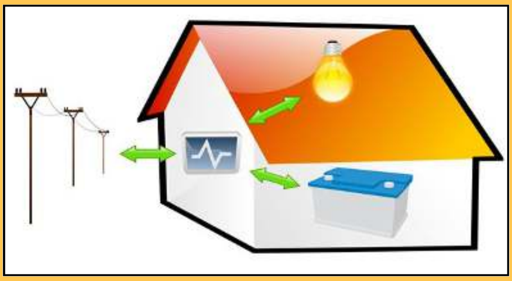
Smart domestic electricity storage therefore offers to make real-time energy pricing a more acceptable solution to intermittent supply, both for consumers and for power system designers.

"Smart, automated 'home agents' will be key to enabling households to interact with a dynamically priced energy market in the future. The understanding that this project provides as to the behaviour of these agents, the impact that this will have on the supply system and how customer interests can be protected is vital."

Jon Bentley, IBM

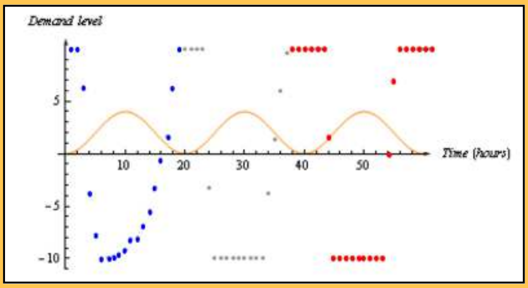
Technical summary

The mathematical theory of stochastic optimal control offers a way to make rational and optimal choices in the presence of uncertainty. It is used in the interdisciplinary area of Real Options Analysis to provide quantitative valuations of real-world capital projects, such as gas storage facilities.



This theoretical approach was applied to a model of smart electricity storage in the home, under uncertainty in the price of electricity. An equation was first derived for the value of the smart storage unit, which can be solved using recent advances in numerical techniques. This value strengthens the business case for smart storage, potentially both incentivising the wealthy and protecting the fuel poor.

In solving this equation, the optimal strategy for the smart controller is also found. Since it is a reasonable assumption that households would set a smart controller to minimise their average electricity bill, knowing this strategy allows us to probe the aggregate behaviour of a community of households in an area, and this was our next investigation. A likely price trajectory was simulated, and the aggregate load was calculated in response to this price process.



It was found that aggregate load responded to changes in price until the stores were exhausted. Further, the rate of change in load remains relatively controlled when there is sufficient diversity in the store levels across the community.

“This project was my first genuine experience of practical applications of my research, which I found to be highly rewarding. Through this, I was able to relate theory with practice as well as develop my current PhD work for scenarios which are more relevant to industry."

Luluwah Al-Fagih
University of Manchester

“A key feature of this project was two-way knowledge transfer. Through collaboration with IBM, we have successfully identified further industrial applications of stochastic optimal control theory, in the context of smart storage. The challenge of integrating electricity storage with future energy networks is a very exciting one."

John Moriarty, University of Manchester

This project was part of the programme of industrial mathematics internships managed by the Knowledge Transfer Network (KTN) for Industrial Mathematics. The KTN works to exploit mathematics as an engine for innovation. It is supported by the Technology Strategy Board, in its role as the UK’s national innovation agency, and the Engineering and Physical Sciences Research Council, in its role as the main UK government agency for funding research and training in engineering and the physical sciences.

IBM

EPSRC
Engineering and Physical Sciences Research Council

Project Details

Partners
IBM UK Ltd
University of Manchester

Project investment
£10,000

Intern
Luluwah Al-Fagih

For details on the technology:
Dr John Moriarty
University of Manchester
J.Moriarty@manchester.ac.uk
+44 (0) 161 275 5883

For information on internships and other collaborations:
Lorcán Mac Manus
Industrial Mathematics KTN
lbmm@industrialmaths.net
+44 (0) 1483 579108