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Forecasting the conditional dynamic elasticity of electricity consumers

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applied. This includes operation in the form of a microgrid. In addition, a real-time digital simulator serves for reproducing a possible connection to the transmission grid. A main scope of study of the TU Berlin Smart Grid Lab is the integration of renewable energy and electromobility into the power system.

The physical structure of the lab is shown in Figure 3. The plug-and-supply interfaces to which resources can be connected are marked in green. Starting from the feed-in, the ring connects a solar photovoltaics (PV) simulator shown in blue. It consists of a commercially available inverter and a solar panel emulated by a controllable electronic amplifier. Loads are shown in yellow. A single family home and an apartment building consist of both off-the-shelf appliances such as dishwashers, refrigerators, and boilers, and electronic loads. A small industrial unit is represented by different electronic loads capable of providing machinery load profiles. Two electric vehicle-to-grid (V2G) charging stations are shown in cyan, one of which is for e-bikes. The simulator for a distributed wind energy conversion system consists of a motor-generator unit. The protective container allows for the integration of battery, super capacitor, and cache control testing [3], [4], as indicated in purple. As a part of the Virtual European Smart Grid Laboratory, the installation will support the development of Smart Grid solutions in Europe and beyond [2].

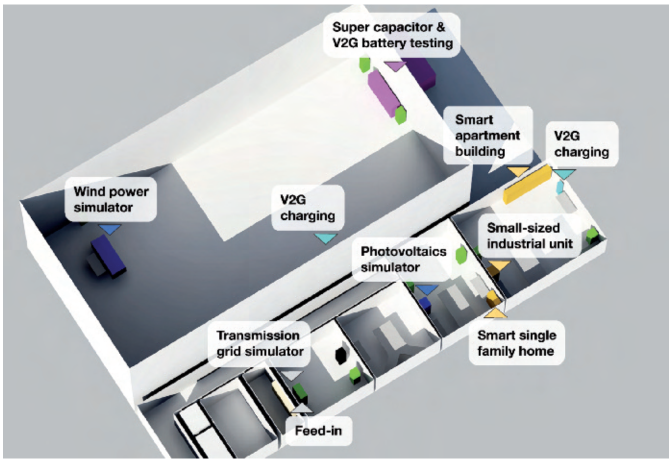

Figure 3: the physical structure of the lab

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Forecasting the Conditional Dynamic Elasticity of Electricity Consumers

by Pierre Pinson and Henrik Madsen

In the development of smarter energy systems, it is vital that we maximize flexibility of consumer demand. To this end, it will be of utmost importance to be able to predict the potential of electricity demand to respond dynamically to varied signals.

Some countries aim to be deriving almost all of their power from renewable sources in the relatively near future (Denmark's timeframe, for instance, is 2050). With greater integration of renewable energy generation, demand flexibility will become ever more important in supporting smart energy systems. This will translate to a paradigm shift, from a system where demand drives generation to a system where renewable energy generation may influence demand patterns. In practice this requires enhancing, and taking full advantage of, the potential flexibility of all electricity consumers, including domestic households.

In contrast to large industrial consumers, for which direct bilateral agreements may be made and used on an ad-hoc basis, domestic consumption is a far greater challenge to manage owing to the large number of individual households, their distribution, the state of the art in ICT (Information and Communication Technologies), the effectiveness of economic incentives, behavioural effects, etc. A number of research and demonstration projects are investigating these factors, including the iPower project in Denmark, funded by the DSR-SPIR-program (project number: 10-095378, see link below).

Regardless of how demand flexibility is to be enhanced at the household level (electric heating, cooling, electric vehicles, etc.), identifying intelligent ways to alter demand patterns is a stochastic optimization or control problem, comprising a whole challenge in itself. This question will depend, to some extent, upon the time scales considered (and corresponding mathematical formulation), engineering considerations - for instance related to ICT capabilities, but also on philosophical aspects of design. The two main approaches currently under study are (i) direct distributed control, and (ii) the "indirect control approach" based on price signals. The latter takes advantage of the elasticity of consumers, ie the adaptation of consumption in response to varying electricity prices. Price signals are to be sent daily for optimal task assignment (bulk heating, washing machines, etc.), but also adapted in real time so as to take corrective action supporting the optimal matching of generation and consumption. In this indirect control by price setup, the stochastic optimization or control problem translates to issuing optimal price signals to be broadcast to groups of consumers whose consumption levels are to be influenced.

With this objective in mind, the core, and most crucial, aspect is to identify and be able to predict how small consumers respond to varying prices. We refer to this as the conditional dynamic consumer elasticity. It is conditional since the potential to affect the timing, and maybe even the magnitude, of the flexible part of the load is clearly a function of external conditions. If considering space heating for instance, outdoor temperature, as well as the settings of the local heat controller, will directly impact the potential demand response to prices. Similarly in the case of electric vehicles, the demand response potential will vary as a function of the time of the day when more or less electric vehicles may be plugged in and their batteries made available for demand response. In parallel this response is dynamic as most consumption patterns cannot be deferred indefinitely: batteries of electric vehicles need to be charged at some point before they are to be driven, while households need to be heated so as to keep indoor temperature at an acceptable level.

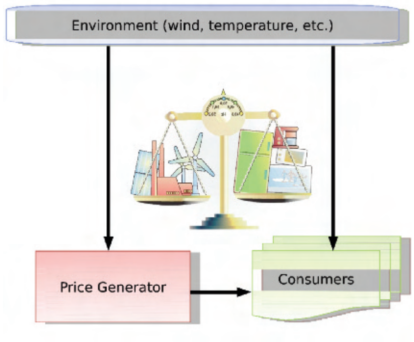

Figure 1: A conceptual view of the balance between electricity production and consumption, as influenced by the external environment and controlled through a price generator.

As a final point, this conditional dynamic elasticity of electricity consumers may smoothly evolve with time, owing to changes in consumption patterns, appliances and their functionalities, etc. As a consequence, one needs to employ a bottom-up approach and use empirical data for the identification of appropriate models, adaptive estimation of their parameters, and continuous monitoring of forecast quality. The quality of such forecasts will be paramount since this data will directly impact the reliability of potential demand response. An unreliable demand response would make this an inefficient solution compared with alternatives, such as using storage or expensive conventional generators, possibly even magnifying the fluctuations that we are aiming to dampen. Ideally, these predictions should be of probabilistic nature, in the form of scenarios, so as to fully describe the range of potential responses from the aggregation of household consumers to be influenced.

Link: http://ipower-net.dk

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Putting Neurons in the Smart Grid

by Bram Vonk, Robert de Groot and Han Slootweg

The collaboration between Eindhoven University of Technology and Dutch Distribution System Operator, Enexis, results in a direct implementation of scientific ideas and models in real world systems and faster feedback of data for analysis or validation. This is illustrated by the Smart Storage Unit: A grid connected battery in a residential area of 240 houses including photovoltaic generation and heat pumps, controlled by an artificial neural network based forecaster.

The Smart Storage Unit (SSU) is the result of a pilot project for development and deployment of a centralized storage unit in the low voltage (LV) distribution network. The system is built around a lithium-ion battery system consisting of four separate strings, each with a capacity of 58 kWh, having a total capacity of 232 kWh and a nominal battery voltage of 720 V. the total system is capable of storing approximately 1.2 hours of the installed watt-peak PV output in the neighborhood. The goals set for the Smart Storage unit include:

- Increase of self-consumption (of the photovoltaic (PV) generated energy)
- Increase of reliability (in autonomous operation acting as a back-up unit)
- Maximization of utilization of local infrastructure (common feed-in at peak consumption of the households: peak shaving)

In order to achieve these goals, the SSU is equipped with an advanced control system capable of controlling battery state-of-charge conform pre-specified objectives and conditions (Figure 1).

The SSU is installed into an LV-grid in the Etten-Leur area, part of the Enexis distribution grid in the South of the Netherlands. The network connects 240 households, of which 40 have locally