

MULTIAGENT CONTROL OF ELECTRICITY DEMAND AND SUPPLY

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Electricity Infrastructure Evolution. *Distributed generation* (DG) of electricity is providing an increasing part of the worldwide energy supply. DG consists of different sources of electric power connected to the distribution network or to a customer site. This approach is distinct from the traditional central-plant model for electricity generation and delivery. Examples of DG are photovoltaic solar systems, small and medium-scale wind turbine farms, and the *combined generation of heat and power* (CHP).

When the share of DG increases in a geographical area, clustered control of DG by common ICT (information and communication technology) systems can add value. As a result, distribution networks are expected to evolve from a hierarchically controlled structure into a network of networks, in which a vast number of system parts communicate with and influence each other. The number of components actively involved in coordination will be huge. Centralized control of such a complex system will reach the limits of scalability and communication overhead.

A key technology for solving this problem is market-based control. In market-based control, many control agents competitively negotiate and trade on an electronic market to optimally achieve their local control action goals. Use of market-based control in the electricity infrastructure opens the possibility for distributed coordination in addition to the existing central coordination.

The PowerMatcher. The PowerMatcher method provides market-based control for *supply-and-demand matching* (SDM) in electricity networks with a high share of DG. It is based partly on earlier research by Fredrik Ygge and Hans Akkermans [6], Hans Akkermans, Jos Schreinemakers, and Koen Kok [1] and Per Carlsson [2]. In this method, a control agent represents each device. The agent tries to operate the device process in an economically optimal way, within the process's constraints. The agents negotiate their electricity consumption or production on an electronic exchange market. The resulting market price determines the power volume allocated to each device.

From the viewpoint of controllability, devices that produce or consume electricity fall into six classes, each having a specific agent strategy. We look at three in this article. The first class are non-controllable devices, either being generators (e.g. wind energy systems) or energy consumers (like audio and video devices). The second class is shiftable-operation devices, which must run for a certain amount of time regardless of the exact moment and thus are shiftable in time. An example of such a device is a ventilation system in a utility building that needs to run for 20 minutes each hour. The third class comprises devices operating thermal processes like heating, cooling or freezing. Here, operational flexibility is determined by the allowed temperature band.

Local agents' self-interested behavior causes electricity consumption to shift toward moments of low electricity prices and causes production to shift toward moments of high prices. So, SDM emerges on the global-system level.

A Simulation. To investigate distributed SDM's impact for a residential area, we simulated a cluster of 40 houses, all connected to the same segment of a low-voltage distribution network.

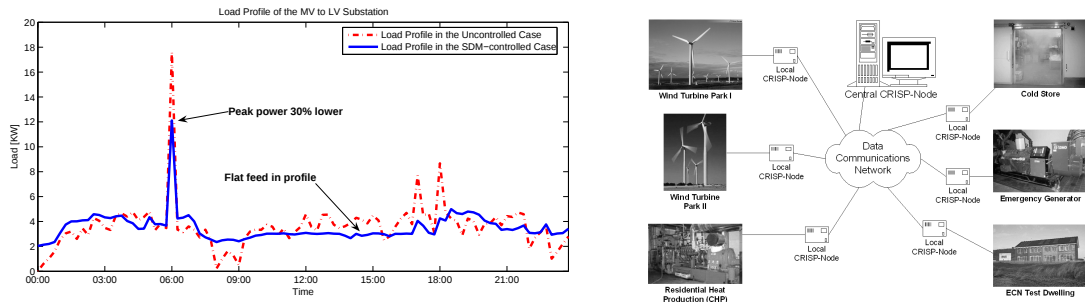


Figure 1: *Left*: Multiagent control leads to peak load reduction and power profile smoothing. *Right*: Market-based control field experiment set-up for imbalance reduction for electricity trade.

Heat pumps (electricity consumers) heated 20 of the dwellings; micro-CHP units heated the other half. The simulation treated washing machines as shiftable operation devices with a predefined operational time window, photovoltaic solar cells as stochastic-operation devices, and lighting as user action devices.

The left side of figure 1 shows the result of a typical simulation run. The graph shows the consumed power in the cluster, both when all devices are free running and when the market-based control agents match supply and demand. This simulation shows that our method can exploit flexibility in device operation through agent bids in an electronic power market. The peak in electricity demand is substantially lower in the controlled case. From the viewpoint of network operations, this result is important, because the highest expected peak demand determines the needed network capacity (transformers and cables). Reducing this peak reduces network investments. Furthermore, introducing SDM results in a flatter, smoother profile of the electricity fed in from the midvoltage network. This result is interesting from the viewpoint of electricity trading, where increased predictability of both production and consumption adds value.

Field Testing. We're investigating the PowerMatcher in real-life environments for two different business cases. One aims to automatically reduce the imbalance in a commercial trader's real world portfolio by aggregating medium sized industrial electricity producing and consuming installations (see figure 1, right). In this experiment, overproduction and underproduction of wind parks induce price changes on the cluster's electronic market. The other devices' control agents react to this with counteractions, which restore the cluster's energy balance. The first test results indicate a decrease of the total power imbalance by more than 40 percent. Reduction of unpredictability in the trade portfolio reduces imbalance costs charged to the trader by the independent transmission system operator.

The other field test, on a cluster of micro-CHP units operating as a virtual power plant, demonstrates their ability to contribute to a common control goal. This experiment uses 15 domestic heating systems at consumer premises. The virtual power plant can provide value through electricity trading or local grid-operation support.

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