The system transforms this kind of input data and constraint definitions (defined in XML) into a mathematical, constraint optimization problem using a Constraint Programming (CP) approach. Our constraint-solving library "firstCS" [3] offers the necessary primitives and Operations Research (OR) functionality to define and solve the necessary equalities and inequalities resulting from variable tariffs as well as the temporal and capacitive restrictions. The achieved solution consists of two parts: a cost-minimal schedule of the loads and the according load distribution. Again, the output is in XML format. In particular, for the load distribution the interface standard for meter reading and control, IEC 61968-9, is used. We have chosen this format for easy comparison of the scheduled load with the real energy consumption measured by smart meters. These data in the same format show the difference between target and reality as well as the financial loss compared to the cost-optimal schedule. In order to perform the necessary analysis and perform a comfortable automatic control of the involved devices (causing the loads), the energy management system can run on our own energy management and control gateway.

This gateway is a programmable communication device that can take over the role of a gateway for Controllable Local Systems (CLS) to allow electrical devices to be switched based on the current load management. The CLS approach is also specified in the German guidelines for smart metering systems and gateways and the respective protection profile [4]. Additional software modules of our gateway enable demand side integration (eg our smart energy management) and load control. For comfortable use, the gateway offers a unified web-based user-interface on PC, appliances, and smartphones (using HTML5). The solution is an open interoperable gateway having a standardized interface to access certified smart meter gateways (SMGW), smart meters, and other machine-to-machine (M2M) devices. It also supports state-of-the-art home automation and facility control technologies such as digitalSTROM, KNX, ZigBee and 868MHz RF.

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Please contact:

Armin Wolf
Fraunhofer FOKUS, Germany
Tel: +49 30 6392 1864
E-mail: armin.wolf@fokus.fraunhofer.de

Thomas Luckenbach
Fraunhofer FOKUS, Germany
Tel: +49 30 3463 7245
E-mail:
thomas.luckenbach@fokus.fraunhofer.de

Mario Schuster
Fraunhofer FOKUS, Germany
Tel: +49 30 3463 7302
E-mail:
mario.schuster@fokus.fraunhofer.de

Market Garden: A Scalable Research Environment for Heterogeneous Electricity Markets

by Felix Claessen, Nicolas Höning, Bart Liefers, Han La Poutré and Peter Bosman

How will we trade energy in the future? We can expect vast technological changes in our energy systems, leading to high heterogeneity in both supply and demand. Knowing the true value of energy at a given time and location will be crucial. Market mechanisms are methods of determining prices in complex, multi-actor settings. In the Intelligent Systems group at CWI, we have developed a research environment in which different market mechanisms for electricity can be studied and evaluated - in interaction, remotely and in a scalable manner.

In order to allocate energy efficiently in future energy systems, it will be vital to take an economic perspective. This is due to three major trends: the rise of intermittent renewable generation, new steerable demand appliances (eg electric vehicles and heat pumps) and market deregulation. The Intelligent Systems group at CWI has developed a software research environment to study market mechanisms for various economic future scenarios.

It is important to design and study a range of possible market mechanisms and their properties, since it is unlikely that a single market mechanism, for example one spot market [1], can be used in all local settings. Consider flattening the loads of the heating devices in a large office building: This can, in principle, be accomplished by continuously collecting price bids from the devices for the next 10 minute interval and updating allocations accordingly (see [2], for example). However, a different mechanism is needed if it is crucial for a substantial number of devices or participants to plan ahead, eg because electric vehicles in a residential area need to charge their batteries in time before their owners go to work [3]. A market mechanism for this situation should allow bidders to announce preferences for future time slots (eg when they need to leave) and incorporate that into the computation of an efficient out-

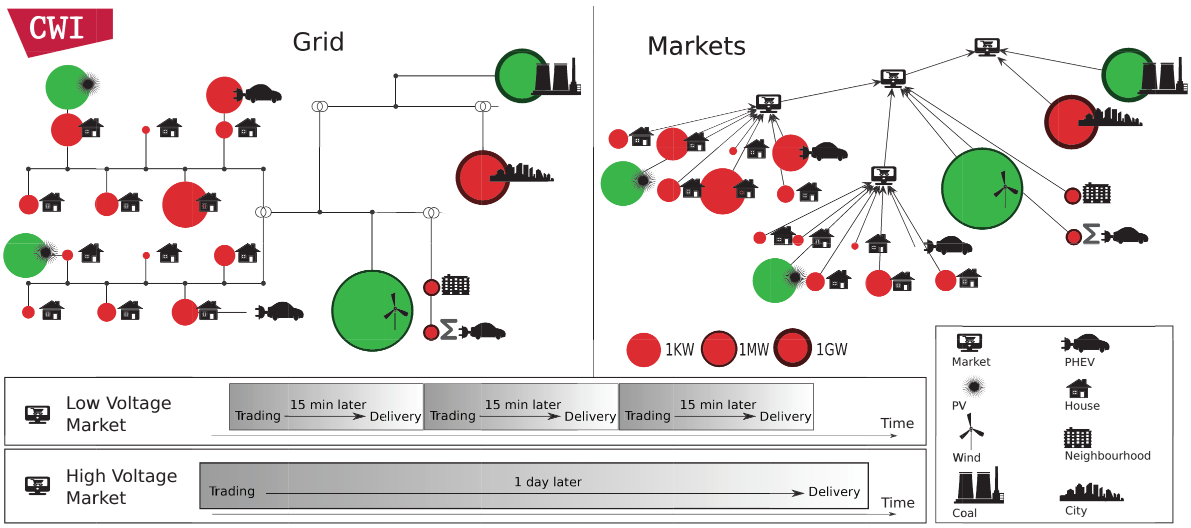

Figure 1: Simulation of a future scenario in Market Garden. A scenario consists of a network topology, a market hierarchy and a market timeline.

come. Other goals of market mechanisms can be to reward flexibility and to provide a minimum level of fairness. Not all such goals are compatible with each other and even if they are, including them can make a market mechanism too complex to be usable.

This has two major consequences for research. First, it becomes important to study which market mechanism works best in a given setting. Second, market mechanisms will differ in important aspects such as timing and expressive power of bids, so how can we expect the results of various local markets (on the low voltage level) to be aggregated and be used in national markets (on the middle and high voltage levels)?

To help answer that question, we have developed Market Garden, a scalable research environment for market mechanisms, written in Java. In Market Garden, users can model a physical grid and then associate the agents which are controlling devices on the grid in markets. Market Garden can host different market mechanisms, which define the formats of bids, the protocol of bidding and how an outcome is computed. For instance, one general market mechanism that is currently included in Market Garden is a clearing market with various possible bid formats (linear, piecewise linear, quadratic). Given a grid model, one or more market mechanisms and bidding strategies for agents, Market Garden runs agent-based simulations to compute the results.

The first advantage of Market Garden is that simulations can be hosted and remotely accessed on powerful servers. In 2011, a collaboration funded by the European Institute of Innovation & Technology (EIT), with participants from science and business, such as Siemens, Imperial College London, Ericsson and also our group at CWI, has developed four Future Scenarios for energy systems, forming a basis for further research into valuable business models. Partly funded by the EIT, the development and use of Market Garden aims to act as a catalyst for innovation in this scenario research by benefiting partners. Market Garden is therefore planned to be made available as an online simulation tool as part of the European Virtual Lab. This initiative enables distributed co-simulation by connecting existing hardware labs and simulators which model wind farms, coal plants, smart offices or houses, etc.

The second advantage is accelerated development through cooperation. Market mechanisms are set up in a modular fashion, allowing users to create different scenarios by coupling and interchanging mechanisms. Furthermore, scenarios, mechanisms and strategies can easily be reused.

In addition to accelerating research, Market Garden will be useful to end users, who can gain experience with their possible future roles and policy makers, who can be assisted in designing laws and regulation that hinder strategic market exploits and ensure societal benefits.

The Intelligent Systems group at CWI uses Market Garden to research trade strategies, novel market mechanisms and their interaction, thereby combining various research areas in computer science, including auction design theory, optimization and agent technology. The group also studies the use of sensor networks in smart buildings and electricity network planning.

It is planned that Market Garden will be available in 2013. If you are interested in writing and testing a scenario or joining a simulation, please contact us.

Link:
http://virtualsmartgrid.project.cwi.nl/wiki/Market_Garden

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Please contact:
Felix Claessen, Nicolas Höning, Bart Liefers, Han La Poutré, Peter Bosman
CWI, The Netherlands
Tel: +31 20 592 4330
E-Mail: {felix.claessen, nicolas.honing, bart.liefers, han.la.poutre, peter.bosman}@cwi.nl