KEMA

Implementing smart grids.

PowerMatching City: a living Smart Grid demonstration.

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Distributed energy resources are a very promising way to solve today's climate and energy problems. To integrate distributed energy resources in the energy network on a large scale, grid operators and utilities will face new social, technical and economic challenges. As the project leader of PowerMatching City, KEMA is looking for the answers required to connect distributed generators and consumers in a smart way.

Smart grids

A sustainable energy system requires that a large proportion of our total energy be generated in the future by distributed energy resources like wind turbines, photovoltaic solar panels and micro cogeneration systems. At the same time, energy demand will change: electric vehicles will become our means of transportation, (hybrid) heat pumps will keep our houses warm during cold winter nights and washing machines will start when the wind power peaks.

The supply chain will change completely: from a classical, top down oriented structure to a full, bidirectional system. But market roles will also change — consumers will become prosumers and new market parties, like commercial aggregators, will enter the supply chain.

To connect and match the energy generators and consumers, the electricity grid is the linking pin. Without introducing smart solutions into the grid and behind the meter, the benefits of a sustainable energy supply won't be fully reached. Advancements in ICT technology make smart grids feasible. ICT will not only provide us direct insight into our energy consumption, but will also become a major controlling component throughout our entire energy system. Intelligent software will seamlessly match supply and demand of energy without human interaction, ensuring uninterrupted availability of energy whenever we need it.

Today, politicians, market parties and product suppliers recognize the potential of smart grids, but much is still unclear. As a utility, grid operator,

or manufacturer, you will have to answer many questions before implementing and connecting all of these sustainable and smart systems, including:

- How can the residual demand for energy be fulfilled without making concessions to cost-effectiveness, comfort and security of supply?
- What is the most optimal combination of technologies such as PV solar panels, wind turbines and micro-cogeneration?
- How can we give priority to sustainable energy sources?
- How can we coordinate the generation of these sources to prevent a local overload of the grid?
- What is the market potential of these integrated smart grids?
- Which standards and coordination mechanisms at the different network levels should we use?

The best way to gain answers to these questions and bring smart grids to the next level is by bringing them to life. This requires detailed engineering and testing of concepts because 'the devil is always in the details'. With our knowledge of the whole energy value chain and experiences gained in previous projects, KEMA can help you find an integrated solution.

PowerMatching City

KEMA has created a living lab smart grid environment together with Dutch research center ECN, software company ICT and utility Essent. This 'PowerMatching City' consists of 25 interconnected households equipped with micro cogeneration units, hybrid heat pumps, PV solar panels, smart appliances and electric vehicles. Additional power is produced by a wind farm and a gas turbine.

The aim of this project is to develop a market model for a smart grid under normal operating conditions. The underlying coordination mechanism is based on the PowerMatcher, a software tool used to balance energy demand and use. The aim is to extend this coordination mechanism in such a way that it can support simultaneous optimization of the goals of different stakeholders:

- In home optimization for the prosumer
- Reduce network load for the distribution system operator
- Reduce imbalance for program responsible utilities

In the end, the goal of this project is to build and demonstrate an industry-quality reference solution for aggregation, control and coordination of distributed energy resources, renewable energy and smart appliances, based on cost effective, commonly available ICT components, standards and platforms.

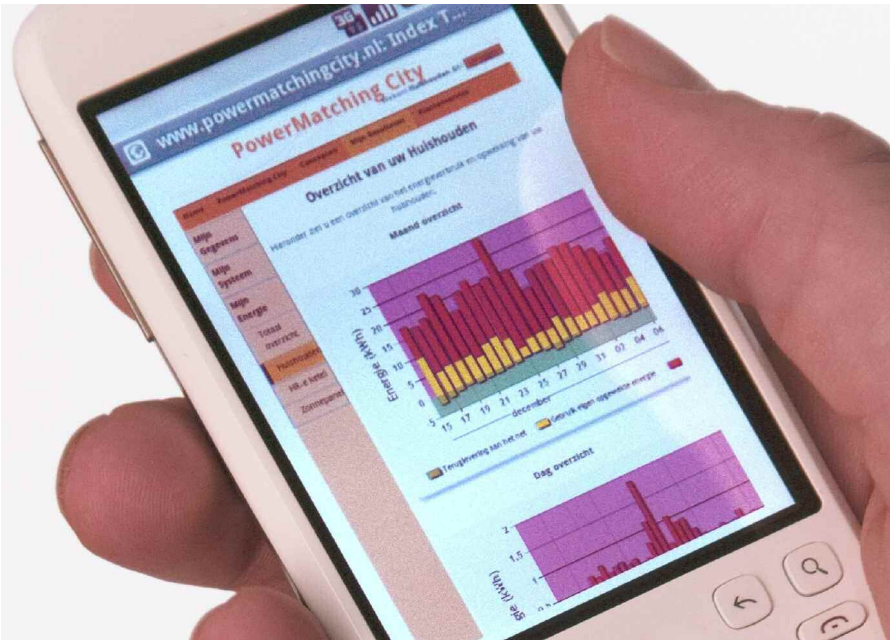
What do prosumers expect?

Prosumers should be willing to invest in smart appliances and distributed energy resources. What do they expect from such investments, and under what conditions will they accept smart power? It's clear that they will only accept smart power as long as their comfort level is not affected. Therefore, systems have to be designed in such a way that, no matter how the flexibility is exploited by a smart grid, their life can continue as it normally would. In our laboratories we have developed installations that meet these requirements. During the field test we will research if the prosumers are willing to exchange comfort for flexibility based on financial incentives.

Furthermore, we assume prosumers will only invest in these technologies as long as they profit from it. Therefore, we strive for economic optimization as a primary goal for these prosumers. In our concept, energy can be imported and exported freely from the house to the network and vice versa, as long as the costs or benefits for the prosumer are optimized. A local PowerMatcher agent that acts on behalf of the prosumer does this optimization in the background without user interaction. From a consumer perspective, the savings in their energy bill increases further because of the energy efficiency of the installation.

Prosumers can access their energy consumption profiles in real time anywhere and at any time via

an internet portal. The necessary data is measured by smart meters connected to each individual installation and collected in a central database. Peer group comparison ranks their performance and triggers them to decrease their energy consumption. An operator portal for system maintenance is created as well. It monitors the performance of the whole system and allows maintenance personnel take action before the consumer has noticed that the performance of their system has decreased and while failure can be prevented.



What do grid operators expect?

Large scale introduction of electric heat pumps and electric vehicles will create a significant increase of the peak load on the electricity grid. This will lead to (local) congestion of the network at peak times. For example at 18:00 when people get home from work and directly start loading their electric cars while there is already a 'natural' peak load. In our cluster, the grid operator can give local price incentives — for example in a network segment behind a transformer — such that the import or export from this network is reduced below a level where the aging of the transformer is limited.

What do utilities expect?

The highest costs for suppliers or program responsible parties are caused by imbalances and imbalance reduction in their portfolio. From a supplier point of view, the cluster of PowerMatching City can be operated as a Virtual Power Plant, adding value from different perspectives:

- Control of the cluster by a Trading Objective agent that provides price incentives so that the energy demand by the cluster can be controlled. One should keep in mind that this control mechanism is in principle limited to load shifting of the whole cluster, since consumers will not produce or consume more energy but will only provide flexibility.
- Improved predictability of the cluster due to price optimization and internal balancing, allowing better day ahead forecasting.
- Smart metering will increase the readout frequency of the energy demand by the whole cluster on a near real time basis, and allows validation of the internal balancing point of the cluster itself.

To gain detailed insight into these processes, and the interaction with the regular trading and dispatching activities of a supplier, the cluster is controlled from the trading room of Essent. The cluster is dispatched near real time and various trading strategies will be tested.

INTEGRAL

The INTEGRAL project is a European project under the 6th Framework Programme. The goal of Integral is to build and demonstrate an industry-quality reference solution for aggregation, control and coordination of distributed energy resources, renewable energy and smart appliances based on cost effective commonly available ICT components, standards and platforms.

The building and demonstration project will take the following steps:

- *Define Integrated Distributed Control as a unified and overarching concept for coordination and control*
- *Show how this can be realized with common industrial, cost-effective and standardized state-of-the-art ICT platform solutions*
- *Demonstrate its practical validity via three field demonstrations covering the full range of different operating conditions including:*
  - *normal operating conditions of DER/RES aggregations, showing their potential to reduce grid power imbalances, optimize local power and energy management, minimize cost (PowerMatching City, the Netherlands)*
  - *critical operating conditions, showing stability when grid-integrated (Spain)*
  - *emergency operating conditions, showing self-healing capabilities (France)*

Elements of PowerMatching City.

Integrating renewable energy

Fluctuations in power production of wind turbines or solar power caused by heavy winds, half open clouds and uncertainties in the weather forecast requires fast responding power. Smart grids can provide this flexibility by rapidly shifting energy demand from loads like electric vehicles, heat pumps and smart appliances towards peaks in the production and use of distributed energy resources, such as mCHP's, to fill in the gaps in production when the wind is fading away. In the field test of PowerMatching City these effects are demonstrated and the amount of flexibility of such a cluster is exploited.

Cogeneration on micro scale

In the coming decade, combined heat and power (CHP) technologies will be introduced into our households based on different technologies, such as Stirling engines, internal combustion engines and fuel cells. These mCHPs will be controlled on the basis of the heat demand in a household and will produce electricity as a side effect. In our laboratories, we have developed a system where the heat is stored in a heat buffer, thereby decoupling heat and power production.

Hybrid Heat Pumps

Combining an electric heat pump with a high efficiency boiler provides a way to generate highly efficient base load with network-friendly peak load demand. The efficiency of heat pumps is very high, because for every kW of electrical power, 3-5.5 kW thermal power is produced. For peak demand activities such as taking showers, or situations like extreme low outdoor temperatures, a high efficiency boiler is used to support the heat pump, thereby reducing the need for auxiliary electric heating, which would

stress the electricity net. We have decoupled the heat production from the moment the heat is produced by inserting a heat buffer to the system. This allows us to generate heat when (renewable) electricity is readily available.

Electric Mobility

Due to the high potential for primary energy savings and the corresponding CO_2 emissions, light electric vehicles like cars, scooter and bicycles might become our main means of transportation. Light vehicles are needed to minimize the energy consumption for transportation.

Without appropriate measures, people will start charging their cars when they come home after work, increasing the already high-energy peak demand in the evenings. These cars will be equipped with a PowerMatcher agent that allows smart charging, spreading the charging process overnight, shaving the peaks in wind power production and ensuring the lowest cost for recharging the batteries. PowerMatching City will be equipped with fully electric cars as well as a plug-in hybrids.

Smart Appliances

Smart freezers or washing machines can help to reduce peak loads on the electricity net or to utilize available renewable energy. In the PowerMatching City, we create flexibility by allowing the system to decide, for example, when to start the wash. The washing machine is programmed to finish the cycle at a given time. Consequently, the PowerMatcher will try to find the optimal moment to start the cycle, for

example when electricity is cheaply available. In the smart freezer, the temperature is allowed to fluctuate between boundaries. Again here, the PowerMatcher chooses the moments when to begin cooling. In both applications it is important that comfort is ensured.

PowerMatcher

PowerMatcher technology is a distributed energy system architecture and communication protocol, which facilitates implementation of standardized, scalable smart grids that can include both conventional and renewable energy sources. Through intelligent clustering, numerous, small, electricity -producing or -consuming devices operate as a single, highly flexible generating unit, creating a significant degree of added value in electricity markets. PowerMatcher technology optimizes the potential for aggregated, individual, electricity -producing and -consuming devices to adjust their operation. This is in order to increase the overall match between electricity production and consumption through dynamic, real-time pricing. These real-time prices provide incentives for off-peak electricity usage and on-peak electricity generation, improving the load factor of the grid.

ICT Architecture

PowerMatching City wouldn't be possible if it wasn't for a modern ICT infrastructure. Secure VPNs (Virtual Private Networks) connect all households, wind turbines, electric vehicles and devices over the public internet. Database servers collect information on a local household level as well as on the level of PowerMatching City. This enables researchers to analyze the results and create improvements. Personal data is available to the household owners via the 'User Portal' website, so they can observe their contribution to a more sustainable environment. An 'Operator Portal' offers information for daily operation of PowerMatching City from the control room.

Project Partners PowerMaching City

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