Architectural and first results evaluation of the PowerMatchingCity fieldtest

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Architectural design and first results evaluation of the PowerMatching City field test

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Abstract:

Starting from the beginning of 2010, in the EU FP6 Integral[4] project, a large-scale SmartGrid field test with active participation of end-user installation nodes in the electricity network is running. A high-bandwidth dedicated ICT-network has been rolled-out to connect electricity supply and demand nodes and to collect data. In the test, the software agent based PowerMatcher technology is applied in a Virtual Power Plant (VPP) setting to satisfy a number of commercial and grid related optimization objectives.

The VPP in the test consists of 25 heating devices in homes in Hoogkerk[5], nodes with PV and wind generated electricity, residential and mobile (full EV's) electricity storage nodes and intelligent home appliances.

Primary process flexibility for the heating system's hybrid heat pumps and micro-CHP is enlarged by using hot water filled heat buffers. Additional gas burning heating capacity to be used in peak periods was added to the system configuration. Additional demand response flexibility is achieved by optimizing the charging strategy of the nodes with electricity storage and the operation of devices connected to demands like refrigerators and washing machines. In this way, on a real-time basis, the VPP has been shown to be usable for optimization to satisfy objectives for compensation of the variable output of renewables, for improving grid operation and functions for commercial operation.

In this paper the architectural design and the application of the PowerMatcher[1] approach is evaluated. The first results of operating the use cases are also presented.

Summary:

The share of renewable energy resources for electricity production, in a distributed setting (DG-RES), increases. The amount of energy transported via the electricity grid by substitution of fossil fuels for mobility applications (electric vehicles) and domestic heating (heat pumps) increases as well. Apart from the volume of electricity also the simultaneity factor of delivery of electricity increases at all grid levels. This poses unprecedented challenges to capacity management of the electricity infra-structure. A solution for tackling this challenge is by using more active distribution networks, intelligent coordination of supply and demand using ICT and using the gas distribution network to mitigate electricity distribution bottlenecks. For small retail consumers in North-Western Europe, heating systems provide for the major part of domestic energy consumption. Domestic heating systems have intrinsic operational flexibility in comfort management through the thermal mass of the dwellings. Thus, the primary processes involved in heating provide demand response flexibility. When using heat pumps or micro-CHP the consumed and produced electricity for the heating systems is considerable and has an impact on the electricity system. Demand response bandwidth in this field-test is enlarged by using hybrid installation concepts with buffering heat in a storage tank to extend the demand response potential even further. Finally, having additional gas-fired heating capacity for electrical heat-pumps adds to increasing flexibility in peak demand periods by switching the energy source for heat production.

To make the supply and demand nodes aware of the rest of the grid, a dedicated highly distributed ICT-network and information system with hardware and software for control and coordination has been implemented in order to create a virtual power plant (VPP). Having created this connectivity, the next step was to implement a coordination strategy. In the experiment, the bottom-up PowerMatcher agent approach was followed. The method showed to

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[4] Integral is financially supported in part by the EU 6th energy research framework (see http://integral-eu.com/) .

[5] Hoogkerk is a residential area near Groningen, the Netherlands

provide for a very flexible and scalable market-based mechanism for matching supply and demand in real-time. The approach can be mapped very easily on embedded information architectures and be connected to low-level appliance logics.

The top-level VPP cluster configuration has been depicted in figure 1. The PowerMatcher agents are in yellow rectangles. Supply and demand functions for each of these agents have been designed and implemented in this field-test. The red and blue ellipses represent bid concentrators that aggregate and transform bid-curves. These are transmitted to the auctioneering level. With only a limited number of software component types composition of a number of configurations to study a number of use cases was possible.

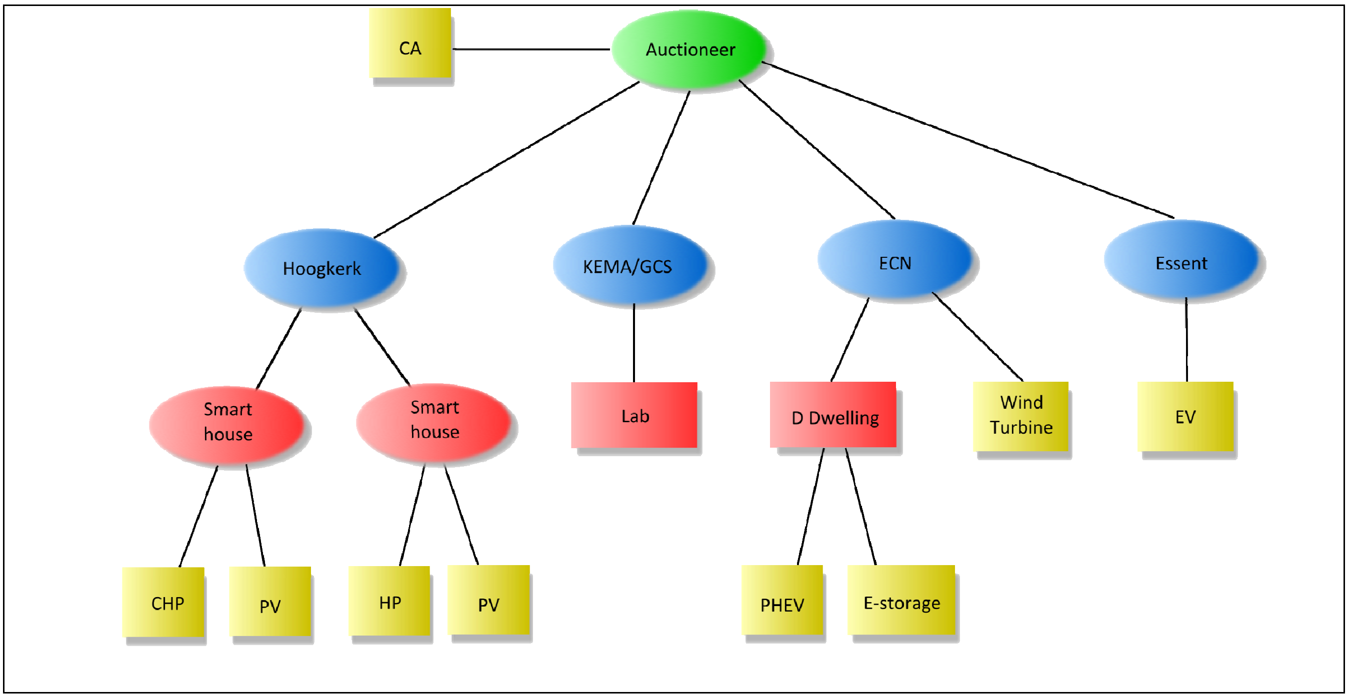

Figure 1 Field-test hierarchical configuration

The use cases evaluated include:

- Commercial aggregation of supply and demand with 4 sub-cases:
    - Real-time compensation for renewables forecast prediction errors in program responsible party portfolios
    - Real-time day-ahead and balance market optimization
    - Trade dispatch of the portfolio to compensate ramp-up/-down of large installations
    - Coordination of EV-charging
- Distribution network optimization with two subcases:
    - Mitigation of distribution bottlenecks. These may occur at times with high heat demand in winter if electricity is used for heating.
    - Residential ‘behind-the-meter’ optimization
- Valorization of renewables. In this setting concerted operation of ‘must-run’ PV-panels or wind turbines with flexible loads is automatically invoked.
- Dual-objective optimization. At certain moments in time once the objectives of operating the distribution system together with commercial operation as part of a market portfolio may be contradictory. This is schematically shown in figure 2.

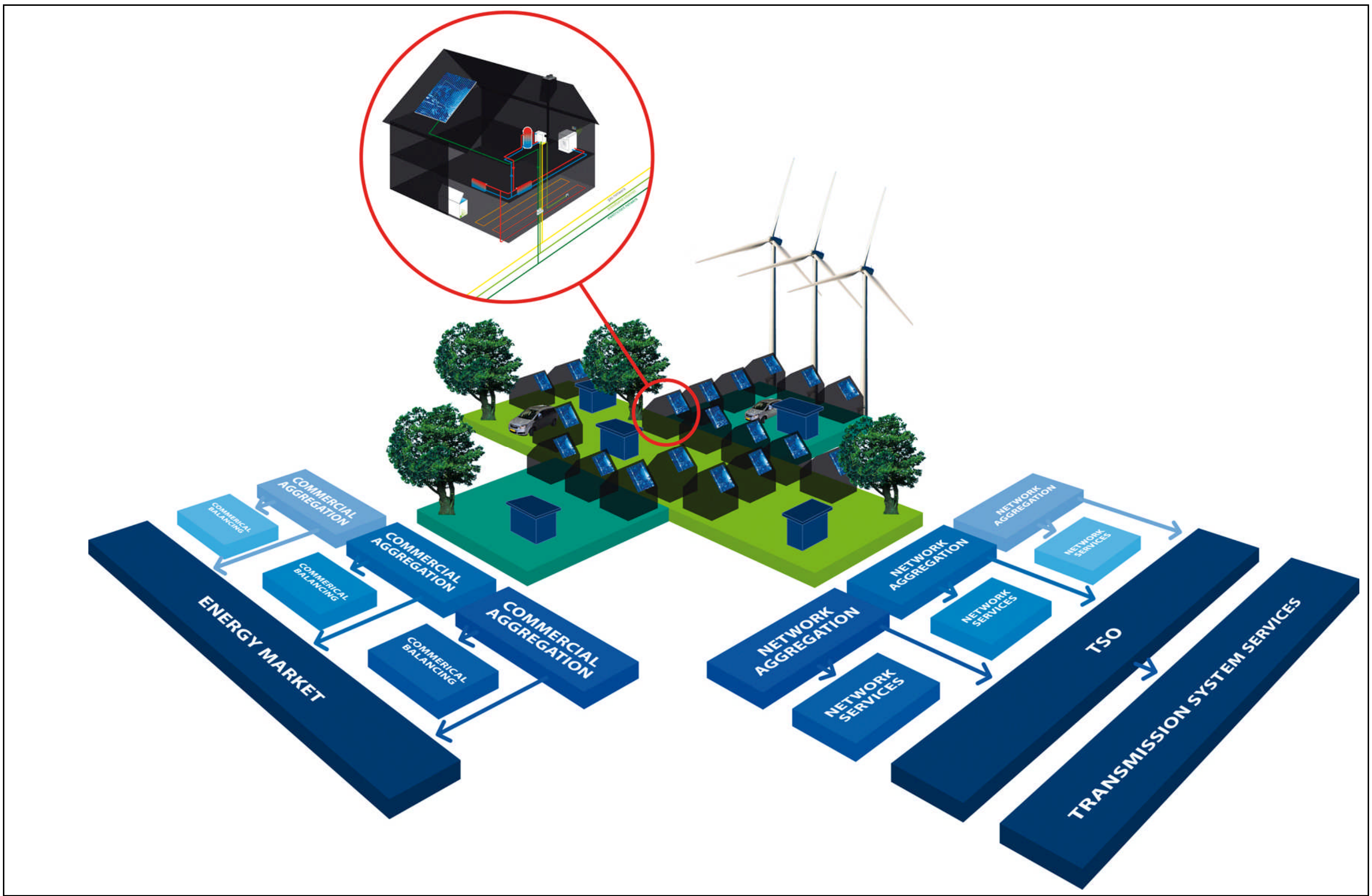

***Figure 2** The PowerMatching city/experiment A field-test configuration and multiple objective optimisation*

The mapping mechanism using PowerMatcher 'building blocks' appeared to be very powerful. The first results also showed, that the implemented control and coordination logic in the agent closely follow the expected behavior.

References:

[1] J.K. Kok, C.J. Warmer, and I.G. Kamphuis: *PowerMatcher: multi-agent control in the electricity infrastructure*, in Proceedings of the Fourth International Joint Conference on Autonomous Agents & Multi- Agent Systems AAMAS'05, ACM, New York, NY, July 2005(ACM Order nr. 607054), Industrial Track Volume, pages 75 – 82.

[2] Also see: http://www.powermatcher.net en http://www.powermatchingcity.nl

ECN

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Objectives PowerMatcher City fieldtest in Hoogkerk (NL)

Show use of aggregated flexibility in supply and demand of electricity for:

- Embedding renewables
- Commercial optimization
- Distribution optimization

Proof PowerMatcher-technology

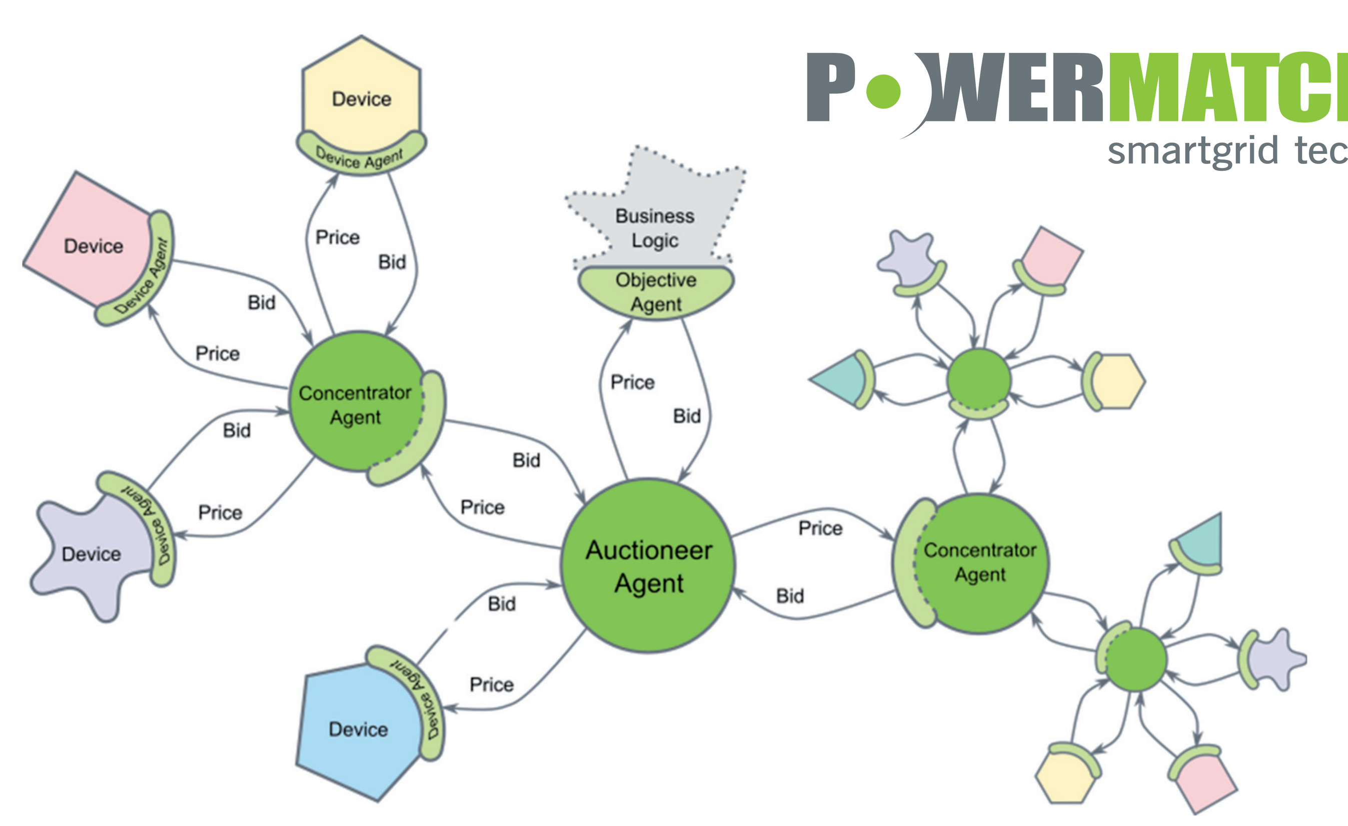
- In real-world application
- In a significant number of real households
- During one year of measurements covering all seasons

Cover heterogeous cluster of appliances

- Dwellings with hybrid heat pumps and μ-CHP
- Solar Cells and windturbines
- Full electric vehicles

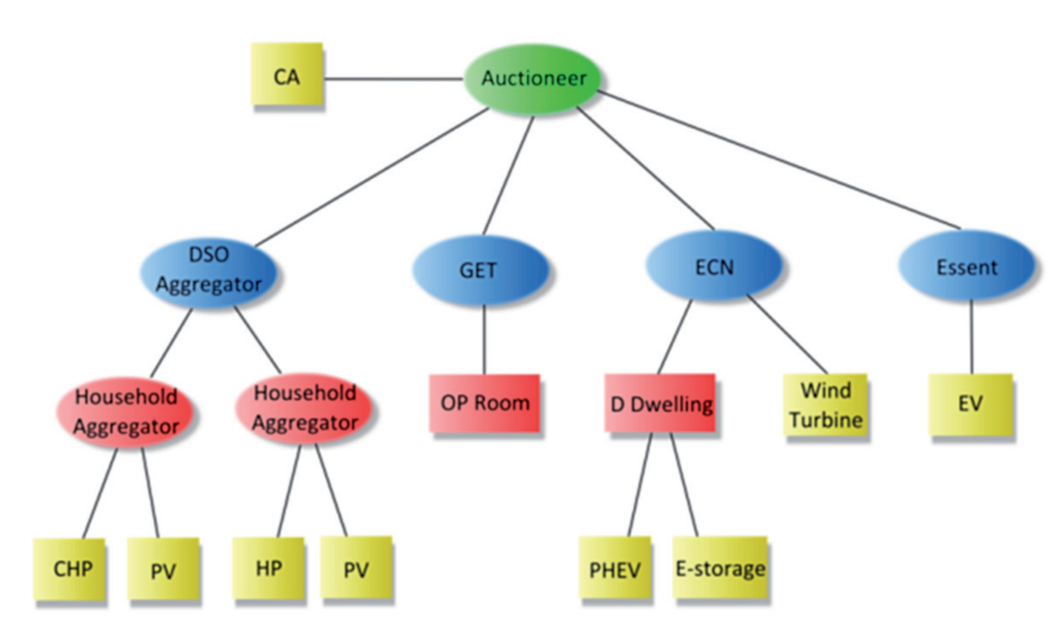
Create flexibility by:

- Storing thermal energy (for space heating or tap water)
- Using primary process flexibility
- Choosing between gas and/or electricity in heating system



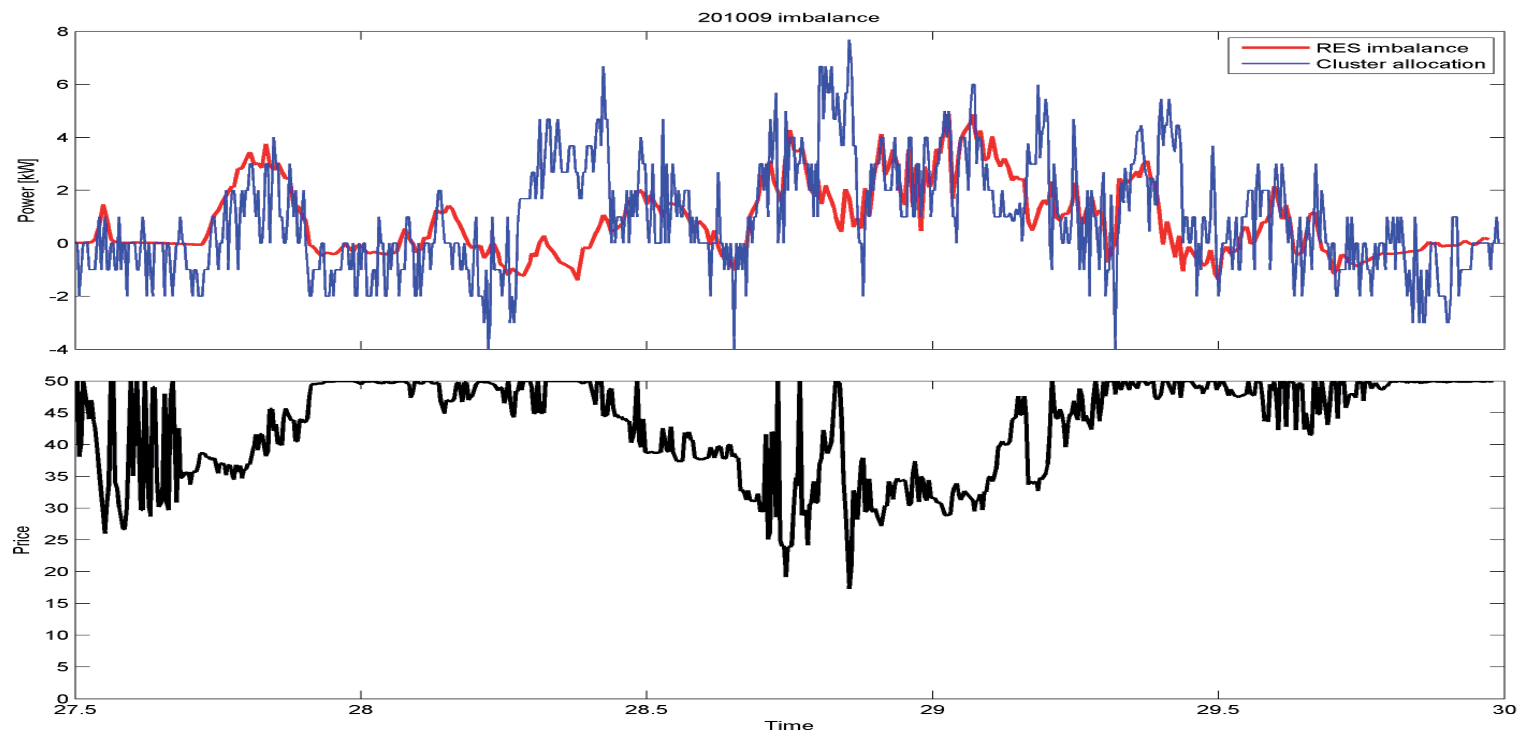
Virtual Power Plant Field test ICT-network configuration

- Full high speed ICT-network with distributed database
- Simulation -> laboratory -> field testing infrastructure
- 25 households with high speed data connections for monitoring, metering and control of heating systems
- Solar and Wind forecasts and realisations in real-time
- Control of charging of two connected full electric vehicles
- Connection to commercial operations and trade dispatch
- Connection to distribution optimization
- Software agents based coordination using PowerMatcher with bids and internal cluster price



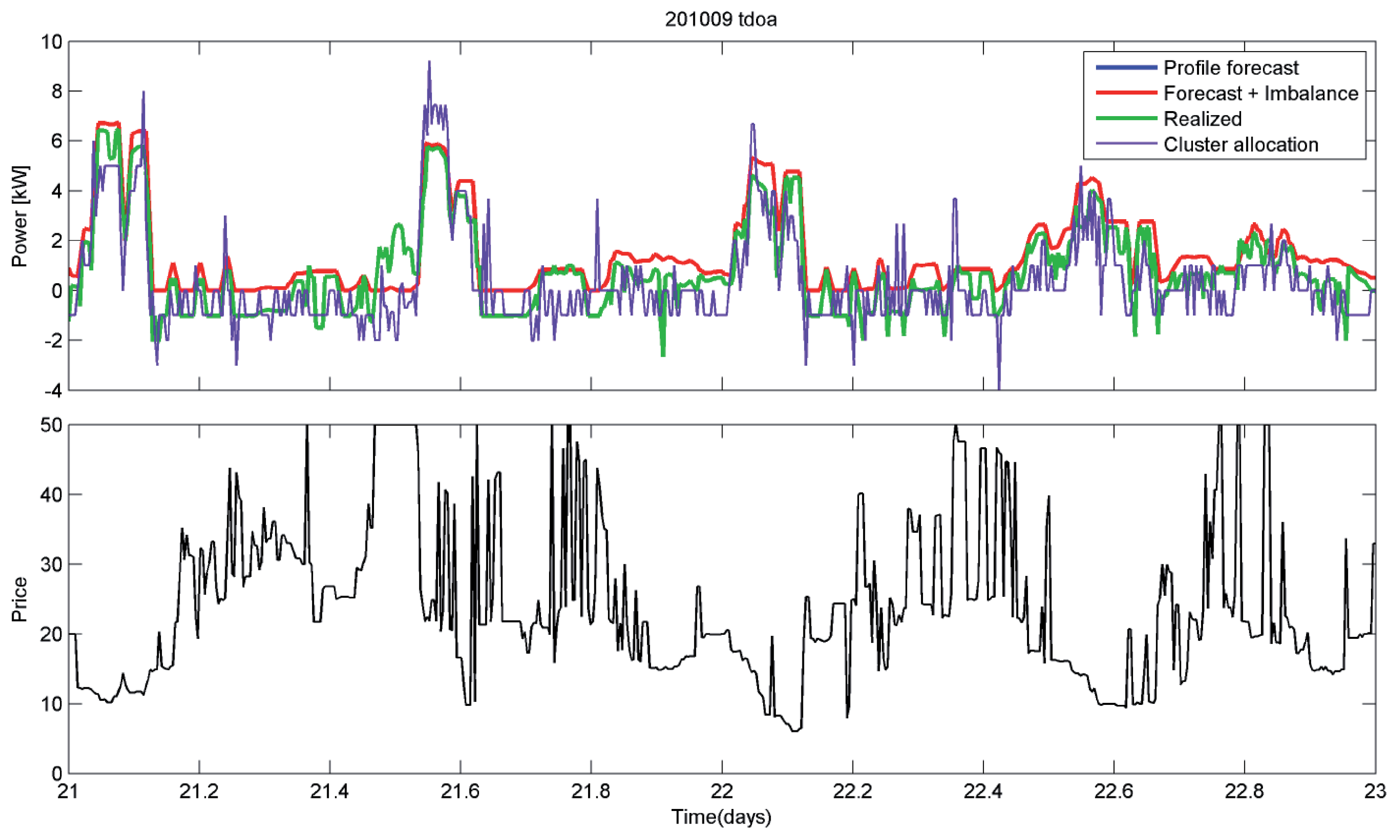
Use case Reduce DG-RES imbalance

- Wind and solar power profiles forecasted one day ahead
- Electricity realizations monitored
- Overproduction -> lower internal cluster price -> flex-demand increases, flex-supply decreases
- Underproduction -> higher internal cluster price -> flex-supply increases, flex-demand decreases



Use case Commercial Dispatch

- Forecasted temperature next day -> heat demand -> Electricity consumption/production -> storage optimization with day-ahead price -> Electricity profile
- Real-time realisations monitored -> cluster follows profile



Conclusions:

- Cluster provides for flexible VPP capacity within minutes timeframe
- Automated reduction of imbalance
- No comfort losses for home owners

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