STASCADE: Stable and scalable decentralized power balancing systems using adaptive clustering

Balancing supply and demand of energy through distributed coordination and market mechanisms

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Whereas in the past, energy supply was determined by demand, in future, demand will need to follow supply. Changing prices is a means to this end, via markets in which bids for demand and/or supply determine the market price for a specific period of time. An important drawback of such markets is that they can be highly dynamic, even with disruptive or chaotic behaviour. This influences the stability and predictability of the energy system. There is a need for decentralised, stabilising, and scalable approaches to balance supply and demand of energy. STASCADE focused the design of dynamic clustering and dedicated market mechanisms as a means to acquire stable and scalable balancing of supply and demand in Smart Grids.

* Studies of clusters of consumers and producers, design of market mechanisms

The basic construct was the existence of various distributed dynamic clusters of synergetic consumers and producers. These clusters are designed to coordinate local load balancing for varying periods of time amongst consumers and producers, typically for substantially longer periods than considered in markets. Local load balancing in clusters thus allows for novel, more reliable solutions for global load balancing and can be used in conjunction with (current or novel) external market mechanisms. In addition, clusters are dynamic and can adapt to changing situations, including network failures. There have been extensive studies of different clusters consisting of a mix of household and service sector buildings. Within these clusters local supply and demand matching using batteries and demand response has been achieved. Different market mechanisms for local clustering balancing have been proposed and different incentive mechanisms have been studied.

Read more

1 M. Warnier, F. Brazier, N. Voulis (2017): *Impact of service sector loads on renewable resource integration*, Applied Energy

2 F. Brazier, M. Warnier, N. Voulis (2018): *Understanding spatio-temporal electricity demand at different urban scales: A data-driven approach*, Applied Energy

3 M. van Etten, E. Chappin, M. Warnier, F. Brazier, N. Voulis (2019): *Rethinking European energy taxation to incentivise consumer demand response participation*, Energy Policy

4 G. Methenitis, M. Kaisers, and H. La Poutré (2016): *Incentivizing intelligent customer behavior in smart-grids: a risk-sharing tariff & optimal strategies*, in *Proceedings of the Twenty-Fifth International Joint Conference on Artificial Intelligence* (IJCAI'16), Gerhard Brewka (Ed.)

5 G. Methenitis, M. Kaisers, and H. La Poutré (2017): *SLA-Mechanisms for Electricity Trading under Volatile Supply and Varying Criticality of Demand*, in *Proceedings of the 16th Conference on Autonomous Agents and MultiAgent Systems* (AAMAS '17)

6 G. Methenitis, M. Kaisers, H. La Poutré (2019): *Forecast-Based Mechanisms for Demand Response*, in *Proceedings of the 18th Conference on Autonomous Agents and MultiAgent Systems* (AAMAS '19, to appear)

PhD thesis

Nina Voulis, *Harnessing Heterogeneity – Understanding Urban Demand to Support the Energy Transition*, awarded Feb 22, 2019

The research programme Uncertainty Reduction in Smart Energy Systems (URSES) aims to make a quick transition to a reliable, affordable and sustainable energy system possible. It is a joint initiative of several departments of NWO, Shell, AMS and the TKI Urban Energy.

Insights & recommendations

[1] Urban areas consist of a mix of households and services, such as offices, shops and schools. Yet most urban energy models only consider household load profiles, omitting the service sector. The research shows that including the service sector leads to statistically significantly better estimations of the potential of renewable resource integration in urban areas. In specific time and weather conditions, including the service sector results in estimations that are up to 33% higher than only households.

[2] The shape of a local demand profile is an important determinant for how much renewable energy can be used directly, and how electric vehicles and electric heating affect a local grid. This research uncovers three types of urban areas: residential, business and mixed. Statistical analysis shows that area types are pairwise significantly different. Moreover, residential-type demand profiles appear only in a small number of areas. It is important to use local detailed spatio-temporal demand profiles to support the transition of urban areas to sustainable energy generation, transportation and heating. To facilitate the implementation of the obtained insights in other models, a spreadsheet modelling tool is made available.

[3] Research to evaluate the potential of a possible European energy tax to provide financial incentives to energy consumers shows that financial incentives are 3.5 times higher for the ad valorem tax than for the per-unit tax. The research gives recommendations for policy makers for the design of energy taxes that provide residential and service sector consumers with adequate financial incentives for demand response participation.

[4] Flat-rate electricity tariffs are not ideal for use in synergetic clusters, which comprise closely-located demand loads and highly-correlated deviations, and can therefore intensify the problem of supply/demand balancing. This research proposes a parameterized risk-sharing tariff that enables consumers to choose the amount of risk they are willing to assume from balancing responsible parties, such as current retailers. The tariff incentivizes consumers to decrease their demand uncertainty, by altering their demand behavior, and can thus reduce overall electricity costs.

[5] Service-level agreements can be adopted to enable electricity trading between producers and consumers within synergetic clusters. This research proposes market mechanisms, coupled with an SLA contracting framework, that can be used by producers that depend their electricity generation on renewable sources and thus may not be able to guarantee electricity delivery to consumers. The proposed mechanisms alleviate the need to curtail excess electricity generation from renewable sources since this can be traded to fulfil non-critical demand loads of consumers.

[6] This research studies the design of market mechanisms that can be used to incentivize uncertain demand response of small-scale users (e.g., EVs, households) in synergetic clusters. The proposed mechanisms can be applied on a local-level from the cluster manager to incite users within the cluster to alter their demand if necessary. To facilitate this, the mechanisms use information that is reported directly from the users, as well as the characteristics of the system. An empirical evaluation shows that the proposed mechanisms can reduce balancing costs associated to balancing supply and demand substantially (up to 16%).

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