PhD candidate in Smart Energy Systems

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Full Project description

Research into new Business Models and HPC technologies in Smart Energy Systems

Introduction

Many industries are nowadays characterized by growing complexity and increasing competition. These circumstances are caused by the transformation towards firm networks, an increasing amount of available data and information, the emergence of disruptive ICT technologies (e.g. Internet of Things (IoT), machine-to-machine (M2M) communication, high performance computing (HPC), Big Data and cloud computing), as well as converging markets and new competitors from prior unrelated industries. As a result, new business ecosystems evolve, in which roles of firms, customers, suppliers, and other stakeholders are reconsidered and configurations adapted.

Research on Smart Energy Systems (SES)

In the energy industry, traditional energy systems rely on fossil fuels that store large amounts of energy that can be delivered on-demand. The problem there is that those resources are limited, expensive and produce a lot of greenhouse gas (GHG) emissions. Sustainable energy systems rely on energy produced by renewable resources like sun and wind, which are typically not on-demand and need to be stored or immediately consumed. Smart power grids are evolving, with networks of loosely coupled, yet fully automated and self-sufficient micro-, meso- and macro-grids, with focus on participation and empowerment of the user. This combination of sustainable and smart technologies is transforming energy company business models and creating new opportunities for existing and new energy service providers.

The challenge is how to match supply with demand and make optimal use of stochastic renewable energy resources. This requires advanced prediction of both supply and demand and decentralization of production and use of energy. The energy ecosystem must therefore evolve from a linear energy production through fuel combustion on-demand towards more interconnected smart electricity, heat and transportation grids for an intelligent production and use of energy. SES combine and coordinate those smart grids with the objective to make use of synergies between them in order to optimize the business case of each of the energy systems, minimize GHG emissions, maximize the use of renewables, and improve the quality, costs and reliability of the delivered energy services.

Our main topic of research is how to make energy systems smarter using HPC and ICT with the ultimate goal to maximize the deployment of renewables, enhance the

resilience of the electricity grid, improve the efficiency of the power system and decrease the costs. Power grids will evolve towards a complex network of loosely coupled micro-, meso- and sometimes macro-grids that are largely automated and self-sufficient, with local production capabilities (mainly renewables), matching local supply with local demand and exporting or importing energy whenever a local imbalance needs to be dealt with. This transition will give rise to new challenges regarding prediction and control of such complex, and dynamic smart energy systems. HPC is expected to help better predicting wind and solar energy production by processing real-time data collected by sensors and satellites and by using weather prediction models. HPC is also expected to improve the prediction of demand by processing and analyzing weather and sensor data, historical usage data, user profiles, real-time energy market financial data and possibly social network information. ICT will help in the M2M communication between sensors, actuators and software agents that make part of the domotica equipment at home and support the prosumers in their energy trading. ICT will play also a major role in the implementation of demand response measures that are required for matching supply with demand in micro-, meso- and macrogrids. ICT infrastructures may also in the future play an active role through Demand Response in providing an energy buffer for matching supply with demand.

In this new competitive environment with changing stakes and roles, organizations are challenged to develop more innovative business models that directly integrate various stakeholders into different forms of value creation and capture and provide a technological infrastructure that allows all players to cope with the increasing amount of data and information. However, business models that reverse the current trend and make organizations in these sectors sustainable, yet profitable businesses are still to be worked out.

Therefore, this research project sets out to better understand how innovative business models emerge from value chain reconfigurations and how will the use of promising and disruptive new HPC technologies and big data and business analytics technologies and services impact SES development. The basic working assumption here is that developments in data analytics, simulation and modeling with HPC, ICT (smart meters, in situ sensor networks, etc.) and agile monitoring technologies, including remote sensing by means of drones and (micro-) satellites, will make it possible to drastically improve the forecast accuracy of local production and consumption, thus enabling efficient control and management of the micro-grids at the appropriate scale.

All those aspects constitute interesting topics of future research, investigating to what extent technology and business models can be harnessed to enable this transition. Some of the important research questions that need to be addressed include:

- How can HPC support to make more accurate predictions of production and consumption profiles (aggregated over the micro-grid) at time-scales that would enable a controller to efficiently match demand and supply just-in-time?

- In particular, how can weather forecasts be supplemented with ultra-local information to improve accuracy of local predictions? How can KNMI and (new) players on the energy market develop new business models and extend their product portfolios in order to improve and strengthen their business ecosystems?
- How can HPC help energy providers improve their mix of production facilities maximizing the share of renewables and minimizing the overall energy production capacity that is needed to guarantee a stable energy system?
- Is it possible to increase the share of renewables in the mix of energy resources without having to raise the price of energy, and how would the business model look like?
- What is the importance of dense sensor networks and M2M communication in this context? Examples of such networks include sensor networks in smart homes/buildings/residential districts/cities[1], smart wireless devices (as a proxy for human activity), and high-frequency, high-resolution remote sensing (e.g. the use of swarms of nano-satellites[2]? What can we learn from existing living innovation labs like thegreenvillage.org, and what living innovation labs should be developed in this context?
- How to integrate local storage and back-up generators (as used by mission-critical facilities, such as emergency services and data-centers) in the SES? And could ICT clouds play a role in energy load balancing via dynamic deferral of server workloads?
- How much (personal) information is needed from citizens, and how can we meet or allay their privacy concerns? How do we guarantee safety and security (e.g. in the case of extensive M2M communication), what would be the appropriate legal/judicial framework? Which private or public initiatives can be stimulated or expected from new entrants in the energy sector (e.g. private prosumers) to develop new or extend existing business models?

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[1] see e.g. www.thegreenvillage.org
[2] see e.g. www.planet.org