Agent-based Methods for Eliciting Customer Preferences to Guide Decision-making in Complex Energy Networks

(Doctoral Consortium)

Micha Kahlen
Erasmus University Rotterdam
Burgemeester Oudlaan 50
3062 PA Rotterdam, The Netherlands
kahlen@rsm.nl

ABSTRACT

The key challenge associated with the transition to sustainable energy is dynamically balancing energy supply and demand. Information systems and smart markets play a vital role in this transition. I study electric vehicles as storage and demand response objects, which are a subset of the smart grid solutions to this societal problem. To elicit consumer behavior and deduct inferences on their preferences towards demand response mechanisms and in particular their price elasticity over time I use field experiments. Based on this experimental data, data from driving behavior, and other field experiments in smart grids I device information system artifacts such as machine learning algorithms as solutions to these problems. These artifacts assume the forms of intelligent software agents and decision support mechanisms that are used for smart energy trading and the operation of virtual power plants based on energy market signals. I validate my findings within the large scale smart grid simulation platform Power TAC. First findings underline the advantage of the trading strategy in terms of the triple bottom line: people, plant, profit. Also significant operational efficiencies in the operation of virtual power plants, in particular negative operating reserve capacity could be demonstrated.

Categories and Subject Descriptors

H.4.2 [**Information Systems Applications**]: Decision Support Systems

General Terms

Economics, Performance, Human Factors, Measurement

Keywords

Smart Grid, Agents, Electric Vehicles, Virtual Power Plant, Sustainability

Appears in: *Alessio Lomuscio, Paul Scerri, Ana Bazzan, and Michael Huhns (eds.), Proceedings of the 13th International Conference on Autonomous Agents and Multiagent Systems (AAMAS 2014), May 5-9, 2014, Paris, France.*

1. INTRODUCTION

Traditionally energy was produced as a top down approach when people use it, but in the future people will have to adjust part of the consumption to for instance the availability of wind as part of demand response programs in a decentralized manner [3]. This is necessary because wind and solar energy production is neither controllable in terms of production quantity, nor is it predictable on a day ahead basis. An inherent property of the electrical grid is that it needs to be in balance all the time; demand and supply need to be matched in real time. Grid instability and blackouts are consequences of instability. The European Union estimates that an annual investment of €270 billion in smart grid infrastructure, information systems, and electrification of transport is necessary until 2050 [2]. In my PhD dissertation I focus on smart (energy) market design [1] and information system's specific contribution to demand response mechanisms with fleets of electric vehicles. The challenge is that traditional energy markets are not designed for an interaction between energy demand and supply. New market designs are required to deal with emerging problems. On the basis of the large scale smart grid platform *Power Trading Agent Competition* (Power TAC) [6] I will evaluate different market designs, agent based strategies for Electric Vehicle charging, and energy trading strategies under smart grid circumstances.

1.1 Research Question

I apply the logic of demand response incentives to fleets of electric vehicles. With different pricing mechanisms at retail, wholesale, and ancillary services level I investigate strategies to balance the electrical grid and its effect on the triple bottom line: people, planet, profits. As a first step I have analyzed electric vehicle charging and driving behavior and am in the process of eliciting consumers price elasticity and willingness to shift electric vehicle charging sessions to a later or earlier point in time. Based on this information I research the viability of using the storage of electric vehicle to balance the market via arbitrage across the day ahead and the intraday on wholesale electricity markets over a 24 hour horizon. In practice that entails training intelligent software agents to offset differences in the provision of electricity and actual usage with charging and storage capacity of electric vehicles (see Figure 1 for a graphical illustration). This constitutes a virtual power plant and goes beyond previous

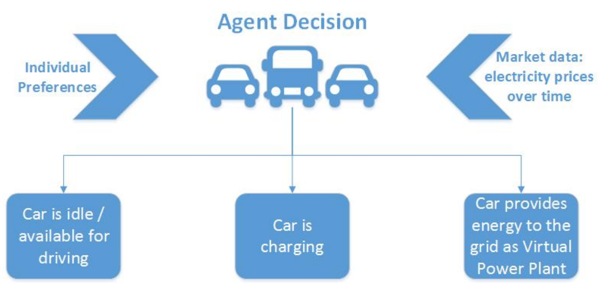

Figure 1: Graphical Illustration Research Question.

research by [8] as it includes the dynamics and uncertainty of driving behavior. Another opportunity for intelligent software agents is on the ancillary service level, that balances the grid over a horizon of a couple of seconds, the secondary operating reserves. For this matter we couple the operation of a virtual power plant to market signals, that produce energy when energy is needed and absorb energy when abundantly available. Research instruments for this research will be simulations, case studies, and field experiments.

2. RESEARCH DESIGN

The research design is centered around decision support systems and information systems and more specifically the design science paradigm [4]. A large part of my research is based on agent assisted decision making. This includes preference elicitation, updating information, and making real time decisions for consumers that would be overwhelmed by the information processing complexity [1]. The field of energy informatics and eco-effectiveness [9] is in that regard relevant, as we consider innovative combinations of market mechanisms in combination with electric vehicle battery storage to balance a grid that was traditionally balanced with relatively flexible energy generation plants.

2.1 Methodology

The smart grid is still under development and only small pilot projects have been implemented. Therefore it is necessary to tap into the potential of simulations to evaluate the impact of a large number of electric vehicle on the electrical grid. The Power TAC platform offers an excellent environment for this as a state of the art smart grid simulation that has been validated by previous research [7]. The intelligent agents that I have devised will be evaluated based on their contribution within this environment and be generalized based on real world electricity wholesale market and operating reserve data.

2.2 Projects

The PhD dissertation is structured in three subprojects. The first project is related to demand response mechanisms and the elicitation of users price elasticity under range anxiety and different travel profiles. The second project implements a trading strategy for electric vehicle fleet owners that has a positive effect on the triple bottom line: people, planet, profit. This research will be part of the AAMAS 2014 proceedings [5]. The third project relates to operating reserves and virtual power plants in a carsharing context.

3. CONTRIBUTIONS

The aim of the PhD dissertation is to shed light on energy consumption behavior from the perspective of electric vehicles (fleet) owners under prices that change over the day. This serves as a building stone to create appropriate demand response mechanisms and results in a win-win situation for consumer and energy provider. Besides that my co-authors and me have demonstrated that there are positive effects of using battery storage as a complement for trading strategies. This holds for the profitability for the trader (profit), but also reduces the electricity for consumers by on average 3.2% (people), and decreases CO_2 emissions by on average 2.4%. A first contribution of the carsharing project is an proposed adjustment to the operating reserve market design so that the ancillary services can tap into storage capacity, which is not possible under the current market design.

4. REFERENCES

[1] M. Bichler, A. Gupta, and W. Ketter. Designing smart markets. *Information Systems Research*, 21(4):688–699, 2010.

[2] European Comission. A roadmap for moving to a competitive low carbon economy in 2050. Communication from the Commission of the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. COM(2011) 112 final, European Comission, Brussels, Belgium, 2011.

[3] S. Gottwalt, W. Ketter, C. Block, J. Collins, and C. Weinhardt. Demand side management - a simulation of household behavior under variable prices. *Energy Policy*, 39:8163–8174, 2011.

[4] A. R. Hevner, S. T. March, J. Park, and S. Ram. Design Science in Information Systems research. *Management Information Systems Quarterly*, 28(1):75–105, 2004.

[5] M. Kahlen, W. Ketter, and J. van Dalen. Agent-coordinated virtual power plants of electric vehicles. In *Proceedings of the 13th International Conference on Autonomous Agents and Multiagent Systems (AAMAS 2014)*, 2014. Forthcoming.

[6] W. Ketter, J. Collins, P. Reddy, and M. de Weerdt. The 2013 Power Trading Agent Competition. Technical Report ERS-2013-006-LIS, RSM Erasmus University, Rotterdam, The Netherlands, 2012.

[7] W. Ketter, M. Peters, and J. Collins. Autonomous agents in future energy markets: The 2012 Power Trading Agent Competition. In *Association for the Advancement of Artificial Intelligence (AAAI) Conference Proceedings*, pages 1298–1304, Bellevue, WA, July 2013.

[8] P. Vytelingum, T. D. Voice, S. D. Ramchurn, A. Rogers, and N. R. Jennings. Theoretical and practical foundations of Large-Scale Agent-Based Micro-Storage in the smart grid. *Journal of Artificial Intelligence Research*, 42:765–813, 2011.

[9] R. T. Watson, M.-C. Boudreau, and A. J. Chen. Information systems and environmentally sustainable development: energy informatics and new directions for the IS community. *Management Information Systems Quarterly*, 34(1):4, 2010.