Intelligent Agents for the Smart Grid

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ABSTRACT

The Intelligent Decentralised Energy-Aware Systems (iDEaS) project at the University of Southampton (see www.ideasproject.info) is developing and demonstrating the application of intelligent agents within the smart grid; a future vision of an electricity distribution network capable of autonomous and intelligent configuration, robust and flexible operation, and two-way information flow between consumers and suppliers. In this demonstration, we show how agent technologies can assist in realising three key components of this vision, specifically: (i) how a home energy management agent is capable of monitoring, visualising and coordinating energy use within the home, (ii) how micro-storage of electricity, coordinated by intelligent agents, can flattern demand across the grid and reduce both costs and carbon emissions, and (iii) how trading agents operating within a novel market mechanism can effectively and robustly distribute energy within the smart grid whilst explicitly accounting for the capacity constraints of the transmission lines.

Categories and Subject Descriptors

I.2.11 [**Computing Methodologies**]: Distributed Artificial Intelligence

General Terms

Design, Algorithms, Experimentation, Theory

Keywords

Agent, smart grid, electricity, storage, trading

1. INTRODUCTION

Meeting the challenge of mitigating the worst effects of global climate change, and ensuring energy security in the face of dwindling oil and gas reserves, requires a radical improvement in the way in which energy is generated, distributed and consumed. Central to delivering the required energy efficiency improvements, is the need to extend electrification to areas of use that currently involve the direct combustion of fossil fuels (such as transport and heating), and to generate this electricity from renewable sources [1].

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Thus, against this background, there is an increasing call for an extended and modernized electricity network, commonly called the smart grid [2], which is capable of:

- Autonomously and intelligently configuring itself to make the most efficient use of available resources; particularly renewable energy sources such as wind, solar and tidal energy which are distributed across the network, are intermittant in nature, and exhibit varying degrees of predictability;
- Maintaining security of supply in the face of equipment and line failures, whilst being robust to the types of cascading failures that plague current networks;
- Facilitating real-time information flows both from the suppliers to the consumers (in the form of real-time price signals), and from the consumers to the suppliers (in the form of real-time and predicted demand signals);
- Allowing the flexible integration of new technologies – such as energy storage in the form of home batteries, fuel cells, and fully electric or plug-in hybrid electric vehicles, or renewable generation such as solar PV panels – as they become commerical viable.

The distributed nature of the smart grid, and the intelligent autonomous behaviour expected of it, naturally lend itself to a multi-agent methodology, and within the Intelligent Decentralised Energy-Aware Systems (iDEaS) project at the University of Southampton (see www.ideasproject.info), we are developing and demonstrating the application of intelligent agents within the smart grid.

2. THE IDEAS PROJECT

In this demonstration, we show how intelligent agent technologies can assist in realising three key components of this vision, specifically: (i) how a home energy management agent is capable of monitoring, visualising and coordinating energy use within the home, (ii) how micro-storage of electricity, coordinated by intelligent agents, can flattern demand across the grid and reduce both costs and carbon emissions, and (iii) how trading agents operating within a novel market mechanism can effectively and robustly distribute energy within the smart grid whilst explicitly accounting for the capacity constraints of the transmission lines.

2.1 Agents for Home Energy Management

A key component of the smart grid is the two-way flow of information between consumers and suppliers, whereby consumers receive real-time price signals that reflect the true cost and carbon intensity of the grid, and suppliers receive up-to-date and accurate predictions of future demand and supply. As a first step to delivering

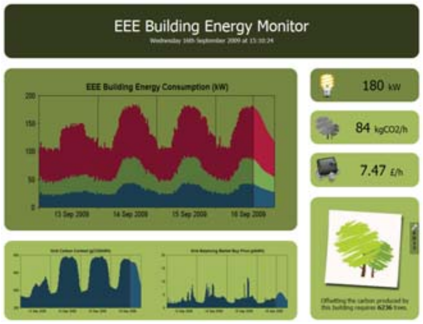

Figure 1: Live information screen displaying energy and carbon emmission data for a building at the University of Southampton (see http://energy.ecs.soton.ac.uk/energy/).

Figure 2: iPhone app displaying live UK gird carbon intensity (available in the iTunes App Store - search for 'GridCarbon').

this information flow, many countries are mandating the roll-out of smart meters, and ultimately, these smart meter will form the core of systems to automate energy use within the home[1]. To this end, we demonstrate our work developing autonomous agents that collect information on energy use and carbon emissions from these smart meters and displays it to householders on in-home screens and mobile devices (see Figures 1 and 2 which show an information screen deployed within the University of Southampton, and an iPhone application that allows householders to see the instantaneous carbon intensity of the UK electricity grid). Furthermore, we demonstrate, within a Java simulation, how this agent is able to optimise the use of heat within the home (using a learned thermal model of the home) in order to satisfy the householder's preferences over cost, carbon and comfort.

2.2 Agent-Based Storage for the Smart Grid

Moving beyond the immediate confines of the home, the use of energy storage devices has been advocated as one of the main ways of reducing peak demand and facilitating the integration of intemittant renewable energy sources within the smart grid. In this demonstration, we present an agent-based Java simulation of the smart grid (based on the existing UK electricity distribution network and demand profiles) that uses an evolutionary game theory approach to show that a novel agent-based micro-storage management technique allows the individually-owned storage devices in the system to converge to profitable and efficient behaviour [3]. The convergence point corresponds to the Nash equilibrium of the system, and at this equilibrium, the aggregate demand profile is flattened (see Figures 3) resulting in both cost and carbon emission savings.

[1]Domestic energy use currently contributes around 25% of UK carbon emissions, and the UK has mandated to roll-out of smart meters to 25M homes by 2016

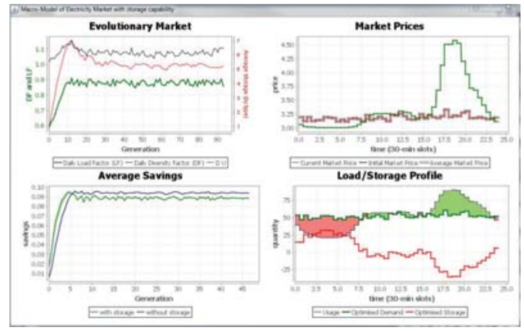

Figure 3: Java simulation of a smart grid incorporating micro-storage showing the flattening of the aggregate demand profile (see http://users.ecs.soton.ac.uk/pv/simulator/storage/storage.mp4).

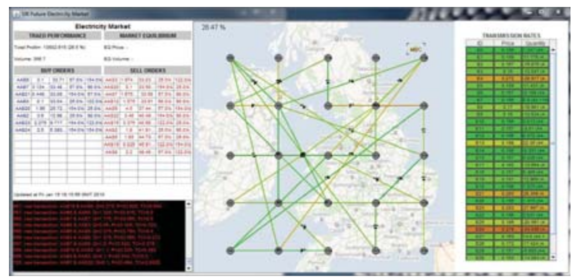

Figure 4: Java simulation of a novel market mechanism and trading strategy for balancing supply and demand within a smart grid (see http://users.ecs.soton.ac.uk/pv/simulator/network/network.mp4).

2.3 Trading Agents for the Smart Grid

Finally, one of the key assumptions underlying the vision of the smart grid is that it will be possible to autonomously manage the trading of electricity between homes and micro-grids while coping with the inherent real-time dynamism in electricity demand and supply. The management of these trades needs to take into account the fact that most, if not all, of the actors in the system are self-interested and transmission line capacities are constrained. Thus, we demonstrate a Java simulation of a novel market mechanism and novel strategies for trading agents within the smart grid (see Figure 4). Our mechanism is based on the continuous double auction (CDA) and automatically manages the congestion within the system by pricing the flow of electricity [4]. This approach ensures that the system can cope with unforseen demand or increased supply capacity in real time, whilst achieving a high market efficiency.

3. REFERENCES

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