Use of the CASCADE agent-based model to examine the UK energy system with climate reanalysis data

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1 Introduction

UK electrical energy demand is met by various sources of generation, with an increasing integration of renewable energy in recent years. By modelling the UK electricity network from 2005-2012 for a two region scenario (Scotland and Northern Ireland, and England and Wales) using climatic reanalysis data, patterns in the UK energy mix have been examined in detail.

2 Method

The CASCADE (Complex Adaptive Systems, Cognitive Agents and Distributed Energy) model was initially set up to investigate the smart grid concept, but its structure has been adapted to model the UK electrical grid with climate data. The structure of this model is shown in Figure 2.1.

Figure 2.1: Structure of the CASCADE model for a 2 region scenario

The first level of the model shows the three inputs. These datasets include:
- Demand data. This dataset contains UK demand at 30min time steps from 2005-2012.
- Generation data. This dataset contains all electrical generators in the UK that were operational for any amount of time from 2005-2012.
- Reanalysis data. This dataset contains temperature and wind speed for both regions, linearly interpolated at 30min time steps from 2005-2012.

The second level of the model is the centre of the model set up, the context. In CASCADE the context is the “area” where agents are built and interact with each other. Here, the data is read into the context, the context creates the prosumers, and the aggregators themselves are added to the context.

The third level contains the prosumers: a producer and/or a consumer of energy. These consist of individual generating stations, and a demand prosumer.

Finally, the forth level contains the aggregators: one for Scotland and Northern Ireland and one for England and Wales. These aggregators select the prosumers that are in their region and sum their supply/demand.

3 Results

Figure 3.1 highlights temporal trends in electrical demand and supply in the UK. In both seasons weekend peak demand is 13-14% lower than the weekday peak demand.

Figure 3.2: Net demand for each region from 2005-2012

This trend highlights the higher non-domestic demand on weekdays. The diurnal cycle consists of minimum demand during the overnight hours, and maximum demand during the morning and evening. The evening peak during the winter appears to be more pronounced, likely due to the requirement for domestic heating at this time of year.

Running the model for the entire period 2005-2012 it is found that the only time demand exceeds supply is on two consecutive 30min periods at the end of 2007 in the in England and Wales region. Figure 3.2 shows the net demand during the week this occurred. The demand outweighed supply on the first occasion by 102MW and the other by 347MW. Looking at the same periods for the Scotland and Northern Ireland region, we can see that there is approximately 1000MW excess supply at both times, so the shortfall could have been supported.

Comparing the actual generation mix for 2009 shown in Figure 3.3 a) and the generation mix produced by the CASCADE model in Figure 3.3 b) it is seen that the UK had the resources to meet demand with a significantly different mix of generation. Note that gas and oil are combined in the model. The model met 33% less of the demand with gas/oil and 36% more of the demand with coal and nuclear. This is a direct result of how the model is set up. Since the model allows nuclear and coal to meet the base demand, and gas to meet peak demand only when needed, a shift from gas to nuclear and coal is expected. Renewable generation was well represented in the model with only 1% difference from the true value.

Figure 3.3: 2009 UK electrical generation by type

4 Conclusions

- There are strong seasonal, weekly and diurnal trends in UK electrical demand and supply.
- Demand exceeded supply on two occasions from 2005-2012 in England and Wales, which could have been supported by Scotland and Northern Ireland.
- Past electrical demand could have been met by a large variation of different generation types including a 33% reduction in the use of natural gas in 2009.
- Further model development is recommended with key improvements including transmission links between regions, a market, ramping rates and regional disaggregation

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