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UNDERSTANDING THE IMPACT OF HUMAN & CORPORATE BEHAVIOURS ON DSO PLANNING

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Abstract

Future flexibility markets will require the participation of new entities, like aggregators and domestic customers. The activities of these entities will have an impact on regulators' market designs as well as Distributed Network Operator (DSO) operations. Existing simulation models fall short in capturing the effects of human behaviour from domestic customers or other actors such as aggregators on the system. The paper presents PyEMLab-Agg, a new agent-based modelling tool that has been created to incorporate impacts like human behaviour, contract and risk management, as well as business model selection. According to preliminary simulations, evaluating DSO flexibility markets without taking into account consumer sentiments and social interactions may result in an over or underestimation of average market pricing of between 20% and 50%. DSO's that use the output of such a tool could improve their ability to host additional capacity on their systems.

1. Introduction

A Future flexibility system will require the participation of new actors like domestic customers and aggregators. The behaviour of these actors will impact on DSO operation and their longer term planning and will impact on Regulator market designs (e.g. Ofgem in the UK). Current tools do not adequately represent human or aggregator behaviour in their models. This is an important for a number of stakeholders including regulators, customers, aggregators and the DSO's. In particular, the DSO will need to better understand the behaviour of customers and aggregators providing flexibility to their system in the short term, but will also need to account for these behaviours for their long term planning. Understanding the effects of market designs on customer and other stakeholder behaviours will be key to their efficient and safe operation. A tool implementing human and corporate behaviour is therefore essential if appropriate designs are to be formulated, in a market with millions of participants.
The paper overviews the design and use of a new Agent Based Modelling (ABM) tool (PyEMLab-Agg) that has been used to simulate a power grid in an area of around 50 square miles, consisting of 50,000 domestic customers and 4500 industrial and commercial customers. The framework enables different stakeholders, such as DSOs, to comprehend how new players, (e.g. aggregators) might affect their systems.

This short paper will briefly discuss various aspects of the PyEMLab-AGG framework including Risk Management representations, Business Models and Social Network interactions. The key novel elements of the model will highlighted and discussed and include:

- A human behaviour module
- Contract adaptation by corporate actors
- A risk management & valuation hedging module including hedging
- Customer social interactions model – for sharing experiences
- A business model adaption methodology/model for corporate actors

We will show that inclusion of human and corporate behaviours is important to more accurately predict system power flows and is important in providing insight to manage additional capacity.
Increased uncertainty would normally require additional "safety" operating margins so reducing risk to the DSO is an important objective if it is to increase hosting capacity on its systems.

Overview of ABM Approach

Over the last few years we have been developing a number of tools and models to help us answer questions about new market structures and how new actors in future flexibility markets e.g. Aggregators, prosumers, EV owners, DSO's, might participate and react to those markets. These market changes have important ramifications for a number of stakeholders including Distribution system operators (DSO) and regulators. In this regard, we have developed an Agent Based Modelling Framework (ABM) called PyEMLab-AGG. The model has been used to help us understand the impact of "less visible actors" to the DSO, such as Aggregators, domestic customers providing Demand Side Response (DSR) and shows their impact on prices and the system in general (flows, voltages etc.).

The tool is being used to answer questions like:

- What are these various actors likely to do under various assumptions and what might be the best response by the DSO to manage their system?
- What are the alternative mitigation strategies and how do they impact on the ability for the DSO to manage its business. Which alternatives are best?
- What are the key drivers of output in the simulation?
- What are the impacts of bidding behaviours and contract types on price evolution and system flows?
- How does the type of social network and interactions on those networks affect price evolution?
- What are the effects of price incentives on system flows and non-visible actor behaviours (i.e. aggregator and domestic customers)?

The model uses agents to simulate the actions of key actors in the environment. The aggregators in this framework compete with other suppliers, such as other competing aggregators, generators or large industrial consumers, in the markets for wholesale power balancing and auxiliary services. Note the framework is extensible so other actors or other interaction scenarios can easily be configured. Figure 1 shows the main actors of the model used in the case study in paper.

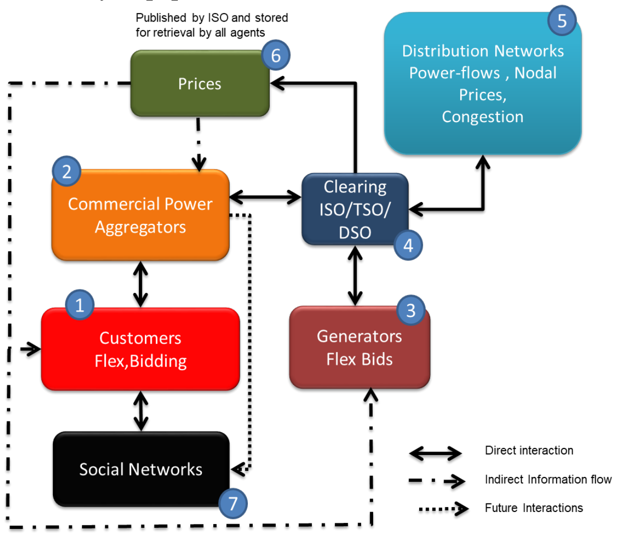

Figure 1: Actor interactions in ABM framework

In the modelling framework used in the case study presented below, Commercial power aggregators② (numbering on figure) interact with their domestic and industrial customers① by managing flexibility bids sent from these various entities. These bids, along with those from generators③, are submitted to the market operator (e.g. ISO/DSO/TS④ - depends on type of market) who clears the proposed flexibility market. Distribution and transmission networks are modelled using an AC OPF representation of a distribution network and provides prices at various nodes and impacts on the ability of some bids from customers to be dispatched⑤. Cleared prices⑥ are published for use by various participants and are also used by the aggregators and other participants to adjust future bids. Customers can choose between a number of aggregators who compete with each other for flexibility and acquiring customers. Domestic customers currently may gossip over a social network⑦ by sharing contract price information and details on the performance of their current aggregators. The dotted line between ② and ⑦ (future work) represents the ability of aggregators to influence social media using their own social media accounts or via bulk advertising channels. In the framework, consumers and aggregators are represented as learning agents using a variety of algorithms and trading heuristics e.g. Cliff's Zip trading agent [1] to determine the best course of action to achieve their goals. For example, aggregators can take bids from consumers and manage these bids when participating in the flexibility market. On the other hand, aggregators need to entice customers to participate in their services, while also having to take into consideration customers' welfare. Aggregators can offer different contract terms in this version of the model, to entice additional customers. Moreover, social customer interactions may play an important role in customer behaviour. Customers can interact with other customers and, in this model, a novel approach based on the Epstein's Agent_Zero framework [2] is utilized.

2. PyEMLab-AGG Modules

PyEMLab-AGG is a object orientated Python based Agent Based Modelling (ABM) framework that uses vectorisation rather than list or stream processing for speed improvements and focuses on the flexibility markets (VPPs' aggregators DSO's), although it can be extended to include other agents like Transmission operators etc. It is based on the Java based EMLab [3] that was designed to focus on simulating the design of policies for transmission assets and simulates the introduction of new generation technologies and their impacts. PyEMLab-AGG includes some important elements that allow us to capture and investigate the effects of human and corporate behaviour. These are shown in Figure 2 and are briefly described in the following sections.

ABM Framework ①: The extensible ABM framework, allows a multitude of actors to be added and includes data storage output routines.

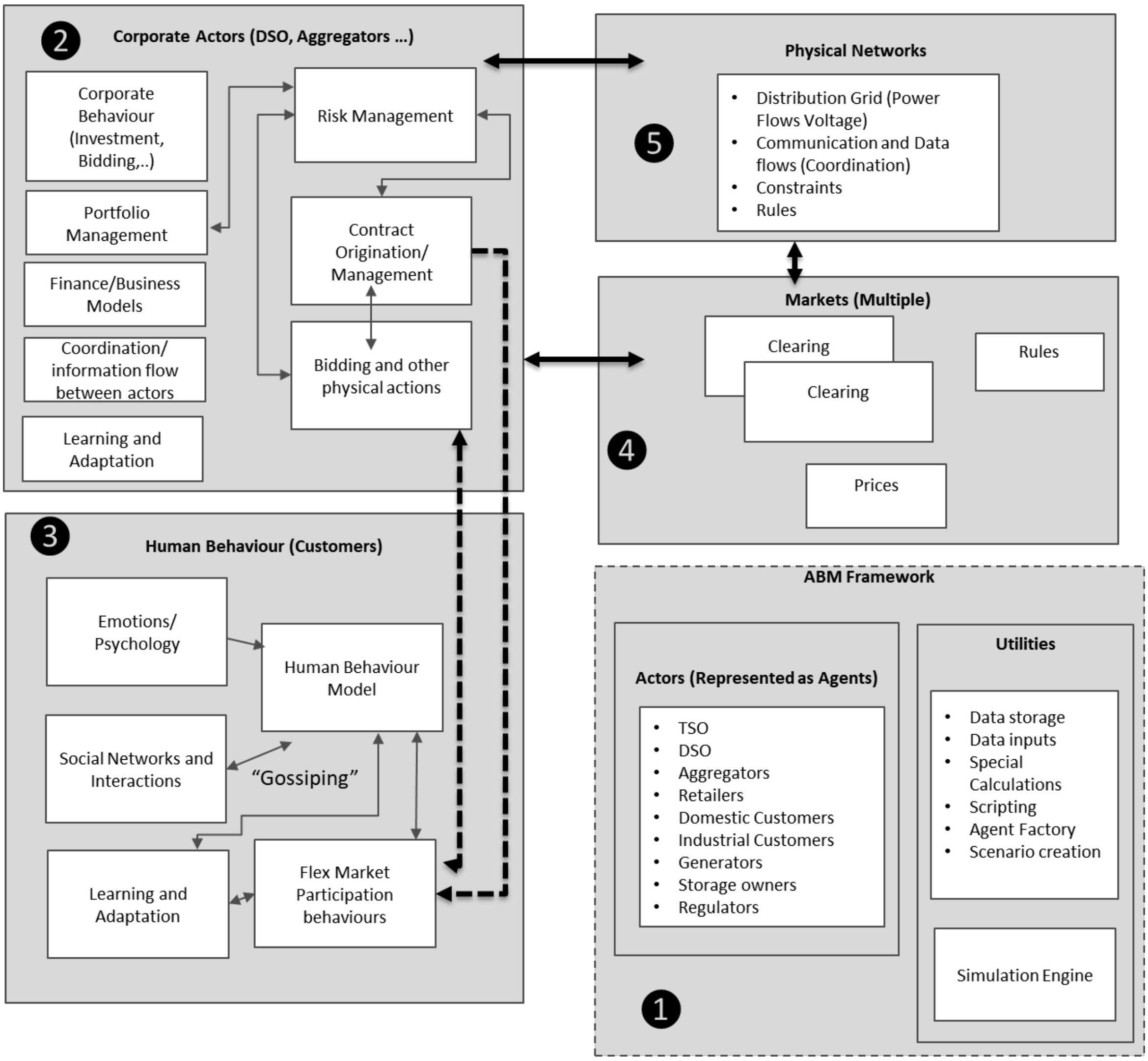

Figure 2: Key modules in the PyEMLab-AGG ABM framework

Corporate Actors ②: Includes aggregator's business models in the context of a future wholesale flexibility/balancing power market. Aggregators can change Business Models throughout the simulation. They are able to assess past performance and forecast the performance of future business models, and select the appropriate one for future use. Corporate actors use risk management techniques to reduce exposure to their business. The framework currently utilizes an exotic three-asset Monte-Carlo based real option approach to represent risk in a power aggregation market. Aggregators have to portfolio manage their bids It allows aggregators to adjust and bid for new customers on a monthly basis.

Human Behaviour ③ : The tool uses a novel extension of the Agent_Zero framework to model emotions, economics and social impacts. When social networks are combined, the Agent Zero framework provides social interactions that influence aggregator choice. Behaviours are seen that are not evident in other system designs. It thus provides a novel tool for implementing human behaviour in a market with millions of participants e.g. domestic customers. This is an important principal contribution to the state of the art in modelling flexibility markets. The framework also incorporates a large social gossiping network that is used to affect emotions and provide a social network dimension to customer's emotions.

Markets & Physical Networks④⑤: Finally, the model includes representations of distribution networks and a variety of markets.

3. Case Study Results

To understand these interactions an illustrative case study consisting of 50,000 domestic customers, 4,500 SME'S (industrial customers), and six aggregators are modelled using the framework, This is representative of a UK city the size of Dundee or York. Figure 3 - 5 shows how the inclusion of some of the modules described above impacts on price and volume predictions vs a base case, which is a simulation without any of the modules in ② - ③. Figure 3 presents the results from a market prospective in absolute terms. Figure 4 shows the differentials of the cases over the base case. Results indicate that on average the addition of these modules can result in an over or underestimation of market pricing of between 20% and 50%. In some specific instances prices more than doubled. Note graphs only show the first 260 hours of simulation.

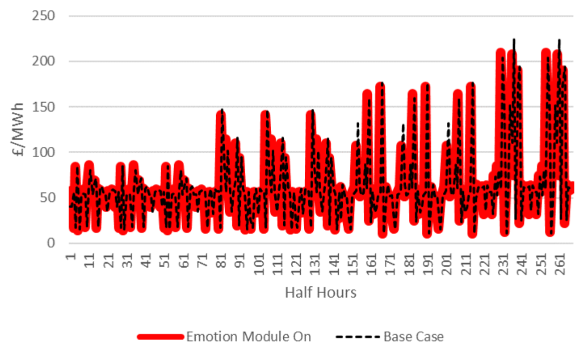

Figure 3: Price impact of modelling

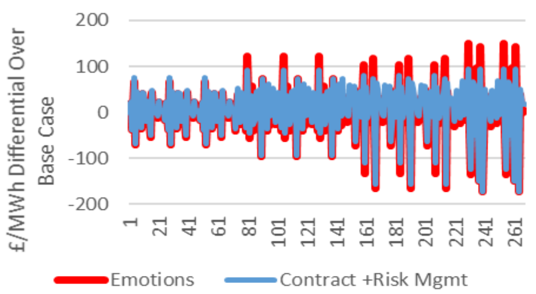

Figure 4: Price differentials (advanced modelling vs base case)

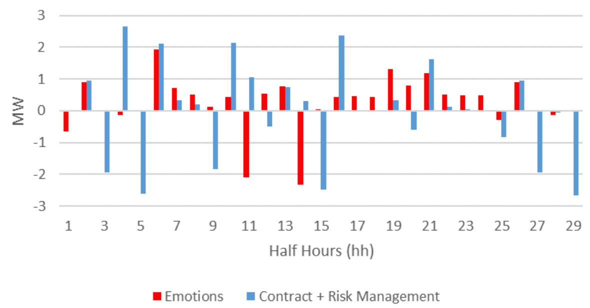

Figure 5: Volume impact of modelling

Figure 5 shows the same scenarios as Figures 3 - 4 but shows the effect on simulated volumes dispatched in the distribution system. Note for clarity we show volumes (MW) as differential volumes. That is scenario volumes – Base Case Volumes. Note the maximum flexibility required in the area of interest is around 9MW, so the volumes in Figure 5 represent around a 23% difference in predictions.

4 Conclusion

This short paper has introduced the ABM framework PyEMLab-AGG. We show that inclusion of human and corporate behaviours is important to more accurately predict system power flows and market prices. Increased uncertainty as a result of less predictable actors like aggregators and domestic customers providing flexibility, would normally require additional "safety" operating margins which may be costly. Alternative mitigation strategies will be important in reducing these costs. The ABM tool PyEMLab-AGG provides us with a new methodology to test out alternative portfolios of risk mitigation strategies, allowing DSO's to potentially increase hosting capacity on their systems.

5 Acknowledgements

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