Desiderata for Agent-Based Power Regulation Protocols in Smart Grids *

Radu-Casian Mihailescu, Matteo Vasirani and Sascha Ossowski

{raducasian.mihailescu, matteo.vasirani, sascha.ossowski} @urjc.es

Abstract. In this work we focus on one particular area of the smart grid, namely, the challenges faced by distribution network operators in securing the balance between supply and demand in the intraday market. Typically, the intraday market is used as a mechanism for coping with various unplanned operational incidents that may arise in the grid. It is anticipated that it will gain even more significance, as a growing number of load controllable devices and small-scale, intermittent generators coming from renewables are expected to pervade the system. On one hand, this means that the task of managing the network efficiently becomes increasingly complex and stochastic due to the large number of decentralized autonomous actors embedded in the network. On the other hand, their dynamic adaptability and capability to conform to higher volatility can lead towards compelling solutions. In this position paper we propose a set of desiderata for a multi-agent design to facilitate coordinating the various actors and alleviate these drawbacks.

As the network is becoming more reliant on the power generated by DERs, the role of the balancing market is expected to gain significant importance. The goal is then to maximise the usage of clean energy upon its availability and maintain the delicate balance between supply and demand in real-time. In order to do so, demand should be able to adapt to the volatility in supply and periods of high demand should be synchronized with intervals of higher generation. This can be made possible assuming that consumers can engage in an online, self-interested negotiation for shifting loads and thus adapting their demand. The problem is far from being trivial as the system is ought to react in real-time to sudden changes of the aggregated generation profile in order to balance supply from intermittent renewable resources, while complying with consumer requirements. In the following, we give a list of prerequisites for a novel multi-agents design, with a brief explanation for each:

- **Decentralization**. The benefits of applying the multi-agent systems paradigm as an approach for distributed control of the Grid entails primarily: autonomy, scalability, flexibility, extensibility, fault tolerance and reduced maintenance [Rob04]. The actors existing in the grid (i.e. consumer loads, distributed generators) represent different owners with particular, possibly conflicting user goals and behaviors hence, deploying an agent-based distributed control over the system becomes highly suitable for such a scenario. Moreover, decentralization increases the systems reliability in case of failures, enables local adaptability to dynamic situations at runtime and allows coordination, as opposed to the more complex task of centralised management.
- **Stability. Fairness. Computational and Communication Simplicity**. Once the network operator determines that a load control action needs to be executed, this information is published and becomes available to all actors in the respective region of the grid. Normally,

* AT2012, 15-16 October 2012, Dubrovnik, Croatia.

no actor in the network would be able to handle such a request alone, thus cooperation is required. For each action request there is a monetary incentive provided by the network operator. This means that another aspect, that needs to be addressed, concerns coming up with an individually rational and efficient payoff configuration that satisfies a notion of stability. Here, stability entails that agents have an incentive for behaving in a certain way. The payoff allocation scheme is resulting from running a negotiation procedure, where agents reschedule loads in order to meet the required constraints. It is well known that the classical stability concepts in coalitional game theory are of high computational complexity [OR94, KG02]. Consequently, considering the real-time constraints, for the payoff distribution, the protocol should minimize computational and communication demands.

- **Dynamic environments**. Confronted with the uncertainty regarding both generation and consumption capacities, the grid operator is running a continuous prediction of both supply and demand in the near future, in order to prepare for reductions in available supply or high-peak demand. Thus, it is responsible for compiling production and consumption schedules to be explicitly passed to the actors in the grid. However, these schedules are volatile in nature, as they can be influenced by a wide variety of factors (e.g. wind speed, solar irradiance, consumer patterns, etc.), though their accuracy improves as the time-to-prediction elapses. Therefore, agents need to be able to reason in advance in this dynamic setting and be capable to instantiate a solution once such a situation arises.
- **Stochastic environments**. It is important to note that the agents, representing both consumers and producers of energy in the grid, operate within significant levels of uncertainty. We aim to model a setting in which we consider the sources of uncertainty to be twofold. From the agent's perspective, on one hand the challenge is in accurately predicting its user's energy profile and preferences. On the other hand, in order to increase their coordination efficiency, agents need to build a prediction with regard to the expected behavior of potential coalition partners. We intend to address both aspects in a unified approach by including sources of uncertainty in the form of random, uncontrollable variables with probability distributions, that each agent attempts to learn in an online fashion.
- **Privacy-Preserving Layer**. Our intended algorithm is run distributively among agents representing various actors in the grid, requiring that valuations of different actions to be communicated between them. This implies that sensitive information will become distributed among numerous agents, without transmitting the data to a central (trusted) site. Thus, in order to avoid the possibility of malicious agents attempting to learn other agents' preference and potentially gaming the system, our scheme is to incorporate cryptographic primitives in order to perform secure multi-party computations. Specifically, we look at *homomorphic* encryption schemes, which make it is possible to perform operations on cyphertexts that translate to operations on the initial cleartext messages, without the need to know the encryption key. This enables that an agent cannot decrypt any of the individual messages received, but can however aggregate the messages using the homomorphic property and ask a subset of the sending agents to help it decrypt the result. Specifically, we are interested in applying an efficient additive homomorphic encryption scheme.

References

[KG02] M. Klusch and A. Gerber. Dynamic coalition formation among rational agents. *IEEE Intelligent Systems*, 17(3):42–47, 2002.

[OR94] M. Osborne and A. Rubinstein. *A Course in Game Theory*. MIT Press, 1994.

[Rob04] D Roberts. Network management systems for active distribution networks: a feasibility study. *DTI Distributed Generation Programme Contractor SP PowerSystems LTD Contract Number KEL003100000 URN*, 2004.