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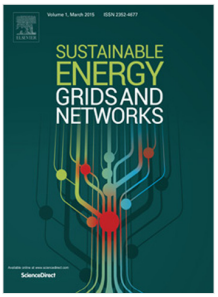

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Electricity Market Policies for Penalizing Volatility and Scheduling Strategies: the Value of Aggregation, Flexibility, and Correlation

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***Abstract*—We consider small energy producers and consumers (i.e. prosumers), organized in groups in order to trade energy in wholesale markets as a single Virtual Microgrid entity. A market procedure is described, from the day-ahead to the balancing market, including load rescheduling procedures. Violations of day-ahead contracts are charged via a dynamic penalty policy in the form of a spread between buy and sell price of electricity in the balancing market. Before the balancing market, the Virtual Microgrid Association calls for its prosumers' flexibility and motivates them for smart load rescheduling to reduce exposure to market losses. Active and passive scheduling strategies are evaluated and a new hybrid approach is shown to achieve better profits for all values of the spread and the flexibility factor. We present a method of quantifying the value of a prosumer's flexibility and provide insights for a future policy of effectively compensating prosumers for their flexibility. The effects the penalty policy and the choice of the spread parameter have on the prosumers' behavior are studied and important insights are provided. The possibility of cooperation among prosumers in a certain geographical area is also studied, showing that it can lead to more intelligent and profitable operation.**

***Keywords*—electricity market, volatility penalty policy, prosumer, virtual microgrids, value of flexibility, value of cooperation, rescheduling**

HIGHLIGHTS

- A penalty policy for charging the day-ahead market contract violations is presented
- Prosumer and Virtual Microgrid Association rescheduling strategies are studied
- Insights for compensation policy for the prosumers' flexibility are provided
- A study of the way penalty policy affects the prosumers' and Associations revenues is conducted
- Effects of the prosumers' cooperation and correlation are studied

1. Introduction

Until the 1980s, electricity systems were considered natural monopolies and were organized under cost-of-service regulation. Regulation in the EU and other countries promotes, or even dictates, that a certain percentage of the produced energy comes from Renewable Energy Sources (RES), thus creating a demand for RES energy as a diversified product. The major directions favored by the EU are the increase of RES penetration in the energy network and the liberalization of the energy market (directive 200/72/EC [1]). Thus, Energy Market Operators (MO) are forced to incorporate RES from small producers in their markets. As RES are being developed and used ever more extensively, a large degree of volatility and unpredictability is added to the grid, necessitating a radical revision of the traditional Grid and of the Market Model. Volatility constitutes a negative externality caused by certain (especially RES) market participants but affecting all participants, and in order to minimize it, the ones causing it should be appropriately penalized. Holding those who cause market volatility financially responsible for it, is increasingly important as the penetration of RES producers increases. With current market rules, RES producers or big consumers with high volatility get a free ride, and the rest of the market pays the price for it.

Distributed generation of electricity has been the principal trigger for developing the concept of the Smart Grid. Currently, RES are less (economically) competitive than traditional fossil fuel sources, while also causing extra costs to the system [2], partly due to their unpredictability, making it very challenging to satisfy demands for both cleaner and cheaper energy. This challenge has opened up new domains of research, including the development of new business models to facilitate the incorporation of more RES in the grid [3], by internalizing both positive (e.g. environmental and location benefits) bit also