AGENT MODELING OF TERRE AND MARI BALANCING MARKETS TO STUDY THE ECONOMIC IMPACT OF MARKET ORDER STANDARDIZATION

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Overview

In a context of liberalization of power systems in Europe, a series of markets have been set up from several months or years prior to real-time to Intraday and balancing mechanisms (up to a few minutes before real-time). The balancing mechanism refers to the period after the last Intraday market up until real-time, and is currently dealt with locally by Transmission System Operators (TSO), who are responsible for maintining consumption – generation balance in real time in their area. ENTSO-E and the European Commission have pushed for balancing markets integration since mid 2010 through e.g. the Network Code on Electricity Balancing, or the Electricity Balancing Guideline, which provides for common rules including the creation of several harmonized reserve types (Frequency Containment Reserve – FCR –, automatic Frequency Restoration Reserve – aFRR –, manual Frequency Restoration Reserve – mFRR – and Replacement Reserve – RR), and of common cross border platforms to monitor the exchange of reserve products.

This paper focuses on two of these platforms, MARI and TERRE, respectively associated with the activation markets of mFRR and RR reserves. Balancing markets actors, namely Balancing Services Providers (BSP) and TSOs (who are still responsible for the balancing of their area), formulate standardized market orders on the platforms according to their generation plan and technical constraints applied to their units (for BSPs), or to the imbalance on their area (for TSOs). This standardization, required for an efficient close to real time common market, implies that orders must follow specific rules regarding e.g. their duration or quantity. The platforms then select orders that will be activated during a stage called Clearing, by maximizing the overall social welfare with the usage of a Common Merit Order List (CMOL), and finally communicate these results back to market actors.

The theoretical design of balancing markets has already been extensively discussed in the literature. However, some pratical considerations are mostly overlooked. Amongst those, technical constraints applied to generators can have important implications on the characteristics and structure of market orders formulated by generators, leading to major impacts on the overall performances of electricity markets. In addition, most studies focus on one balancing market or platform alone, although the interaction between simultaneous TERRE and MARI markets processes, together with the integration of balancing markets within the whole electricity markets process, can lead to distortions caused by strategic behaviour. This paper presents a new agent model that is able to take into account these missing features. It is then used to analyze the impact of market order standardization on balancing performances, both technical and economic, by gradually looking at each step of the transition from local balancing processes to balancing markets.

Methods

A literature review has been conducted to identify modeling approaches suited to simulate successive electricity markets with time-dependant uncertainties on consumption, solar and wind generation forecasts, while representing actors heterogeneity and sufficient technical constraints. Several articles, notably [1], show that agent-based models are better at dealing with this kind of complexity than other models, such as equilibrium models. Agent models can also simulate strategic behaviour in electricity markets, for instance with reinforcement learning [2]. As our review of existing agent models showed that none seemed to provide all of the tools necessary to simulate TERRE and MARI markets at once (mainly time granularity, technical constraints consideration, time-dependant uncertainties), the balancing section of the agent-based electricity market model ATLAS (used in studies of the European project OSMOSE [3], and developed within the Prometheus platform) was built for this study. The whole ATLAS model can take as input data from an Antares[1] study, introduce time-dependant forecasts uncertainties with the method described in [4], and then simulate sequential Day Ahead (DA) and Intraday (ID) markets based on the power system of the original Antares study. This consequently creates a relevant power system state for the balancing section. The new section then consists of several modules simulating the consecutive steps of balancing markets, and of a module simulating the current balancing process used by RTE (called Balancing Mechanism).

Markets are modeled in a 3 stage process described in Figure 1:

[1] Antares is an open source adequacy tool used by RTE for their Bilan Previsionnel or in various ENTSO-e's studies, and getting data from this source guaranties a realistic and referenced European power system model.

- The first stage formulates standardized market orders for all agents, at portfolio level or unit by unit, taking into account a wide range of technical constraints (e.g. maximum and minimum power, gradients, startup duration and other specific duration constraints), production and consumption uncertainties as well as price forecasts that depend on time horizon, and production cost of each generating unit. These constraints can impose bounds on some characteristics of orders, or force the creation of coupling links between them.
- The second stage replicates the Clearing process applied in real markets, by using marginal pricing and CMOL and by considering coupling links between orders.
- Eventually, in the third stage, orders accepted during the Clearing stage are transmitted back to the agents, who modify their units generation schedules. If the orders are originally formulated by portfolios, each of them perform an optimization to dispatch on their units the overall Clearing activated quantities at least cost.

Figure 1- ATLAS Electricity Markets Simulation Process

Using this process, DA, ID, TERRE and MARI markets are repeatidly simulated over the course of multiple days, to encompass different power system states. The performances of incremental balancing architectures are compared:

- Balancing Mechanism (BM), the historical balancing process used by RTE in France.
- TERRE + BM, the current process consisting of the TERRE market followed by a BM if needed.
- TERRE + MARI, which is the target configuration proposed by the European Commission.

Results

Simulation conducted on data from RTE's study "Energy Pathways to 2050" are used to compare our three architectures on technical (security of supply, post-process imbalances, quantities and structure of orders, type of units activated, etc.) and on economical (market prices, market liquidity, social welfare, etc.) criterias. An analysis of the transition from local balancing processes to European balancing markets is then conducted, based on those criterias.

Initial results show that the complexity of order formulation required to represent technical constraints is a major difficulty during the Clearing stage, especially when determining market prices. Indeed, coupling links between orders can create paradoxically accepted or rejected orders (meaning out of merit order). When they occur, the price given by the intersection of demand and supply curves may not correspond to the price of marginal order(s), and the price determination requires a combination of heuristical and optimization methods that can lead to non-intuitive prices. Moreover, ATLAS simulations indicate that such complex orders are common, especially for thermal units, and even compose the majority of orders in balancing markets. The same observation can be made on actual data coming from the operational TERRE process. Impacts of orders standardization on market liquidity is also analyzed and quantified.

Conclusions

The European power system is undergoing the last steps towards its complete liberalization with the integration of balancing markets. The theoretical design of these markets has already been largely discussed in the literature, but pratical considerations such as technical constraints on generating units and TERRE and MARI interaction are mostly overlooked. A new agent model was developed on the Prometheus platform and integrates these missing features, and is used to conduct a practical analysis of the standardization of orders by simulating several stages of the transition from local balancing processes to common European balancing markets. Further work includes the consideration strategic behaviour for agents, focused around arbitrages that can arise between TERRE and MARI.

Références

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