Smart TSO-DSO interaction schemes, market architectures and ICT Solutions for the integration of ancillary services from demand side management and distributed generation

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1. Market Layers

One of the main goals of SmartNet consists in demonstrating the capabilities of distributed energy resources in providing flexibility. This flexibility is expected to participate (and be eligible to participate) to the various energy markets, as well as the ones in which ancillary services are traded (SmartNet simulation will be focused on the real-time balancing market). Since ancillary services markets represent the last resort to sell flexibility, the level of participation depends on the strategy adopted by controllable resources in previous markets, such as the day-ahead and intraday ones. This means that the same unit of exchanged energy could have attempted to participate to various market layers, or even been activated more than once in opposite directions. Therefore, the intricacy of energy markets is evident and simulating a realistic scenario is a significant challenge.

This document aims to illustrate the interconnectivity of the energy trading markets and the place of the real-time balancing market in the entire energy trading chain and merit order. According to this, it is important to define the related markets, the timing and which effects they have on each other, hence how the price signal from one market can affect the participation and result from the next one. Let's briefly cover the different market layers one by one:

FUTURES: This market sets the general price curve for the future. It is dominated by utilities (who are hedging their consumption profile on the basis of general forecasts) and large-scale producers (who want to secure long-term income based on their often relatively predictable production / consumption assets). In the future, we can reasonably expect to see an increase in participation to the futures' markets derived from the deployment of long-term power purchase agreements from renewable assets. In this market volumes are matched bilaterally between producers and consumers.

DAY-AHEAD AUCTION: The next trading interaction is represented by the day-ahead auction (also known as spot). According to the fact that forecast (of both production and consumption) begins to firm up, each player must place the expected exchange profile on the grid alongside with eventual complex restrictions. The matching of traded consumption and production determines a price for each time block corresponding to the baseline price for electricity in the given time period. According to the clearing results, the same participants can then develop their trading strategies for the following markets according to their expectations on price evolution.

INTRADAY: The intraday market is targeted to be a continuous trading mechanism, aimed at giving to the participants the possibility to rebalance their position in case of deviations with respect to day-ahead profiles (in order to reduce their imbalance exposure). Intraday markets play a very important role since, as forecasted profiles are becoming more and more accurate by approaching the interested time slot, they "price" the most updated grid circumstances (i.e. wind or solar production under/overestimation, outages in conventional power plants, consumption pattern deviations, etc.). Intraday is normally arranged as bilateral market, where participants can transparently propose and see posted prices, make and accept bids, hence playing a central role in revitalizing the "market price signal". These markets open shortly after the day-ahead auction closes and trades can then be made continuously until the market closes shortly before delivery (gate closure). The latency between intraday gate closure and beginning of delivery is called "intraday lead-time" and it is a fundamental piece of the discussion, as it sets the time horizon in which no further intraday market actions are possible. In this time interval, unforeseen events and any deviation from the program (nomination) is considered an "imbalance", unless it results from an activation in the next market (ancillary service).

The figure below illustrates the deviation in intraday price metrics in Germany (lowest and highest bids, and ID3 price) against the day ahead forecast error of solar power production (one of the main sources of forecasting uncertainty in the reported period). The trends illustrate how the regions with a mostly negative forecast error (lack of solar production) yields intraday prices above day-ahead and vice versa:

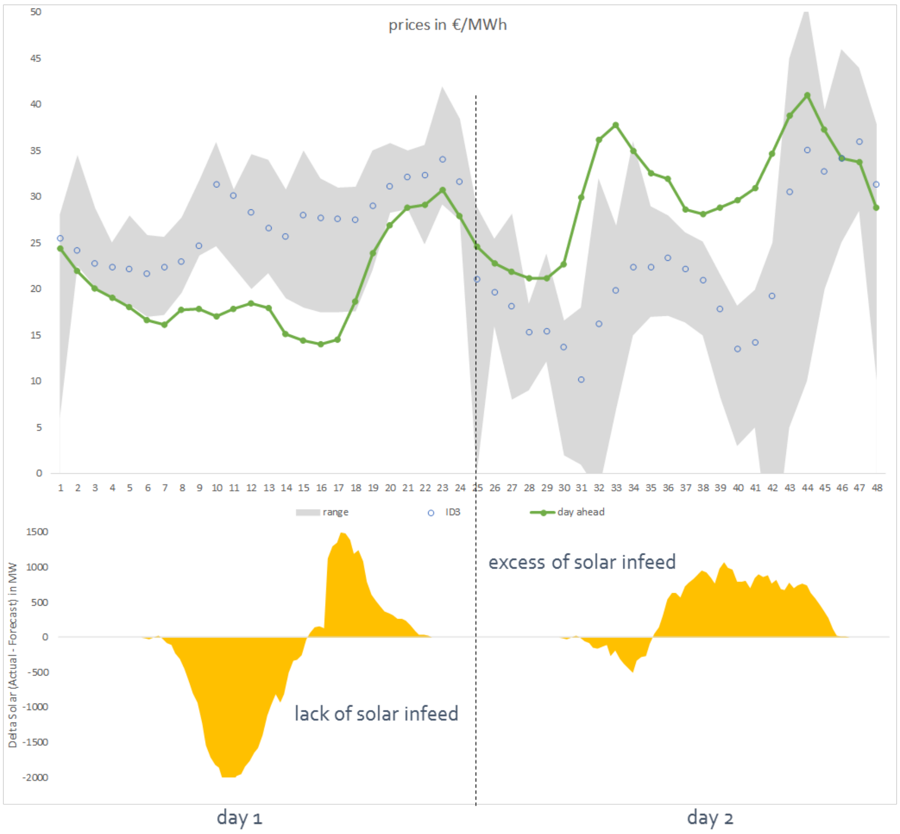

Figure 1 Illustrates the effect of changing renewables production on price development

ANCILLARY SERVICES: After the closure of the intraday market it is up to the grid to ensure a balance between production and consumption. Since a mismatch between short-term actual and forecast profiles is unavoidable, the grid operator will activate ancillary markets where the enabled resources trade their readiness to dispatch controllable flexibility to support grid operations. This extra cost (which depends on how the ancillary services market processes the resource bids) is then distributed amongst market participants proportionally to their individual imbalance.

The imbalance prices correspond to the network operation costs assigned to the mismatching between production and generation. These costs can be evaluated in different ways: one-price system (e.g. in UK, Germany), two-price system (e.g. in Scandinavia, southern Europe) or different hybrid schemes which combine the previous two options (e.g. in Belgium, Netherlands). Furthermore, other considerations should be taken into account, such as whether the imbalance price has mix/max boundaries and other measures that make more complex the final math that balancing responsible parties must consider when adopting risk-neutral strategy towards market prices.

2. SmartNet

The real-time balancing market (main focus of SmartNet simulations) aims to replace the flexibilities activated by network operators for the continuous and automatic support of the balancing services (automatic Frequency Restoration Reserve – aFRR). According to this, SmartNet simulates the processes of manual reserve activation (manual Frequency Restoration Reserve – mFRR – and Replacement Reserve – RR) which lays between the intraday and automatic reserve markets and has a direct impact on the final calculation of imbalance prices

From a flexibility perspective, each market is dependent on the others (previous and next) and its pricing signal is the results of the previous markets and expectations on the future. To illustrate this concept, the following figure shows how the imbalance resolution (Network Regulation Volume – NRV) diverges from the day-ahead solar production forecasting error. This deviation demonstrates that, within intraday market, most updated forecasting profiles has been used in order to sell/buy the expected energy mismatching.

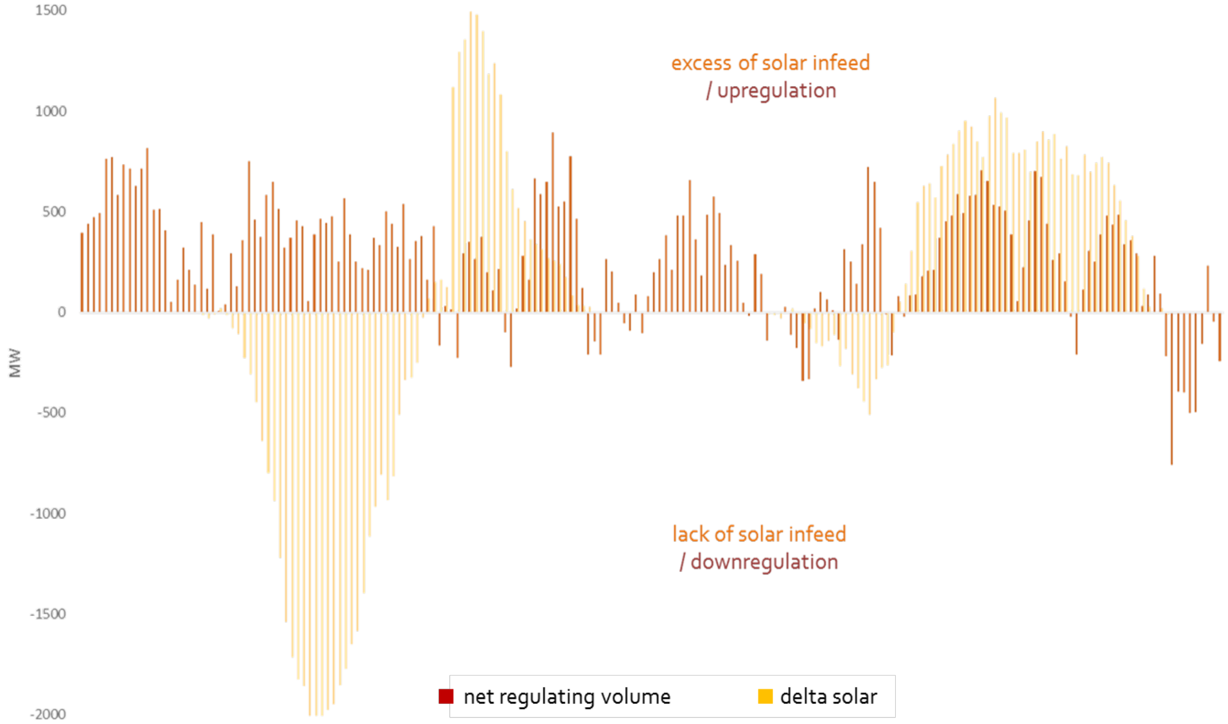

Figure 2 Actual solar infeed day-ahead forecast error (yellow) and net regulating volume (red)

So, having considered the possibility to move flexibility offers from one market to the next until delivery, bidding within the real-time balancing market is expected to have consequences on the behavior of the players in the next (intraday and future balancing) market iterations. For this reason, SmartNet Project is considering the inter-dependency between the adjacent intraday and real-time balancing markets, by processing the following two points:

1) SmartNet investigations includes forecasting error models aimed at simulating how the deviations between the actual consumption/production profiles and their prediction (used by network operators and aggregators) evolves in time. Thanks to these models, it is possible to realistically simulate the impact of the forecasting error evolution on the (intraday) market price signal.
   An exemplificative process is illustrated in the following figure, based on the situation described above. Having considered a significant lack of solar production (high forecasting error), intraday prices are expected to increase. In this case, if the price increase is significant, a rational load aggregator would bid a consumption curtailment:
   - If it is accepted, the same aggregator can offer downward regulation flexibility within the next market (real-time balancing), trying to restore its original position and making profit.

- On the contrary, if the bid is not accepted, the same aggregator still has the opportunity to offer load curtailment as flexibility within the real-time balancing market at a competitive price.

In both cases, the aggregator can also bid in the opposite direction, by taking into account the instantaneous price of energy and the consequences of consuming more or less than the intraday market commitment.

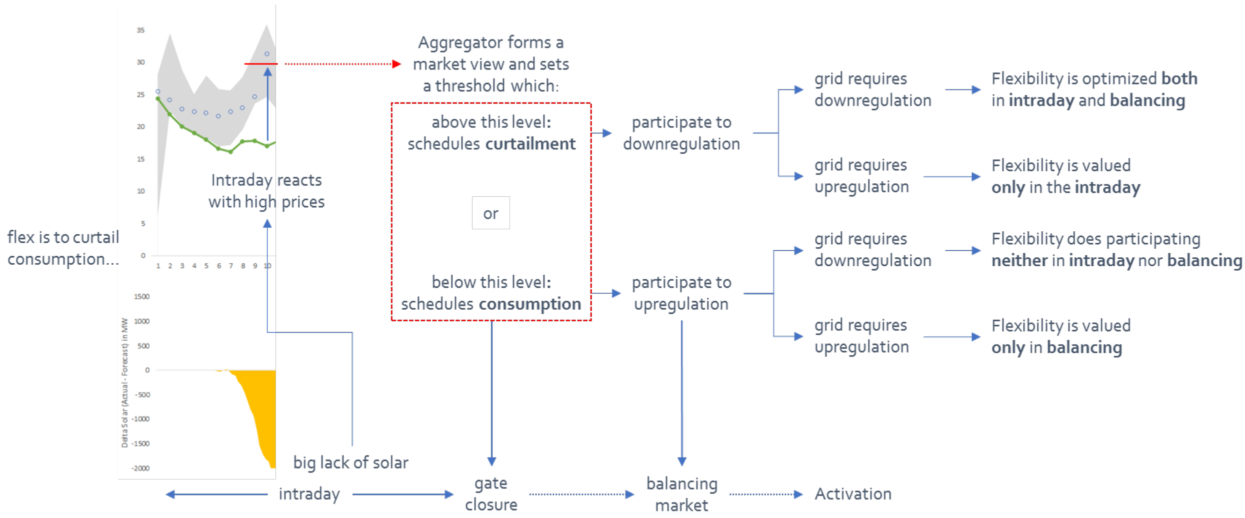

Figure 3 Illustration of how balancing services can be used to regulate the market

2) The second element for accounting the complexity of market design is the incorporation of a risk-premium parameter into the aggregator's bidding strategy. This is meant to delay flexibility activation in the real-time balancing market when, by doing so, there are further opportunities to bid the same quantity to the next and potentially more profitable markets (future intraday and future SmartNet). This is implemented through a "market discomfort" parameter which aims to account for the expectations of aggregators for better opportunities in subsequent (intraday/balancing) markets in the near future.

   The rationale behind this strategy is based on the fact that forecast errors are often correlated, and these represents the main source of regulating volume procurement by network operators. Therefore, forecast error may determine a sudden spike in intraday price and, as illustrated in Figure 1, a single delivery period normally brings higher prices in the adjacent nearby future periods.

   Some flexibilities can remain activated for long periods of time, such as load and generation curtailment. However, some others may present severe rebound effects when one activation in the present time prevents an activation in the future. In this case the aggregator (who tries to maximize the profit) must choose accurately in which market the flexibility should be offered. Therefore, aggregators are not always expected to immediately activate flexibility as soon as it is "in the money", but to dynamically optimize their portfolio on the basis of risk management strategies in which multiple market layers and multiple periods are considered.