Tool to prepare market requests

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1 Introduction

The EcoGrid 2.0 project develops demand response services provided by aggregations of small residential loads for both Transmission System Operators (TSOs) and Distribution System Operators (DSOs) and tests them on a real market platform. The project focuses on *Manual Frequency Restoration Reserves* as services, traded between Aggregators and the TSOs. The services are provided by aggregations of thermostatically controlled loads such as heat pumps and resistive heaters of residential customers. Such loads typically have a small thermal time constant, which introduces an interdependency of the individual clearing time steps on the balancing market. Current market structures are not designed to take this time coupling into account and are therefore not suited for Aggregators which control groups of residential loads. In order to allow demand response to provide grid services in the future, the market structures have to be adapted. In the context of EcoGrid 2.0 a market clearing mechanism with a receding horizon has been proposed, in order to take into account future time steps. For this purpose, forecasts of balancing quantity are needed. The purpose of this document is to describe how these forecasts are created in the Flexibility Needs Assessment Tool for the Transmission System Operator. This tool is used to create flexibility requests as defined in Business Use Case 02.

2 Current market design in Denmark

This Section describes the obligations of Balance Responsible Parties (BRPs) who participate in the market for ancillary services. The market rules are defined in [1] and [2]. Here, we will focus on the regulations in DK2.

2.1 Balancing Power

The Nord Pool Spot's Elspot closes at 12.00 and defines the trade hour by hour for the next day of operation. After the market has cleared and the BRPs are informed about the results, they send operational schedules to the TSO containing planed power consumption and generation for each hour of the following day in MW. The first schedule for the entire 24 hours has to be sent latest at 14.00 o'clock the day before the day of operation. This schedule can be updated until 1 hour before the hour of operation. The initial schedule as well as all updates have to be approved by the TSO.

During operation, BRPs have an obligation to stick to their announced schedules as much as possible. Deviations from the schedule are penalized, since they require the activation of regulating power. For production imbalances, there are two cases which are distinguished, when the price of balancing power is calculated:

- The deviation from the BRPs schedule is in the same direction of the total system deviation, further destabilizing the system. In this case, the BRP is settled with the price for regulating power.

- The deviation from the BRPs schedule is in the opposite direction of the total system deviation, stabilizing the system. In this case, the BRP is settled with Spot price.

Consumption and trading imbalances are always settled with regulating power price.

2.2 Regulating power

Manual frequency restoration reserve is a service, which is activated when a deviation from the operational schedule in the power grid is continuous. When a deviation from the operational schedule occurs, first frequency containment reserves, namely frequency controlled normal operation reserve (FNR) and frequency controlled disturbance reserves (FDR) are activated to stop the frequency drop or increase. If the deviation persists, frequency restoration reserves (FRR) are activated to bring the grid frequency back into the operating range. Then the units providing FNR and FDR can be released and are free for other potential deviations.

Both upward and downward regulation are traded hour by hour. Only BRPs are allowed to participate in the market. The capacity market makes sure, that enough bids are available at all times. BRPs which sold capacity to the TSO are obliged to send bids and have to do this not later than 17.00 o'clock before the day of operation. Bids can then be updated until 45 Minutes before the upcoming delivery hour. The minimal bid size at the moment is 10 MW, the maximum is 50 MW.

During operation, Energinet.dk activates bids in the order of cheapest to most expensive. Prices for Down regulation are smaller than Spot-Market prices, since the TSO is selling energy. Through

Up-regulation the TSO is buying energy, hence the prices are higher than the Spot-price. Bids are activated by sending updated schedules to all the market participants. The TSO sends these schedules every 5 minutes. This two price system is illustrated by Fig. 1. The upper graph shows the hourly price for manual reserves. The lower graph shows the quantity of activated bids in DK2. When the power markets in Scandinavia are coupled, balancing costs can occur even though no bids in Denmark have been activated.

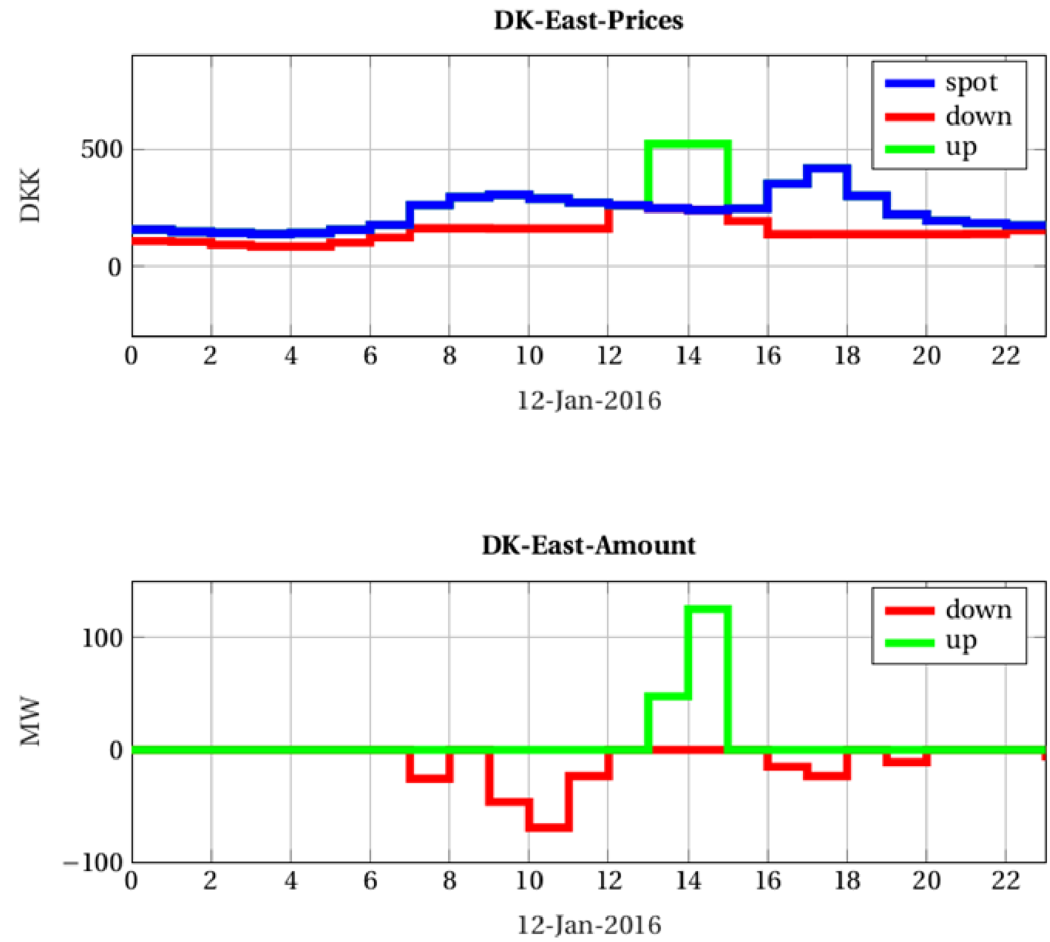

Figure 1: Resulting prices for up and down regulation together with the Spot-price for the 12th of January, 2016.

3 Market design of WP 2

As described in Section 2, the sequence in which bids are activated during operation is currently mainly determined through the bid price. Although this procedure is simple and intuitive, it is suited for a market with conventional power plants only. Asymmetric blocks can be used to represent market bids of thermostatically controlled loads [3]. When allowing asymmetric block offers in the balancing market, it is not intuitively clear which bids are the most viable ones. Depending on the direction of the expected balancing power, the rebound effect of demand response bids could be either advantageous or harmful for the overall system. Demand response bids might be offered at a very low price, due to the low marginal costs, but rebound effects can induce costs for the TSO at later times.

The EcoGrid 2.0 Market design, proposed in [4] defines a single market clearing algorithm for providers of up- and down-regulation for both classical players operating conventional units and new players offering products based on demand response using asymmetric block bids. Given the bids of all participants and an expected system power imbalance forecast for the next couple of time steps, the algorithm minimizes the overall system balancing cost and defines the units, which should be activated during the next time step. Implemented as a receding horizon method with a 15-minute time-resolution, this market-clearing algorithm can replace the current activation decision method. Fig. 2 illustrates this setup.

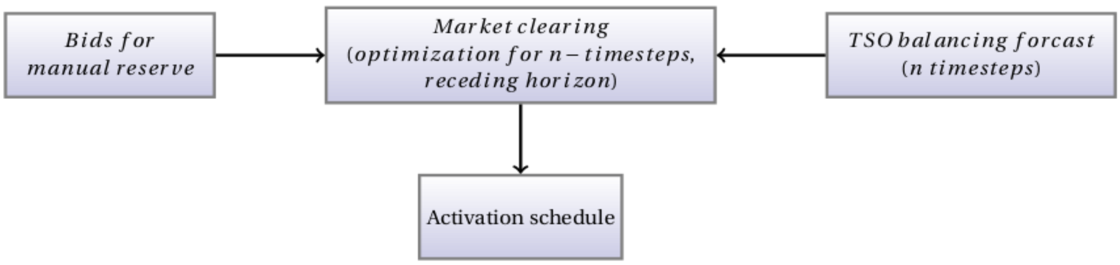

Figure 2: Visualization of market inputs

4 Flexibility Needs Assessment Tool

In this Section, the Flexibility Needs Assessment Tool is described, which replaces a real TSO in the EcoGrid 2.0 project. In order for the market mechanism from WP 2 to work, a Balancing Need Forecast is required on a 15-min basis. To generate such a forecast, data of the hourly acquired balancing volume (in MW) for year 2016 has been used which was downloaded from the Energinet.dk website.

4.1 Markov Matrix

The maximal and minimal balancing power required by the system in 2016 was 522 MW and -271MW respectively. To generate reference profiles with a 15-min resolution, we split this interval into 100 bins, defining the different "states" of the system and calculate the corresponding Markov matrix. The entry m_ij of the Markov matrix contains the probability for the system to switch from state i to state j. These probabilities were calculated based on the data from Energinet.dk. This matrix has then been used to create two random 15 min balancing power profiles, which are used as lookup tables for the time period between 2017 and 2020.

4.2 Forecasts

The first profile is considered to model the true TSO balancing power need, for which a forecast has to be created. Forecasts are created for the next 2 hours with a resolution of 15 min. Each forecast is created as the sum of the two generated profiles from Section 4.1.

Forecasts are expected to be accurate in the near future, while being less precise for later time instances. To model this behaviour, the forecast is created as a linear combination of the two created reference profiles, where the share of the "real" balancing power demand gradually decreases from 100% for the current time step (basically modelling, that the TSO has full knowledge of how much balancing power is required at the moment) to 20¬% 2 hours later. The share of the "forecast error" linearly increases from 0% to 80% for the same time horizon.

In addition to this linear composition of reference profiles, a normally distributed error (20 % stddev, 0 mean) is added to the forecast.

Figure 3 and 4 show an example of created balancing forecasts for the 1st of July 2017. Figure 4 shows the forecast created at 7.30 o'clock in the morning. Since at that point, the imbalance between 9 and 9.30 still lies rather far in the future, it cannot be forecasted well.

Figure 4 shows the forecast created at 8.45 o'clock. Now the imbalance occurring between 9 and 9.30 can be forecasted much better.

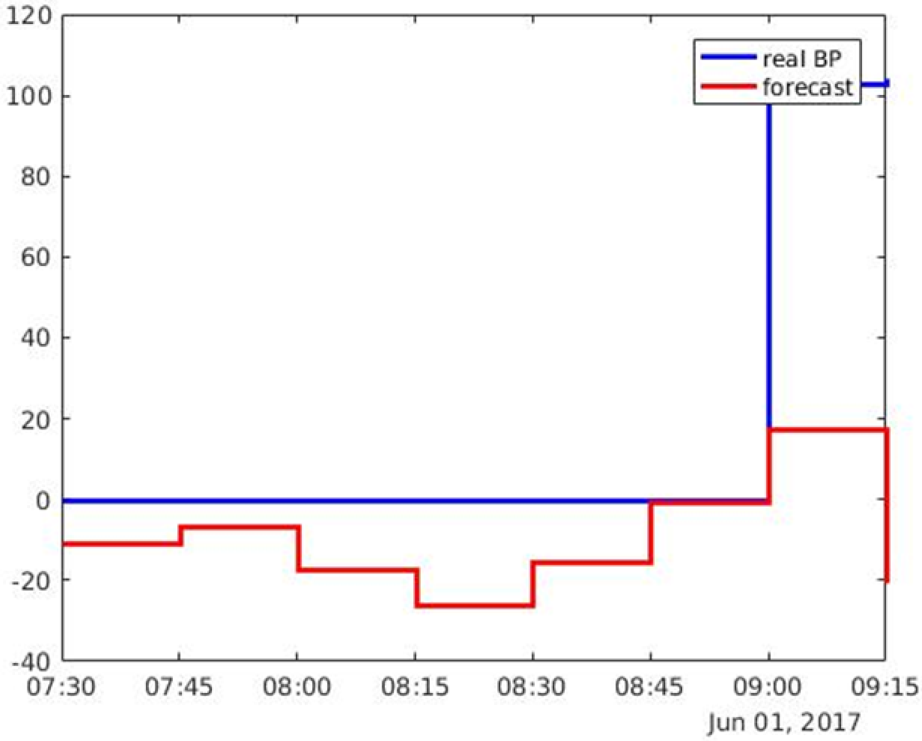

Figure 3: Balancing power forecast created at 7:30 (red) in comparison to the modelled real balancing need.

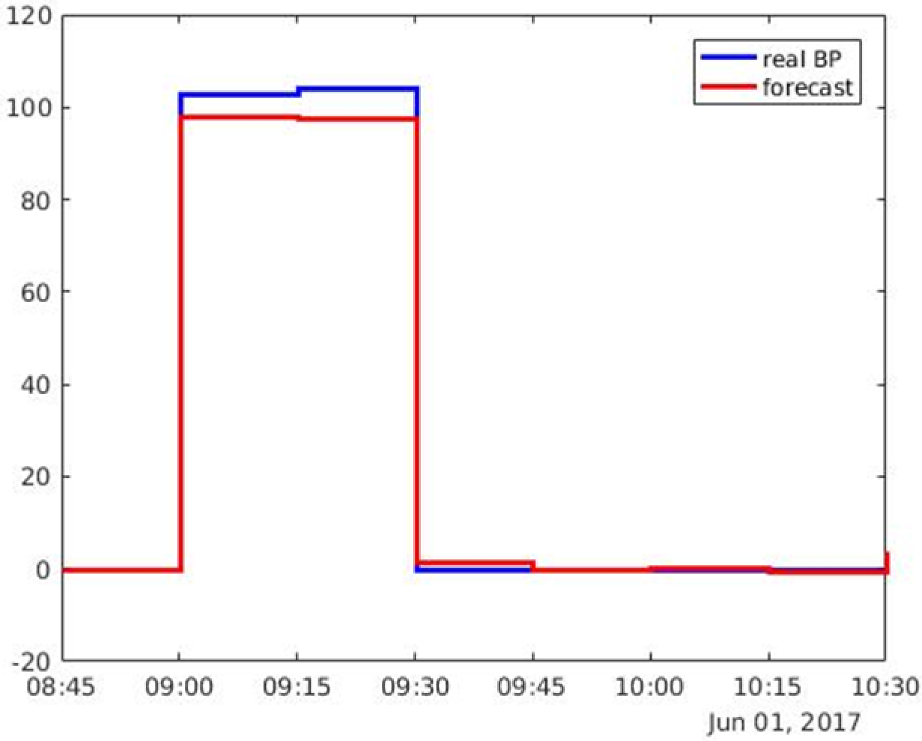

Figure 4: Balancing power forecast created at 8:45(red) in comparison to the modeled real balancing need.

5 Code

The balancing need forecasting tool has been formulated in Matlab code. The core of the tool is the bal_forecast function. This function calls the "create_markov_matrix.m" file and loads the historic balancing power data "data.mat".

The input of the function is an hour of the day in datetime-format between the 30th of May 2017 and the 29th of May 2020.

The output of the function are 3 things:

1. the vector "real" containing the actually required balancing power for the next 6 hours on a 15-min basis.

2. the vector "y" containing the balancing need forecast for the next 2 hours on a 15-min basis.

3. the vector "t", containing the timestamps for the next 2 hours in 15 min steps.

6 Next Steps

The approach that was chosen for this deliverable is a “mock-up”, which does not take into account, how a TSO would proceed to create an imbalance forecast. Hence, as a next step, the question, how accurately a TSO can forecast imbalances, must be answered. Rebound- effects are predictable, as well as structural imbalances, which occur due to the temporal resolution of markets. Other imbalances, which are due to unexpected behaviour of market players should be very hard to predict. If the TSO is not able to predict balancing needs reasonably, a stochastic optimization procedure for the market clearing mechanism might have to be introduced.

References

[1] Energinet.dk. Ancillary services to be delivered in Denmark Tender conditions. 2012.

[2] Energinet.dk. Regulation C2: The Balancing Market and Balance settlement. 2008.

[3] O'Connell, Niamh, et al. "Economic dispatch of demand response balancing through asymmetric block offers." IEEE Transactions on Power Systems 31.4 (2016): 2999-3007.

[4] Stefanos Delikaraoglou, Jalal Kazempour, Pierre Pinson. EcoGrid 2.0 Market Formulation. 2017.

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