Institute of Energy Systems and Electrical Drives, Energy Economics Group (EEG)

Quantitative Analysis of Renewable Energy Aggregator Business Models

Motivation

The **BestRES** project (`https://bestres.eu`) investigates current barriers for Energy Aggregators and aims to improve their role in future electricity market designs. In the first stage, the project is focusing on existing European aggregator business models taking into account technical, economic, environmental and social benefits. In the second stage, **improved business models** are developed considering different market designs in various European countries with a focus on competitiveness. These improved business models are then implemented or virtually implemented with real data and monitored in the following target countries: **United Kingdom**, **Belgium**, **Germany**, **France**, **Austria**, **Italy**, **Cyprus**, **Spain** and **Portugal**.

Before the real life implementation, the improved business models have to be analyzed quantitatively in terms of economic efficiency. In total, thirteen improved business models for renewable energy aggregators have been developed, which differ significantly in terms of **addressed customer segments**, **considered technologies**, **targeted market places** and **existing market structure**. For this purpose, a simulation and optimization framework is required that allows to flexibly construct different models to quantify the operation of various renewable energy aggregators in European countries. This methodological framework is briefly introduced and its functionality is illustrated with an example.

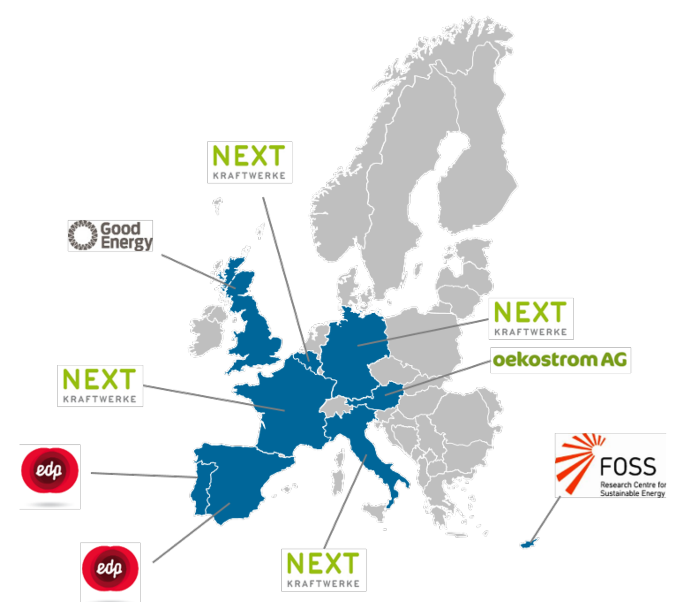

Figure 1: Countries represented by Renewable Energy Aggregators in the BestRES consortium.

Methods

The framework is implemented as a package library in the **Julia** programming language (`https://julialang.org`). It provides a convenient, flexible and modular way to simulate the operation of renewable energy aggregators on different markets, including **reserve** or **balancing**, **day-ahead** and **intraday** markets.

An overview of the general model structure is illustrated in Figure 2. In total an entire year of market operation is simulated with a quarter-hourly time resolution. At market auction times, schedules for the following week or day are submitted. The optimization models for reserve and day-ahead market scheduling are implemented as **mixed-integer linear programming** (MILP) models.Finally, at each time step, reserve market activations are simulated based on the chosen bidding strategy, the market product's merit-order curve and historical activation data.

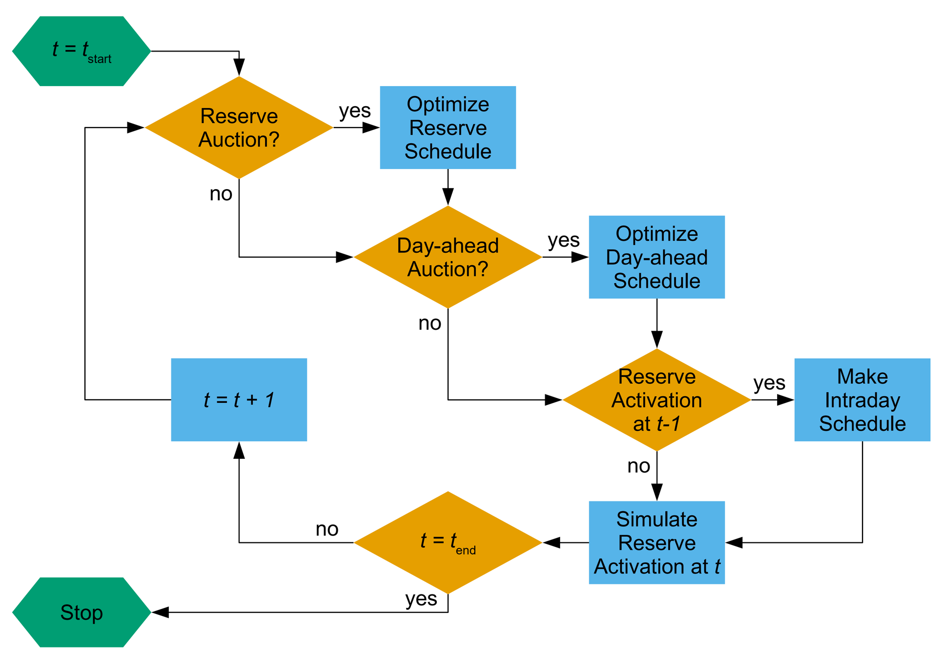

Figure 2: Overview of the model structure

Model Capabilities

- Manifold aggregator portfolios consisting of:
  - Flexible producers
  - Intermittent renewable energy sources
  - Energy storage devices
  - Flexible loads
- Various market places:
  - Pay-as-bid reserve markets
  - Day-ahead spot market
  - Intraday market
- Simulate and evaluate different bidding strategies
- Consider forecast errors

Example

Table 1: Test Portfolio

Type	Nominal Capacity	Other Information
Flexible Producer	2 MW	Piecewise-linear efficiency curve given by the relative output $x = (0, 1/3, 2/3, 1)$ and corresponding efficiencies $\eta = (0.6, 0.67, 0.7, 0.65)$
Flexible Producer	1 MW	$\eta = 0.65$
Battery	2 MW, 2 MWh	$\eta = 0.9$
Battery	4 MW, 10 MWh	$\eta = 0.85$
Shift-able load	1 MW	Up to 3 shifts for at most 2 hours per day during peak hours with a maximum load change of 2 MW
Intermittent RES	1 MW	Curtailable

To illustrate the functionality of the presented framework we will compare the operation of an aggregator with **different** reserve market **product lengths**. In the baseline scenario historical data for secondary reserve bids and activations in Germany from the year 2016 is used. To simulate four-hour products the historic energy bid data of the corresponding weekly product is used.

Table 2: Annual profit on different markets

	Weekly	Four hours	Difference
	[kEUR]	[kEUR]	[%]
Negative Reserve	7.5	−4.5	−160.7
Positive Reserve	1511.5	1322.2	−12.5
Day-ahead	165.9	198.5	+19.7
Intraday	−384.8	−207.1	+46.2
Total	1300.1	1309.1	+0.7

The respective power bid data is scaled according to the product length. Furthermore, historical day-ahead price data from EPEX and average intraday prices are used. The portfolio of the test aggregator is listed in Table 1.

The operation of the aggregator's portfolio during two days is illustrated in Figure 3 for weekly reserve products and in Figure 4 for four-hour products. It can be seen that shorter product lengths allow for more flexibility with respect to reserve market bid sizes and spot market operation. The annual profit of the portfolio per market is listed in Table 2. It shows that the aggregator would achieve more profit on the spot market, but less on reserve markets with four-hour products. In total, shorter product lengths yield a slight increase in annual profit.

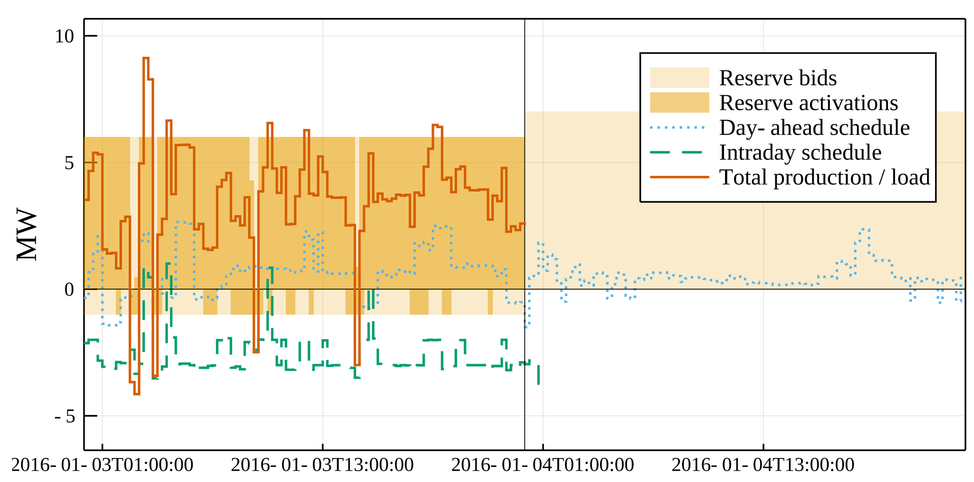

Figure 3: Operation with weekly reserve market products

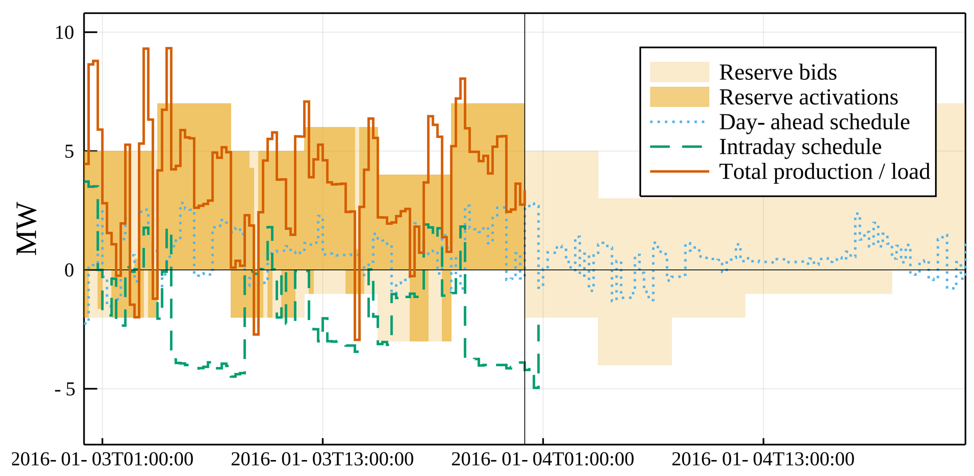

Figure 4: Operation with four-hour reserve market products

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Daniel Schwabeneder
Energy Economic Group (EEG)
Gußhausstraße 25-29 / E370-3
1040 Wien
schwabeneder@eeg.tuwien.ac.at
www.eeg.tuwien.ac.at

Andreas Fleischhacker, Georg Lettner
Energy Economic Group (EEG)
Gußhausstraße 25-29 / E370-3
1040 Wien
{fleischhacker, lettner}@eeg.tuwien.ac.at
www.eeg.tuwien.ac.at