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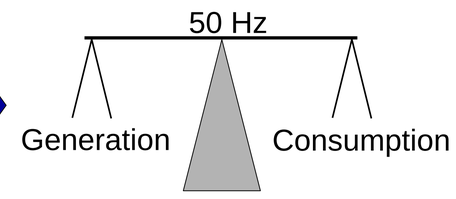
# Business models for battery storages

= ? **Operation possibilities**

**Frequency control market**




**Electricity exchange on EEX**

EEX EUROPEAN ENERGY EXCHANGE

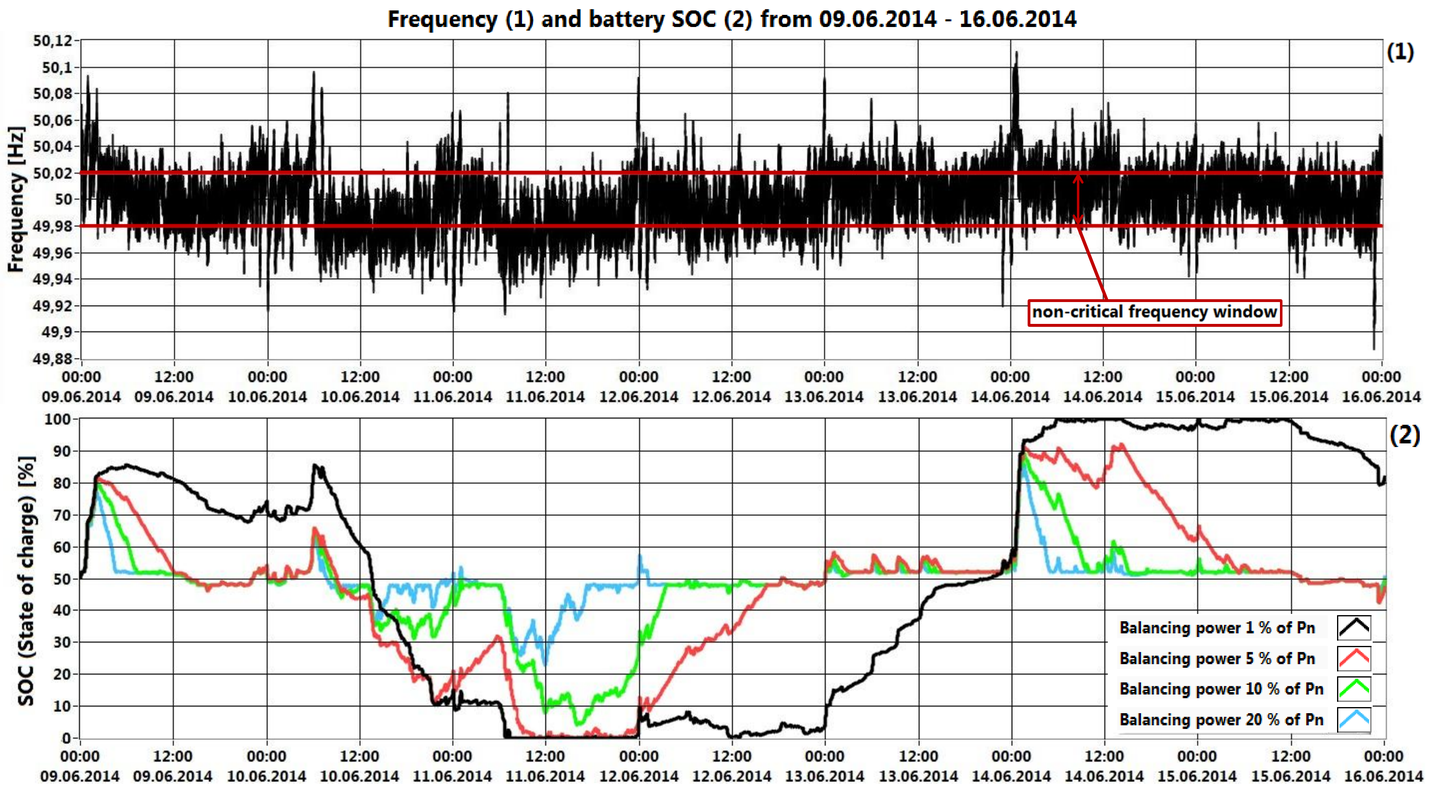
## Primary frequency control market

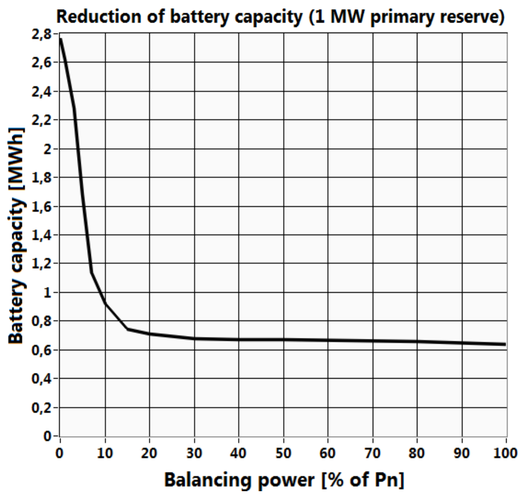
### Algorithm

- Based on frequency measurements
- Battery is charged when **f > 50,02 Hz**
- Battery is discharged when **f < 49,98 Hz**

### Non-critical frequency window

- **± 20 mHz**
- Continuous use of balancing power to idle battery on **50 % SOC**
- Different balancing power leads to changed load conditions




### Providing service contravention

- Alternative power flow options needed (e.g. **pooling**)

### Capacity reduction

- The higher balancing power chosen, the smaller battery capacity can stay

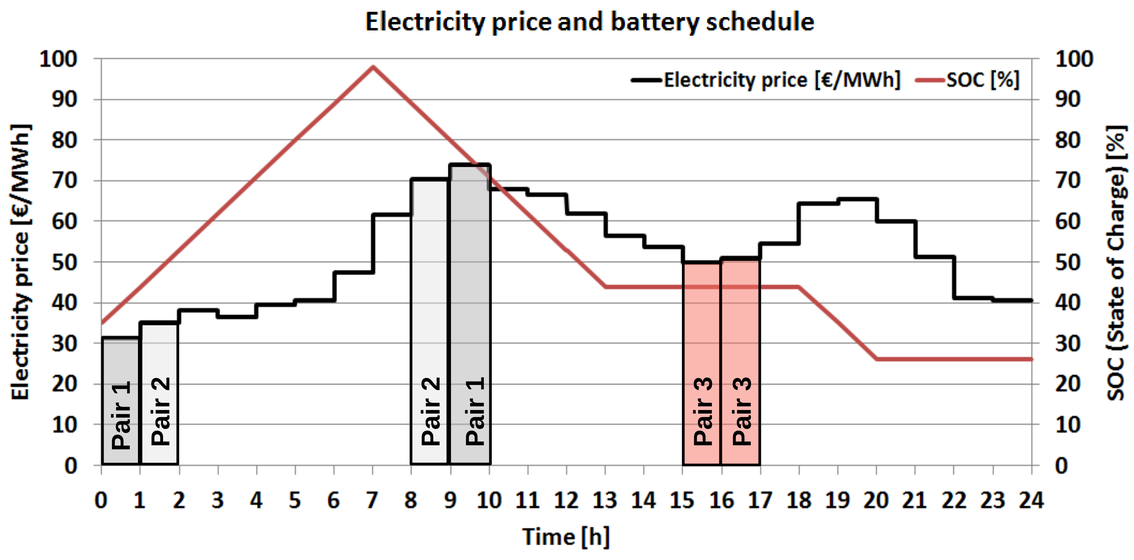
### Economics

- Selling **±1 MW** of primary reserve
  - **Revenue: ~ 150.000 €/a**
  - **Costs: ~ 70.000 €/a**

## Trading of electricity on European Electricity Exchange (EEX)

### Electricity exchange on EEX

- Electricity prices between **-84,88 €/MWh** and **163,44 €/MWh** for 2013
- Reasonable prices during the **night** and at the **weekend**
  - Battery is charged on low electricity costs
  - Battery is discharged on high electricity costs




➡ $\text{Revenue Pair 1} = C_{Sell} - C_{Buy} = 73{,}94 \frac{€}{MWh} - 31{,}25 \frac{€}{MWh} = 42{,}69 \frac{€}{MWh}$

### Algorithm

- Prices are sorted ascending and descending for different **intervals**
- **Price pairs** are formed (cheapest to the most expensive):
  - ➡ **as long as:** $\frac{C_{Buy}}{\eta_{charge}} \leq C_{Sell} * \eta_{discharge}$ (compare Pair 3)
- Electricity prices are associated with the real schedule
- Longer interval length: + **Higher** profit
  - **Larger** capacity




### Economics

- Interval: 24 h
  - **Revenue: ~ 540.000 €/a**
  - **Costs: ~ 620.000 €/a**

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