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posytyf

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POSYTYF WP5

Optimal DVPP operation in energy and ancillary service markets

WP5 – Objectives

Title: **Optimal operation and configuration of DVPP under uncertainty of non-dispatchable RESs**

- Other WPs look at the DVPP from the dynamic, control and/or stability points of view for the development of solutions to improve its dynamic performance.

- We look at the problem from a *business* perspective.

  - How can we maximize the DVPP economic benefits when trading energy in the different *mid-term* electricity markets?

  - If a fast and reliable coordination among DVPP assets can be achieved by other WPs, can we also benefit from participating in ancillary service markets?

  - Can we anticipate to the many uncertainties that characterize the problem? If not, can we *adapt* to them quickly (*"real-time")* while minimizing the cost?

  - …

WP5 – Objectives

- **How can we maximize the DVPP economic benefits when trading energy in the different mid-term electricity markets?**

  - Despite their relatively **low operational costs**, nondispatchable renewable sources show **limited competitiveness** against conventional power plants due to their **stochastic sources**, and relatively **small size**

  - Each country has particular **regulations** that characterize its electricity **market structure**
    - **Sequence** of market trading floors
    - **Requirements** for market participants
    - **Penalties** if not compliance with schedule
    - …

WP5 – Objectives

- **How can we maximize the DVPP economic benefits when trading energy in the different mid-term electricity markets?**

  - For small DVPPs, a **price-taker approach** can be used
  - **Larger** DVPPs → Larger benefits, but also higher **impact on the market price**
  - If DVPP is *too* large → a **price-maker** approach should be used
  - To avoid market power, regulators **limit the size of market** participants with aggregated units
  - Last (but not least!), we can't forget about **uncertainties**

WP5 – Objectives

- **If a fast and reliable coordination among DVPP assets can be achieved by other WPs, can we also benefit from participating in ancillary service markets?**

- **Can we anticipate to the many uncertainties that characterize the problem? If not, can we adapt to them quickly ("real-time") while minimizing the cost?**

  - Need to look at **shorter time frames** than in the previous problem

  - The DVPP needs to respond to:

    - **Changes in** power **setpoints** imposed by system operator (at 4-seconds intervals in Spain)

    - **Contingencies** (e.g., unit outages)

    - **Forecast errors**

WP5 – Objectives

- **Two main lines of research are being studied in this WP:**

Optimal electricity market participation of DVPPs under uncertainty for maximum profit

Optimal operation of DVPPs in real-time at minimum cost

Optimal electricity market participation of DVPPs under uncertainty for maximum profit

Spanish Energy Market Structure:

- The sequence of markets
- Different time period
- Different payment for each market
- The objective of each market
- Interactions between different markets

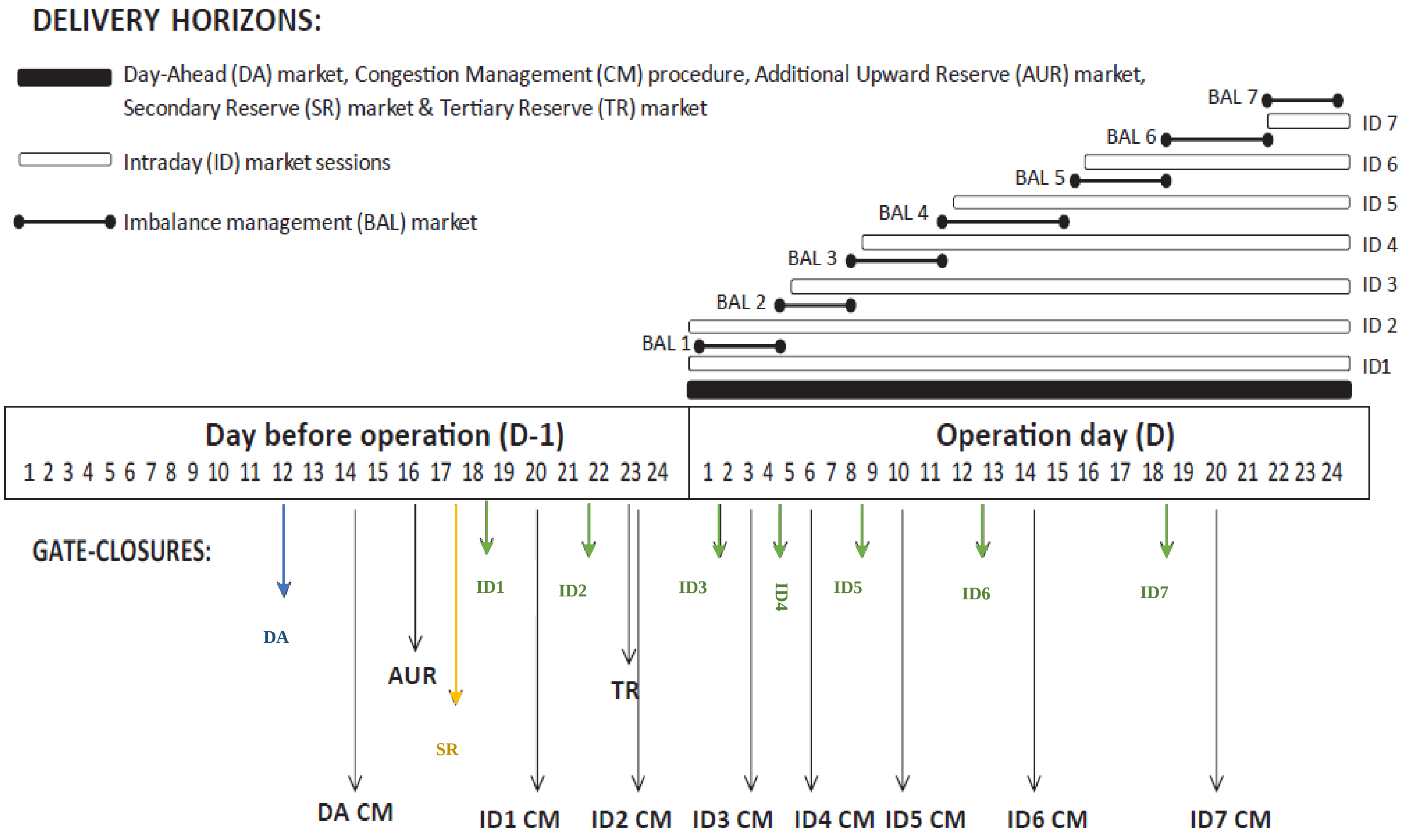


Fig. 1. Delivery horizons and gate-closures of the Spanish short-term electricity markets.

Price taker DVPP objective in the Day-Ahead (DAM), Secondary reserve (SRM), and Intra-Day (IDM) Markets:

- ## 1.1 DAM:

Known Data: -

Optimize DA power + up/down SR

Bid DA power

$$M\text{ax}\begin{bmatrix} DAM\ \ benefit + SRM\ \ up/down\ benefit \\ -DRES\ \ cost - NRES\ \ cost - ESS\ \ cost - Load\ \ cost \end{bmatrix}$$

- ## 1.2 SRM:

Known Data: DA power bid

Optimize up/down SR + ID1 power

Bid up/down SR

$$M\text{ax}\begin{bmatrix} SRM\ \ up/down\ benefit + IDM1\ benefit \\ -Changes\ in:\ DRES\ \ cost, NRES\ \ cost, ESS\ \ cost \end{bmatrix}$$

- ## 1.3 IDMs:

Known Data: DA power + up/down SR + previous IDs power

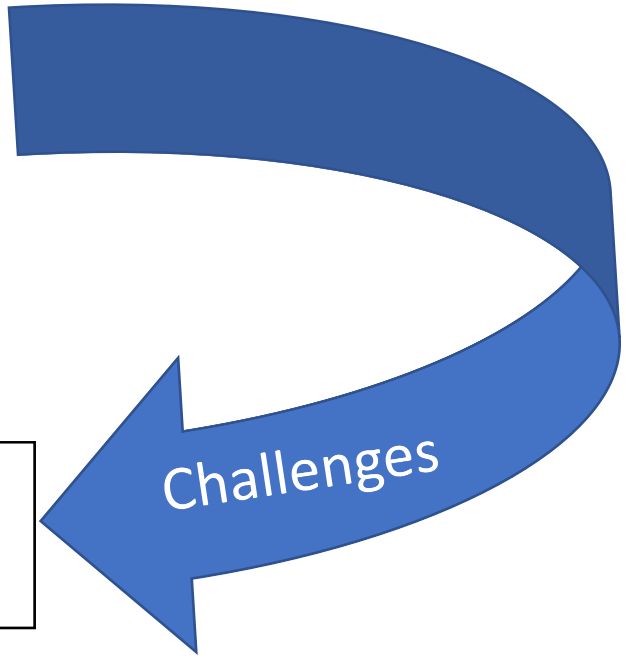
Optimize each Ids power

Bid each IDs power

$$M\text{ax}\begin{bmatrix} IDMs\ benefit \\ -Changes\ in:\ DRES\ \ cost + NRES\ \ cost + ESS\ \ cost \end{bmatrix}$$

Constraints of DAM, SRM, and IDMs:

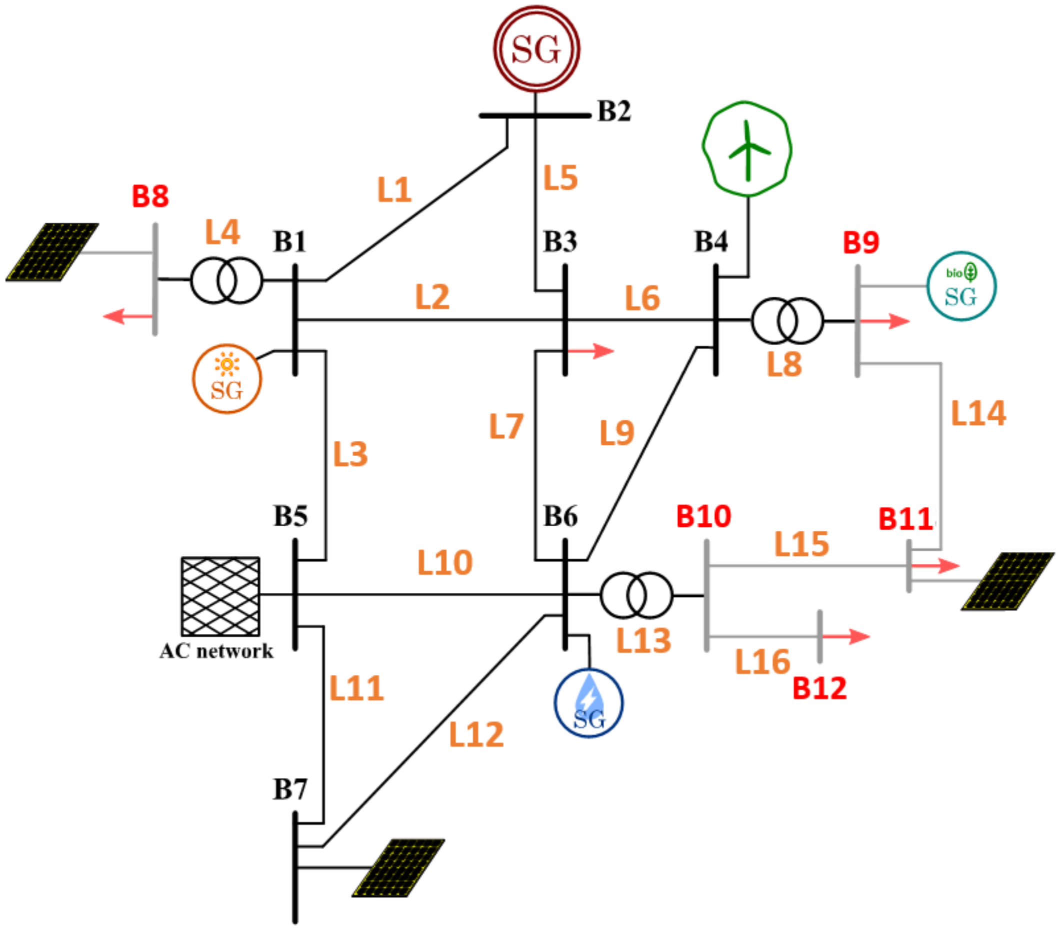
- Energy Balance Constraints
- Dispatchable RES Constraints (Hydro, Biomass)
- Non-dispatchable RES Constraints (Wind, solar PV)
- Solar-Thermal Power (CSP) Constraints
- Flexible Demand Constraints
- Energy Storage Systems Constraints (Pumped-hydro, CSP storage)
- Battery Energy Storage (BES) Constraints



- Feasible operation of assets when it comes to power delivery
- Confining penalties (specially for SRM)

Test Case

- **Test case: South Spain region**



VPP ASSETS

- **Hydro Power plant** (110 MW) – Bus 6
- **Biomass** (5 MW) – Bus 9
- **Wind Power Plant** (50 MW) – Bus 4
- **Solar PV** (50 MW) – Bus 8
- **Solar Thermal Plant with Storage** (50 MW) – Bus 1
- **Industrial load** (55 MW peak) – Bus 3
- **Airport load** (69 MW peak) – Bus 12
- **Residential load** (50 MW peak) – Bus 9

3 profiles for each load
24 time periods

Comparison between Case 1 and Case 2

- **VPP Participating in Energy Markets in the Spanish System**

Clear Day										
Market		DAM	IDM1	IDM2	IDM3	IDM4	IDM5	IDM6	IDM7	TOTAL
Profits	Base Case – No Coord.	65,713	4,058	-	-	-	-	-	-	69,771
	DVPP	68,128	5,416	92	0	8	0	0	0	73,644

Cloudy Day										
Market		DAM	IDM1	IDM2	IDM3	IDM4	IDM5	IDM6	IDM7	TOTAL
Profits	Base Case – No Coord.	28,295	3,227	-	-	-	-	-	-	31,522
	DVPP	33,013	4,714	28	398	699	446	157	0	39,455

Future Steps and Possible Questions

- **Future Steps:**
  - Investigating other Ancillary markets, such as **Tertiary reserve market**
  - **Uncertainties** in Energy and Ancillary Service Markets Participation → **Robust Optimization**
  - Comparison with **BES** Solutions
  - DVPP as **Price Maker**
  - Studying DVPP from a **system level perspective**

- **Possible questions:**
  - How big DVPP could be to not disrupt the market?
  - Other networks with different characteristics

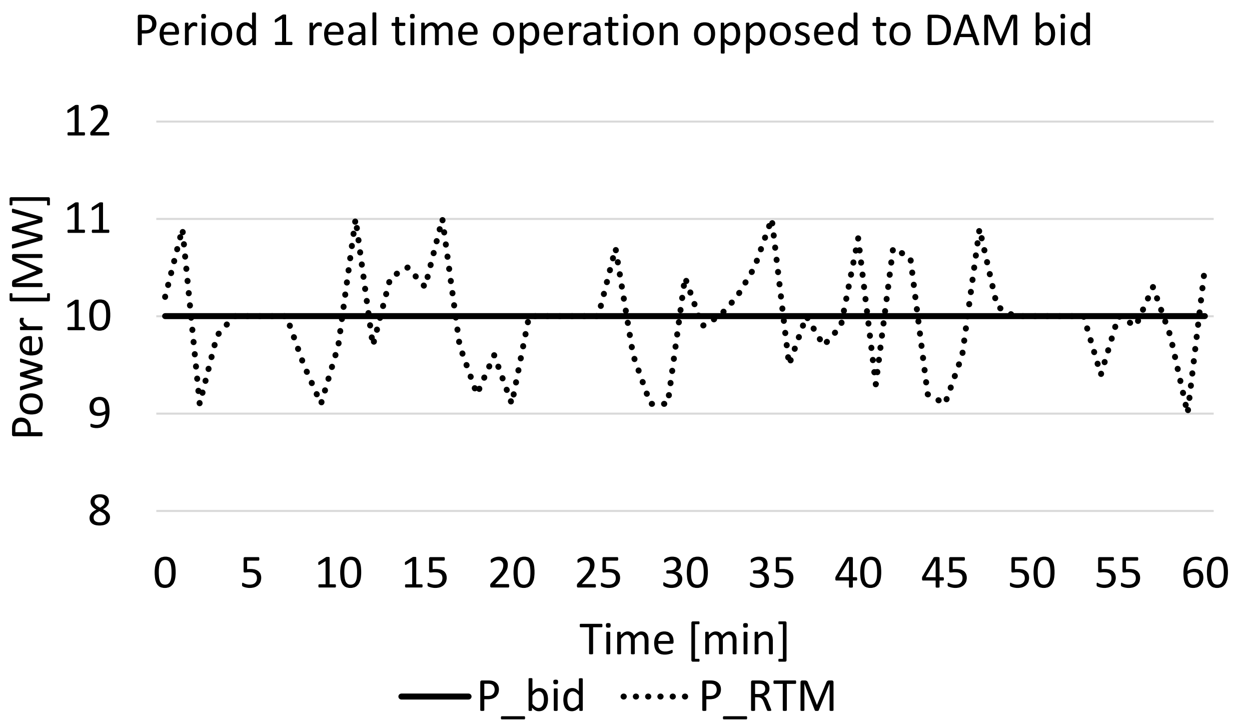
Optimal operation of DVPPs in real-time at minimum cost

WP5 – Real Time Optimal Operation

- **What is our perspective of real time operation?**

Objectives:

- Coordinate VPP assets.
- Minimize deviation from DAM/IDM bids; avoid TSO penalties from failure to meet offers/bids.
- Follow TSO set points



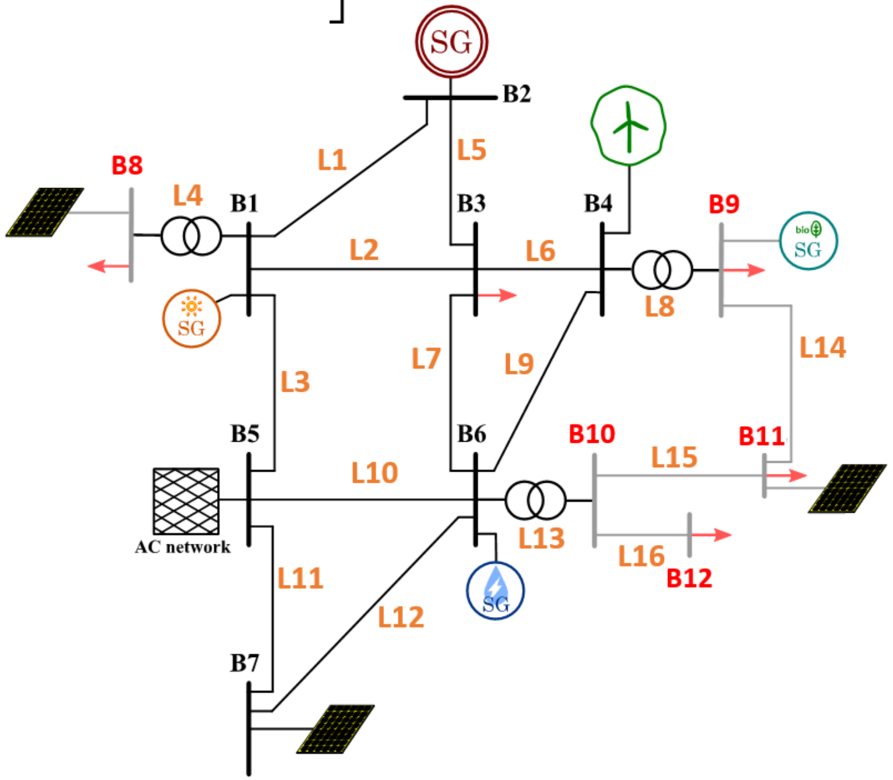
WP5 – Model formulation of Real-Time Redispatch

- **Formulation of the real time optimization redispatch model:**

$$\min_{\Xi^{RT}} \sum_{\text{time}} \left[\sum_{\text{VPP units}} \left(C_{\text{Regulation}} \times p_{\text{regulation}} \right) + \sum_{\text{buses}} \left(C_{\text{penalty}} \times p_{\text{unmet}} \right) \right]$$

S.T. :

- Power Balance Constraints
- Bounds on reserve provision
- Assets Technical Constraints
- Power flow constraints (DC/AC power flow) *



WP5 – Model formulation of Real-Time Redispatch

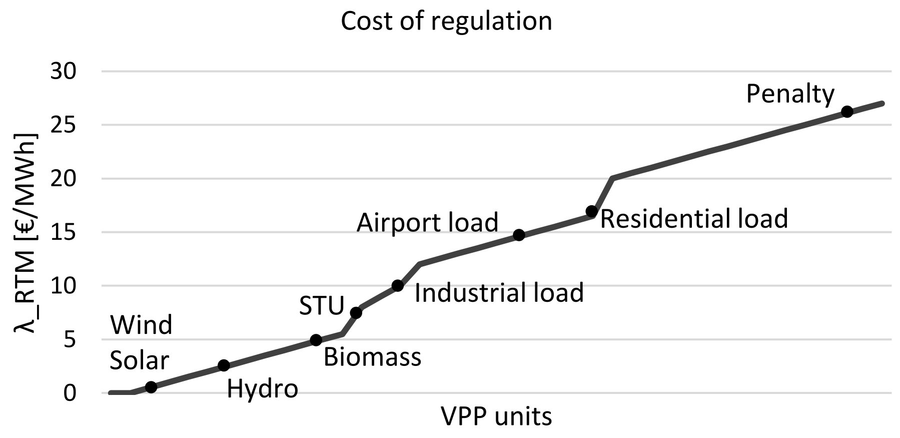
- **Constraints:**
  a) Real Time Balancing Settlement
  b) Secondary Control Command

$$\sum_{\text{VPP units}} p_{\text{units}} - \sum_{\text{lines}} p_{\text{line flows}} + p_{\text{unmet}} = P_{\text{DAM offer}} + p_{\text{regulation at bus}} \,, \qquad \forall \text{ buses}$$

$$\sum_{\text{buses}} p_{\text{regulation at bus}} = P^{TSO}_{\text{Secondary control command}} \,, \qquad \forall \text{ time}$$

WP5 – Priority of Assets for Real Time Redispatch

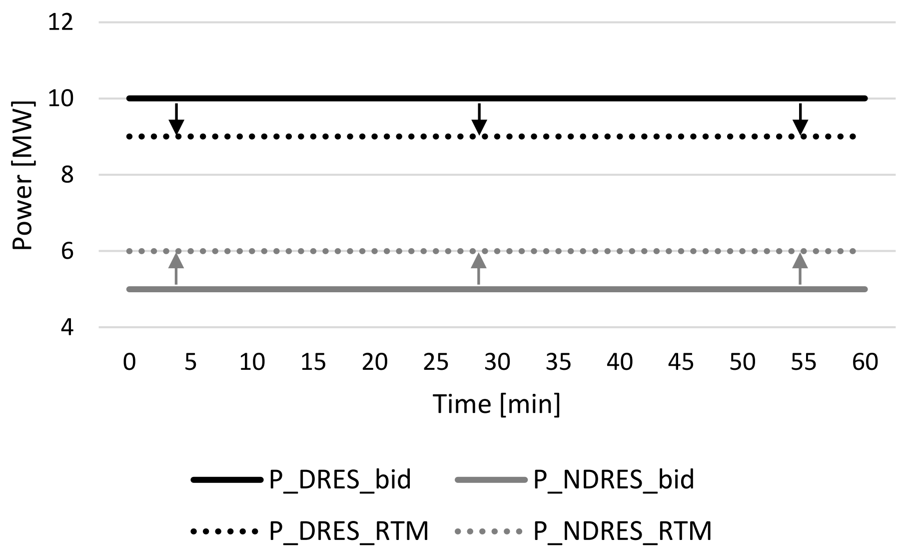
- **How do we select appropriate costs on this regulation cost curve?**



References:

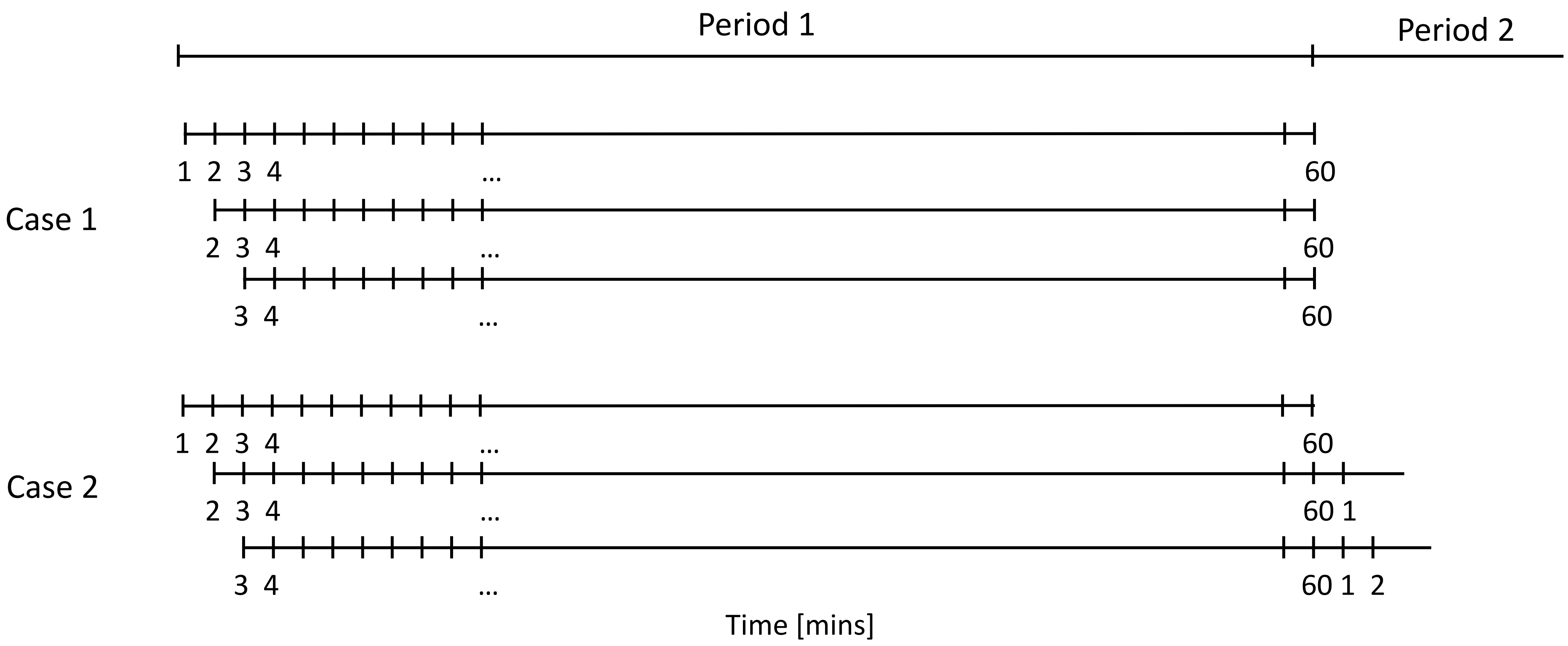
- Raab, Andreas Franz Alois. "Operational planning, modeling and control of virtual power plants with electric vehicles." Technische Universitaet Berlin (Germany), 2018.
- You, Shi. "Developing virtual power plant for optimized distributed energy resources operation and integration." Technical University of Denmark (2010).

- **How do we model real time redispatch optimization to make profits during redispatch?**



WP5 – Receeding Timeline during Redispatch

- **Can we appropriately model real time redispatch optimization with a receding timeline?**



WP5 – Objective Reformulation

$$\min_{\Xi^{\mathrm{RT}}} \sum_{\text{time}} \left[\sum_{\text{VPP units}} \left(C_{\text{Regulation}} \times p_{\text{regulation}} \right) + \sum_{\text{buses}} \left(C_{\text{penalty}} \times p_{\text{unmet}} \right) \right]$$

- **New objective function that seeks to answer some of these questions:**
  - Introduce operation costs used in submitting DAM/IDM offers (this ensures that there is no total reschedule based on regulation cost alone)
  - Retain regulation costs for choosing preference of which units provide regulation first
  - Introduce a cost that avoids simultaneous provision of up & down regulation at the same period

$$\min_{\Xi^{\mathrm{RT}}} \sum_{\text{time}} \left[\sum_{\text{VPP units}} \Big((C_{\text{DAM offer}} \times p_{\text{units}}) + (C_{\text{Regulation}} \times p_{\text{regulation}}) + (\lambda \times p_{\text{regulation}}) \Big) + \sum_{\text{buses}} \left(C_{\text{penalty}} \times p_{\text{unmet}} \right) \right]$$

WP5 – Concluding Remarks

- **Two conference papers have resulted so far.**

1. O. Oladimeji, et. al., "Optimal Participation of Heterogeneous, RES-based Virtual Power Plants in Energy Markets", submitted to the 2022 *Power System Computation Conference (PSCC 2022)*

2. O. Oladimeji, et. al., "Modeling Demand Flexibility of RES-based Virtual Power Plants", to be submitted to the 2022 *IEEE PES General Meeting.*