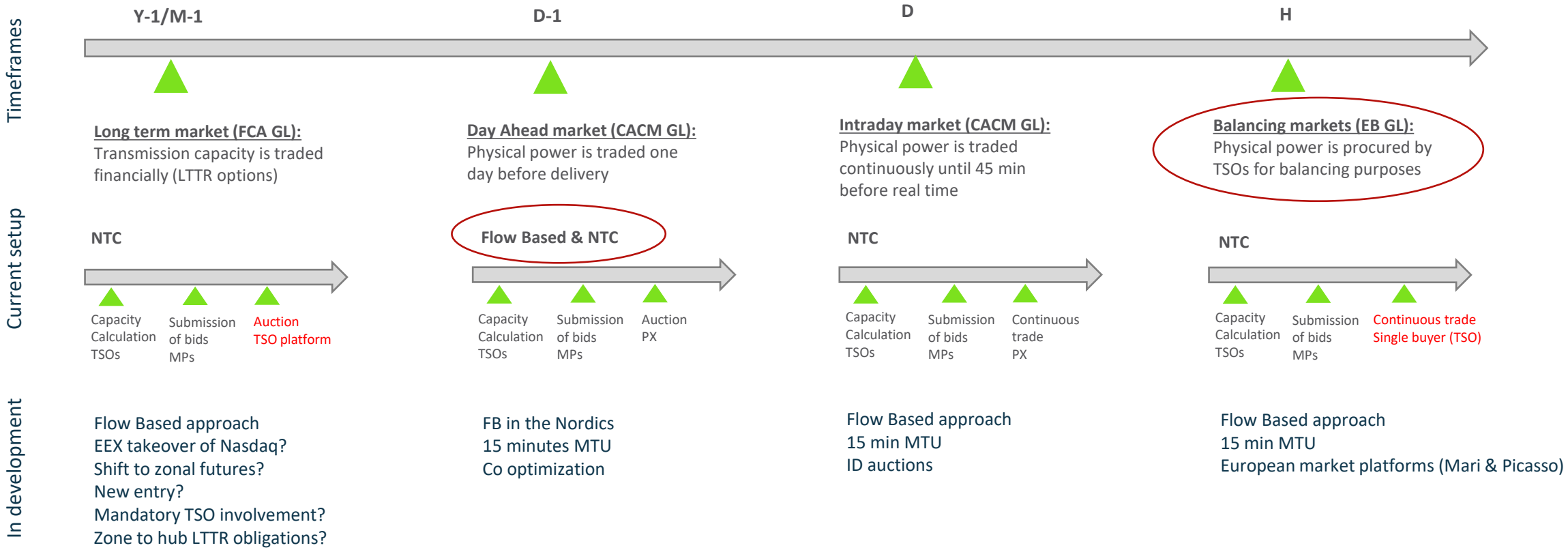
Re-inventing the European power market

Statnett

The European market processes

Objective of the European power market: Maximize the welfare economic surplus constrained by grid security and market balance → Market equilibrium (Net Positions & Prices)



Capacity Calculation: From complexity to simplicity

The physical world

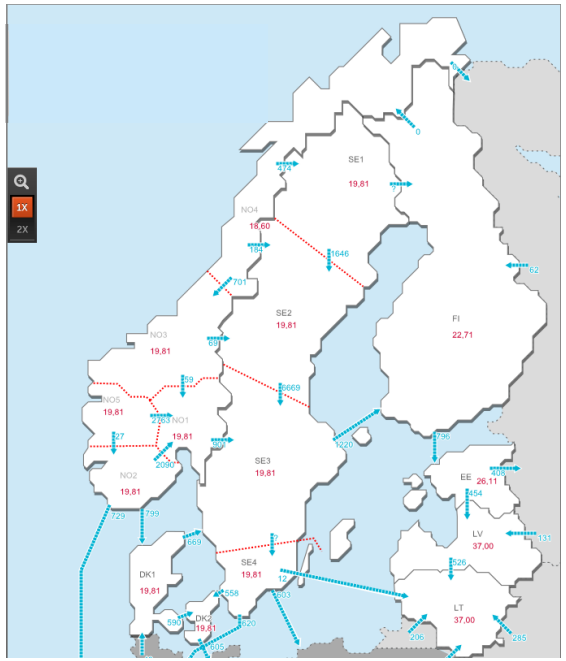
Complexity — Simplicity

Detailed grid model (CGM) → Nodal pricing → FB → NTC

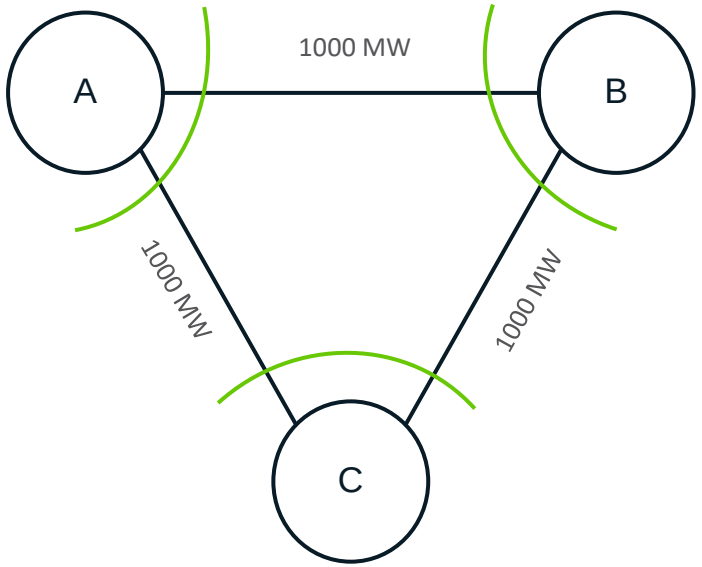
Capacity calculation is the process of translating the complex physical grid into a simplified form that can be understood and applied by the power exchange

- **Providing grid constraints to the market platforms**

The power market

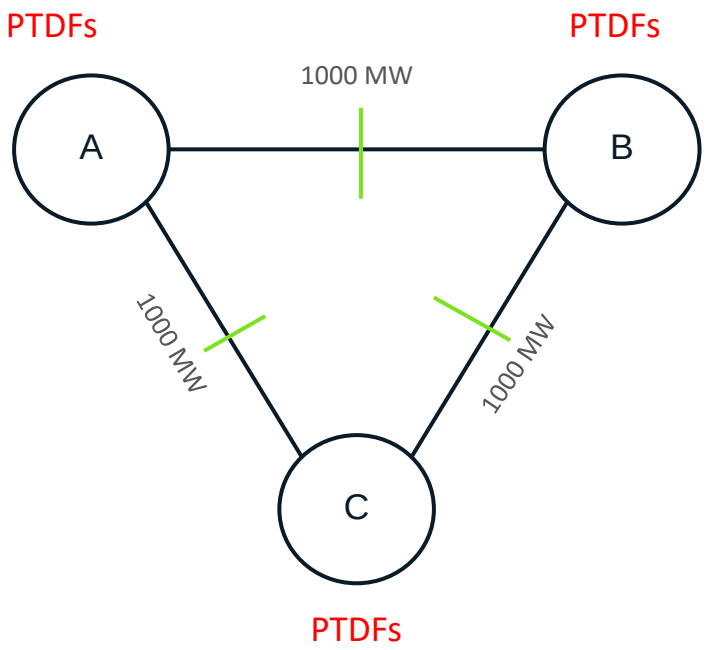


The Net Transfer Capacity (NTC) model



- Secure grid operation requires no overloads to be allowed
- Physical flows follow the path of least resistance:
  - Cannot allow bi-lateral trades at physical capacity
  - Limitations are expressed by NTCs on each border
  - Each bidding zone is limited to a max export and import
  - The distribution of NTCs on borders is an operational choice
- In general, the NTC market constraints is:
  - $NP_i \leq \sum_j NTC_{ij}$
  - $NP_i \geq \sum_j NTC_{ji}$

The Flow Based (FB) model



- Secure grid operation requires no overloads to be allowed
- Physical flows follow the path of least resistance
  - Limitations are expressed by PTDFs and RAMs
  - Each bi-lateral trade will cause a known flow on all Critical Network Elements (CNEC) → PTDFs
  - Allow flows at physical capacity for all CNECs → RAM
  - Each bidding zone is limited by the physical capacity for import and export
  - PTDFs and RAM are uniquely defined by the grid model
- In general, the NTC market constraints is:
  - PTDF * NP ≤ RAM
- FB allows for net positions that cannot be obtained in NTC
- All obtainable net positions in NTC can be obtained in FB

Price properties in FB and NTC

NTC: $p_i = \lambda + \tau_i^{imp} - \tau_i^{exp}$

1. Equal prices in all bidding zones when no constraints are limiting
2. A bidding zone cannot be import and export limited at the same time – Only one positive shadow-cost
3. Higher prices in import limited bidding zones
4. Lower prices in export limited bidding zones

FB: $p_i = \lambda - \sum_n \rho_n * PTDF_i^n$

1. Equal prices when no grid constraints are limiting
2. Lower prices in bidding zones who increases flows on limiting grid elements
3. Higher prices in bidding zones who relieves flows on limiting grid elements
4. All zonal prices becomes unique if one or more CNEs are congested

Notations:

λ = Dual variable on the energy balance constraint (Price in the slack zone)

τ_i^{imp} = Dual variable/shadow cost for the import constraint in NTC

τ_i^{Exp} = Dual variable/shadow cost for the export constraint in NTC

ρ_n = Dual variable/shadow cost for the grid constraints in FB

In general:

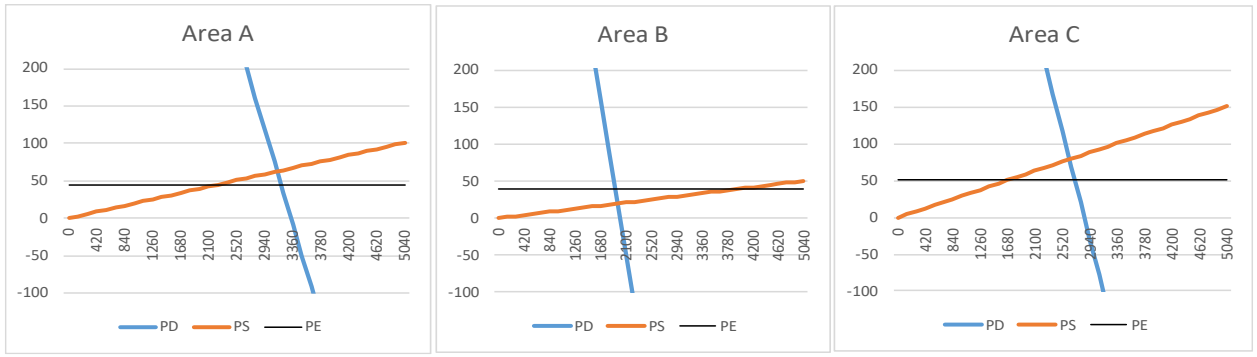
Value of the dual variable = Incremental increase in the objective function by an incremental relaxation of the constraint

Dual variable ≥ 0

[Dual variable] * [Distance from Constraint] = 0

Small example of a FB market coupling result

CNEC	RAM	Budområde A	Budområde B	Budområde C (Slack-sone)	ΣPTDF * NP	Skyggepris
NP		-946	1973	-1027		
Pris		44,76	38,95	50,7 (λ)		
A → B	1000 MW	33%	- 33%	0%	-973	$\rho_1 = 0$
B → C	1000 MW	33%	67%	0%	1000 MW	$\rho_2 = 17{,}43$
A → C	1000 MW	67%	33%	0%	27 MW	$\rho_3 = 0$



- Alle markedspriser er gitt av skyggepriser:

$$p_i = \lambda - \Sigma\rho * PTDF_i$$

- λ = Den samfunnsøkonomiske kostnaden ved å levere kraft i slack-sonen
- ρ = Den samfunnsøkonomiske verdien av en ekstra MW RAM for en CNEC

- Alle prisområder har lik pris dersom ingen begrensninger er bindende
- Alle prisområder har unike PTDFer og alle områder får derfor forskjellig pris dersom det finnes en flaskehals i systemet
- Dette gir oss mulighet til å vurdere den samfunnsøkonomiske verdien av kapasitet på våre snitt

- FB kan gi flyt fra høy til lav pris når handel mellom to prisområder genererer en positiv samfunnsøkonomisk verdi i form av reduserte nettkostnader:

$$p_i - p_e = \Sigma\rho * (PTDF_e - PTDF_i)$$

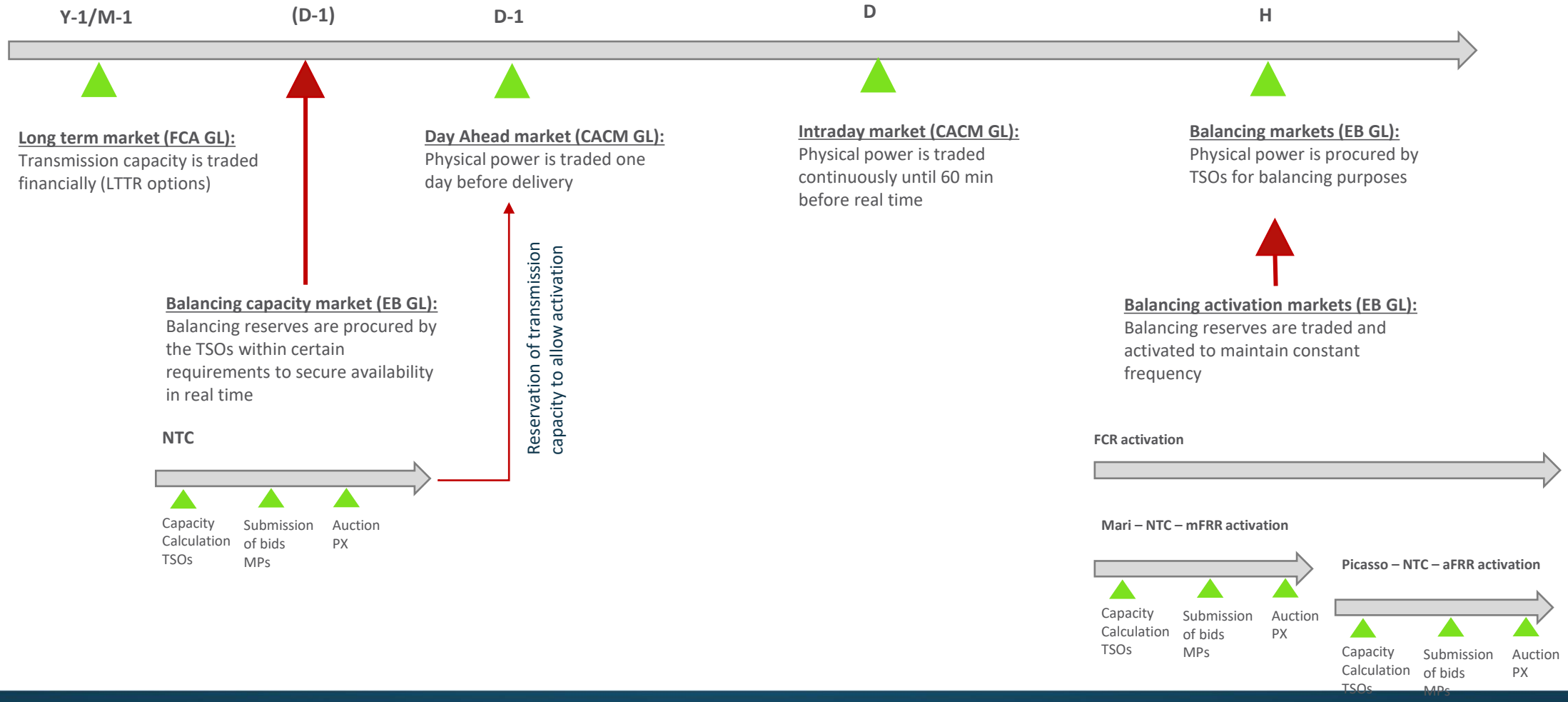
The balancing market

- Stakeholders (Balancing Responsible Parties – BRPs) may manage their own imbalances in the intraday market

- The TSOs will manage real time imbalances in the balancing markets
  - If BRPs is not able to balance their positions in the Intraday market, TSOs will take over and manage the imbalances in the balancing markets
  - The BRPs will be invoiced for this service

- The balancing market is meant for:
  1. Managing real time frequency deviations/maintain constant frequency
     - Upper threshold 50,1 Hz – Lower threshold 49,9 Hz
     - > 50 Hz → Excess generation (reduce generation/increase consumption)
     - < 50 Hz → Excess consumption (reduce consumption/increase generation)
  2. Manage real time overloads on grid components (redispatch/countertrade)

Balancing activities



Balancing capacity market (procurement of balancing reserves)

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TSO Requirements

Volumes needed to secure the system in case of a dimensioning outage

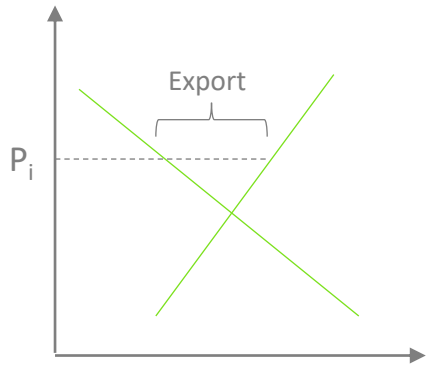
Need reserves available for both up and down regulations in all bidding zones

Grid capacity

Provide transmission capacity for trading reserves between bidding zones (max 10% of availability)

Bid submission

Market clearing

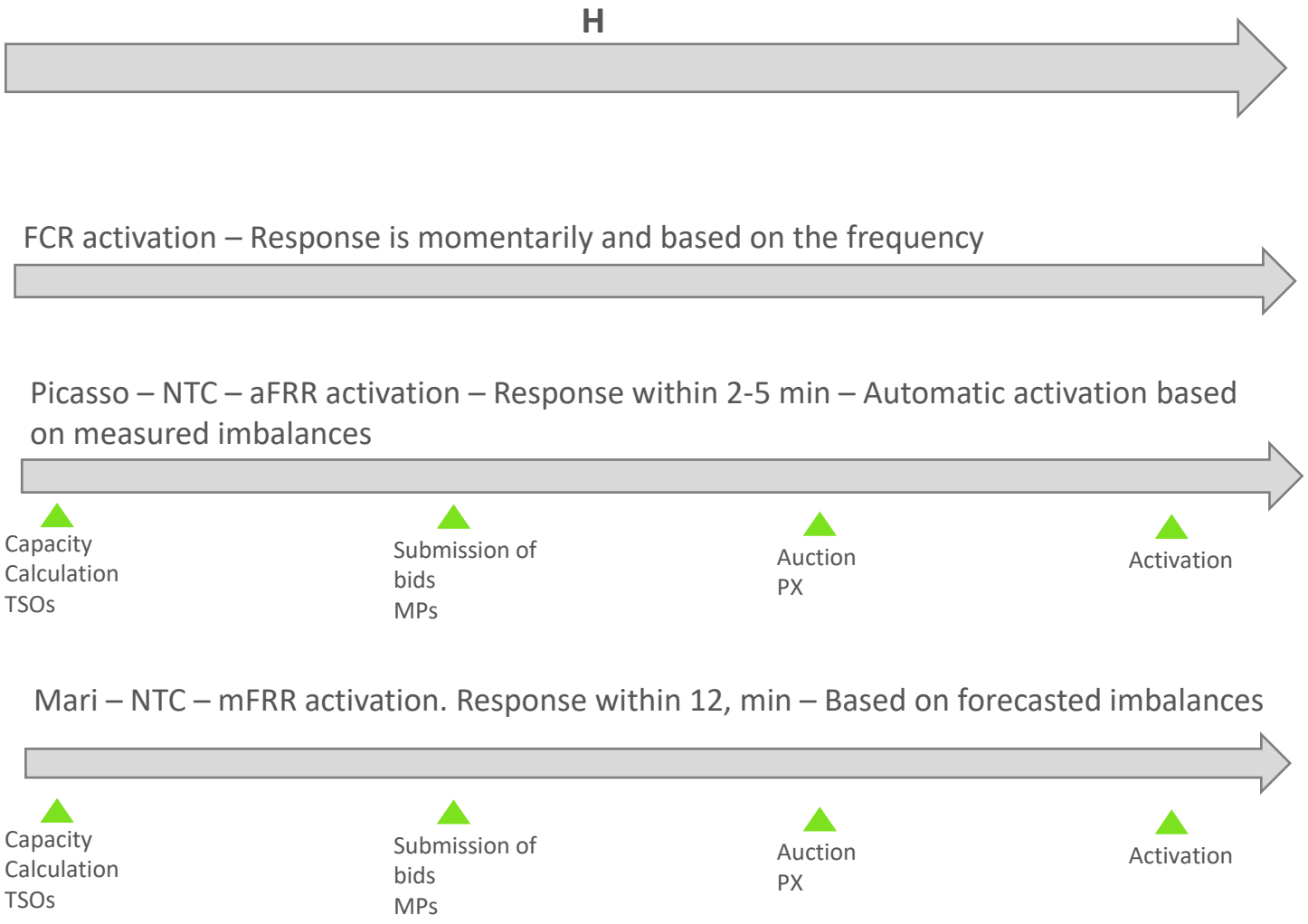


Implicit market coupling based on forecasted prices on transmission capacity

Reservation of transmission capacity

Transmission capacity needed to secure activation of procured reserves is withheld from the DA and ID market and released to the balancing activation markets

Balancing market - Activation



Imbalance-cost is forwarded to the BRPs

FCR activations is not part of the imbalance-price while aFRR and mFRR is relevant for the imbalance-price

Normally, activations are done within the markets. However there is also a possibility for the TSOs to apply direct mFRR activations between the markets