Callia - a design for a digitized flexibility trading platform and its operative and economic benefits for DSOs and TSOs

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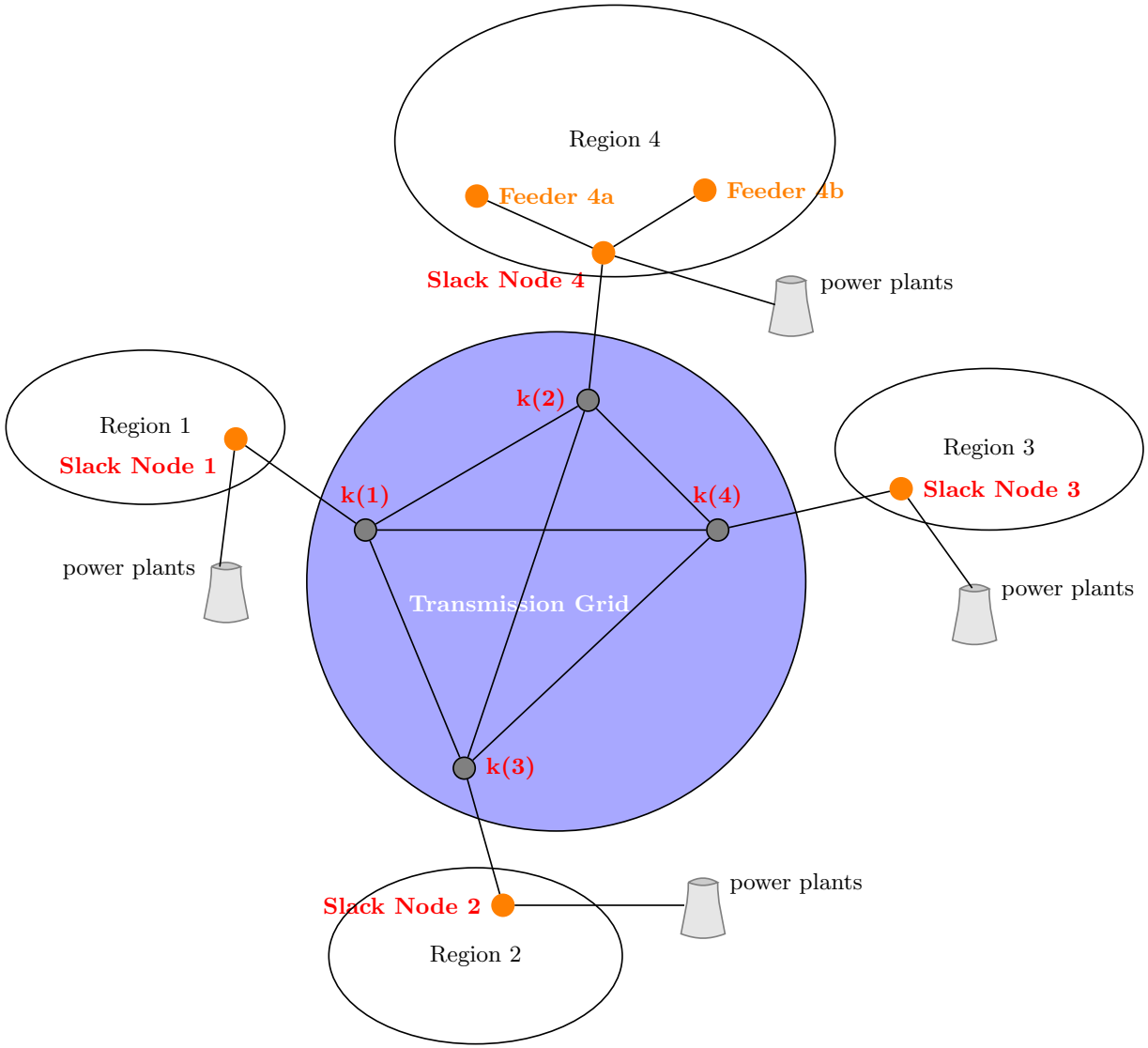
- Expansion of RES
- Impact on all voltage levels
- Higher volatility in generation
- Markets to acquire flexibility are needed
- Grid topologies have to be integrated
- Digitization for smart grids
- Integration of small and medium scale flexibility units
- Handling complexity
- Local/regional offers - but system wide competition

Flexiblity Trading - Use Cases

- Use Case I: Energy Neutral Flexibility Trading
- Use Case II: Congestion Management
- Use Case III: Voltage Control
- Use Case IV: Loss Mitigation

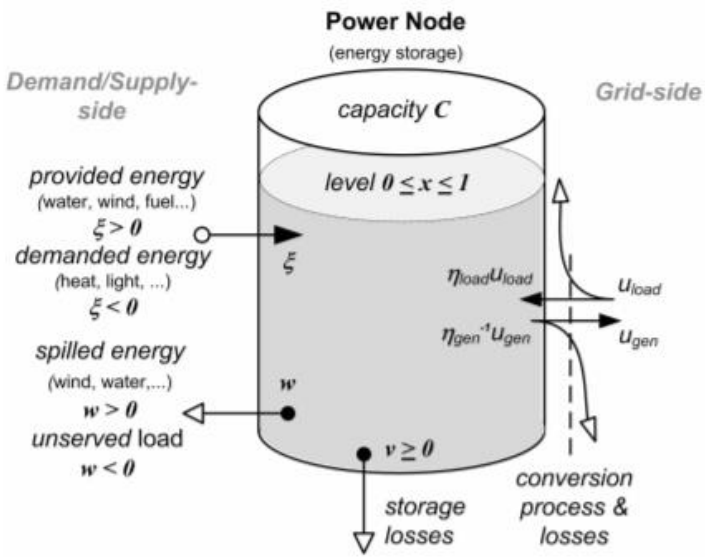
System Approach

System


Region 4
Feeder 4a
Feeder 4b
Slack Node 4
power plants
Region 1
Slack Node 1
power plants
k(2)
k(1)
k(4)
Transmission Grid
k(3)
Region 3
Slack Node 3
power plants
Slack Node 2
power plants
Region 2

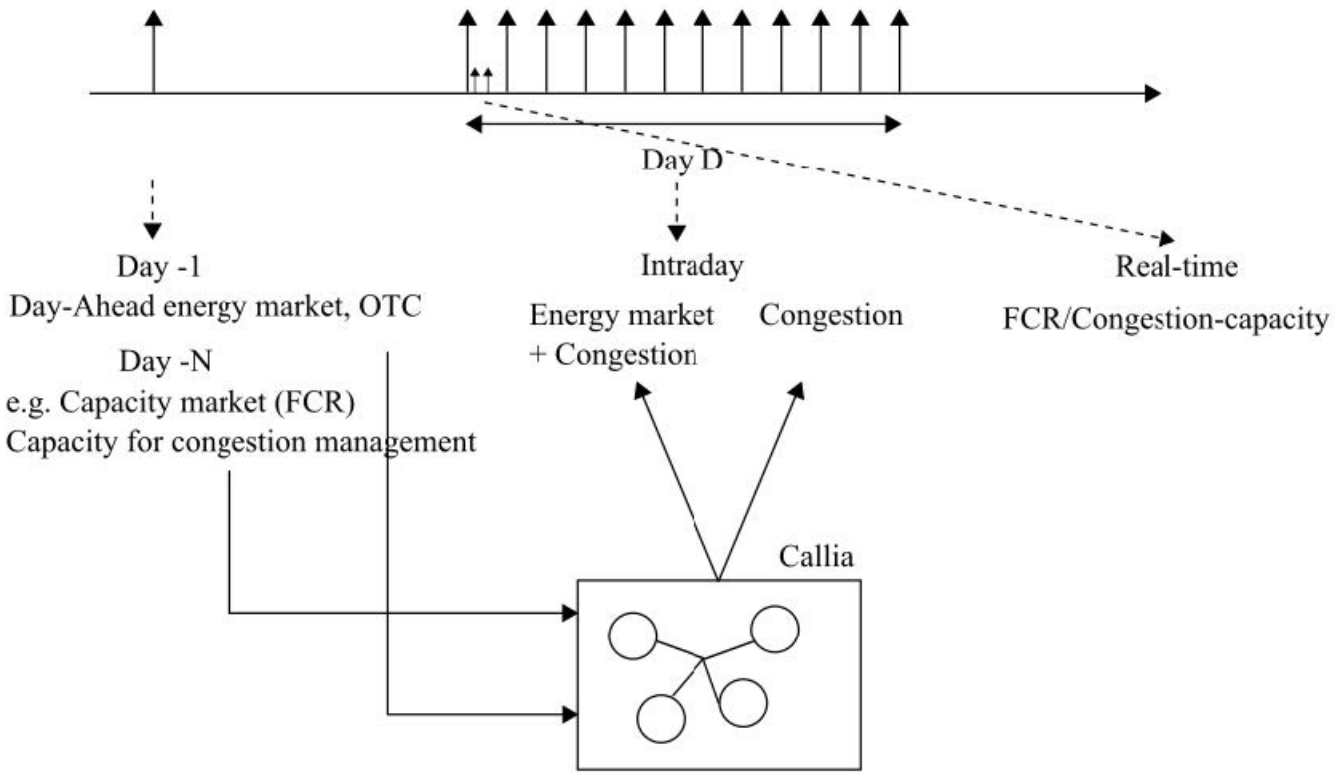
Flexibility Offer Types

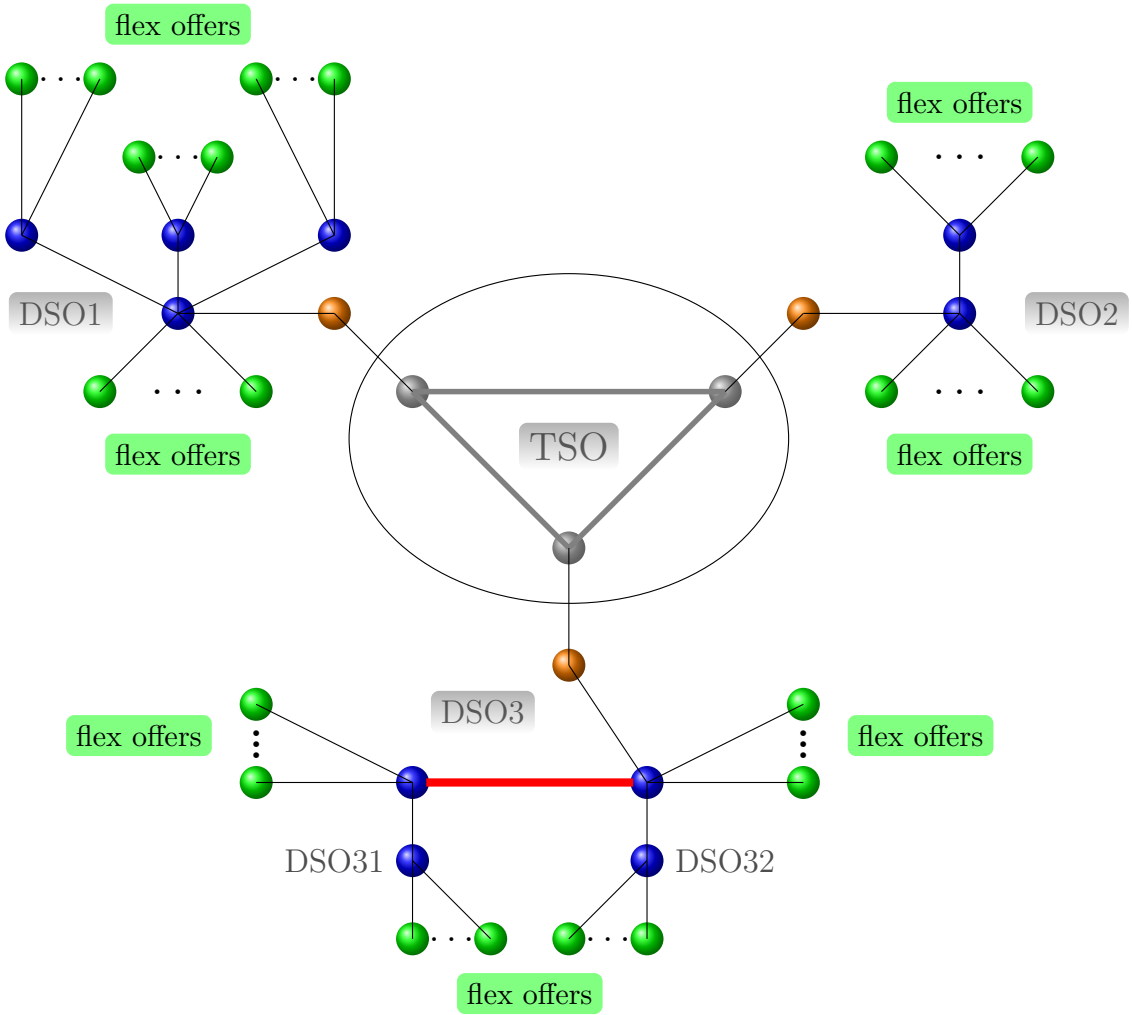
Tank Offers

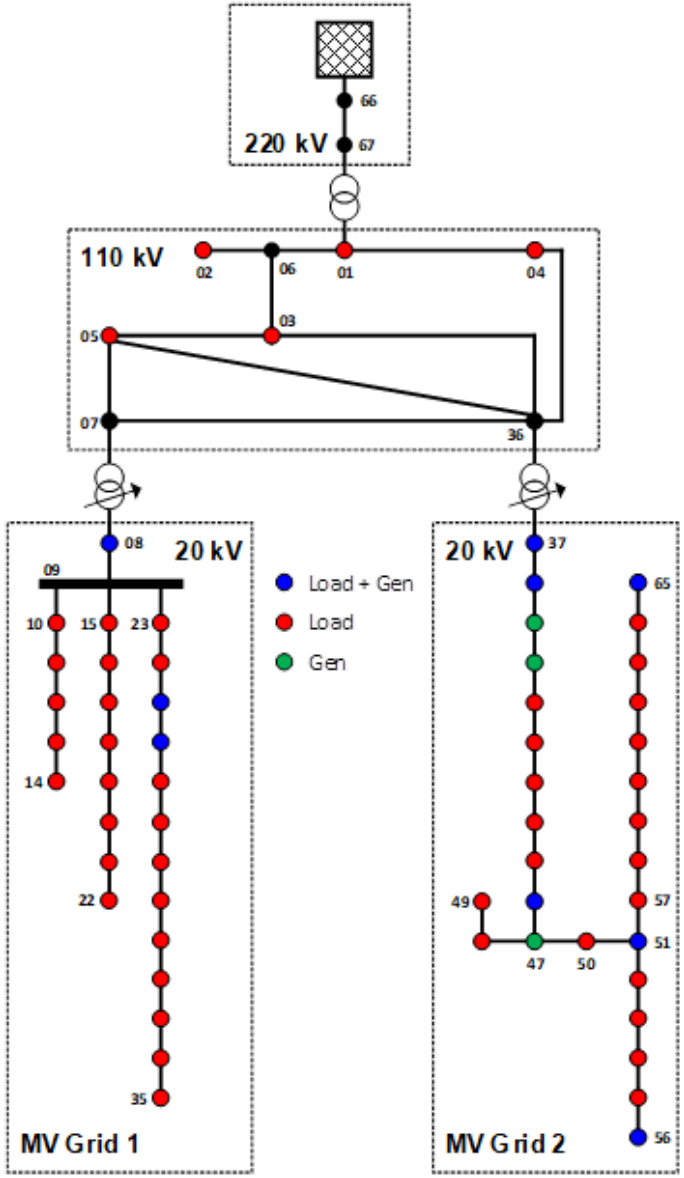


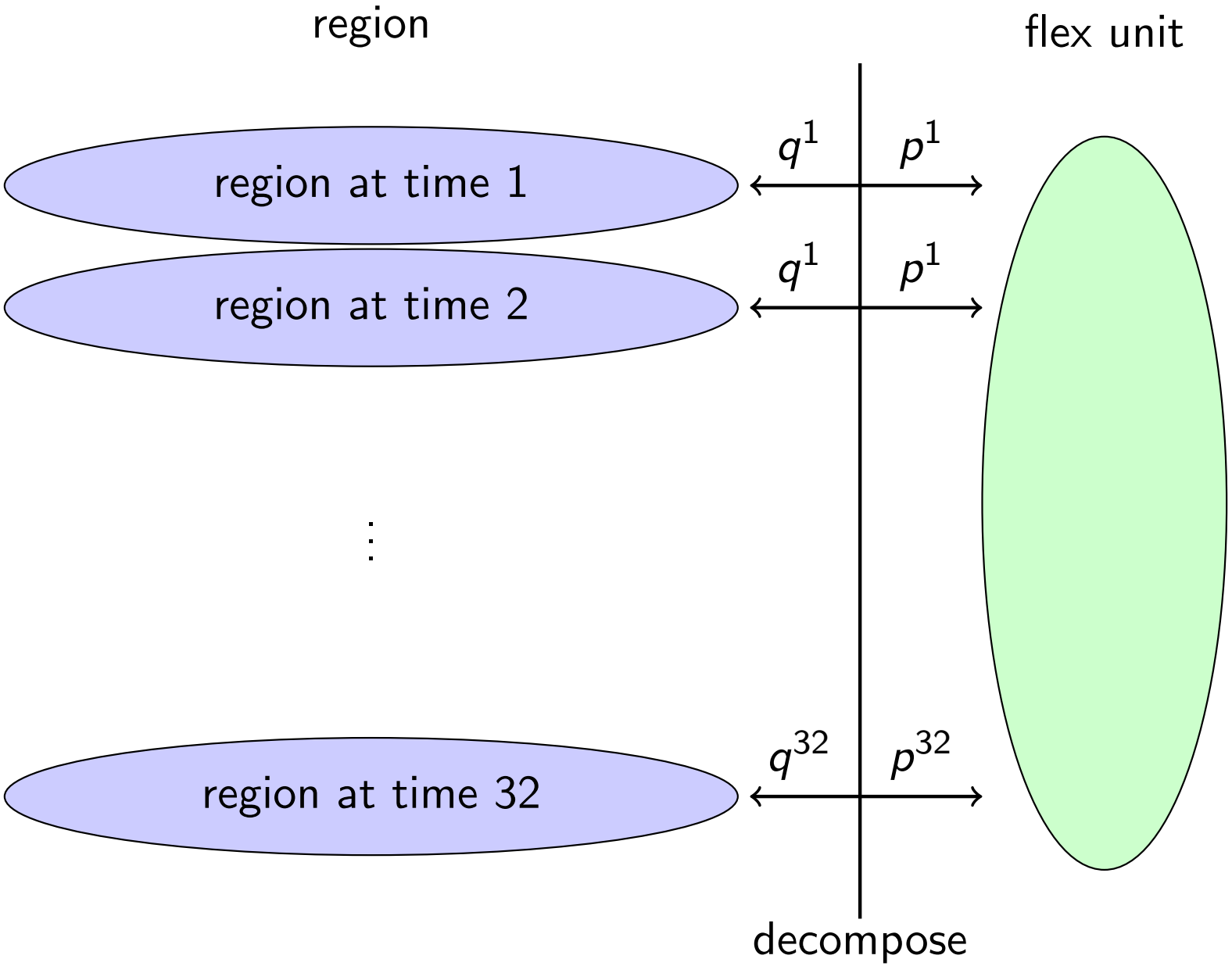
Batteries, Market Aggregator, office building/air-condition

Receding Horizon - Model Predictive Control




flex offers
flex offers
DSO1
DSO2
TSO
flex offers
flex offers
DSO3
flex offers
flex offers
DSO31
DSO32
flex offers


220 kV
66
67
110 kV
02
06
01
04
03
05
07
36
20 kV
08
09
10
15
23
14
22
35
MV Grid 1
Load + Gen
Load
Gen
20 kV
37
65
49
57
51
47
50
56
MV Grid 2


region
flex unit
region at time 1
region at time 2
region at time 32
q^1
p^1
q^1
p^1
q^{32}
p^{32}
decompose

Duplicated variables for decomposition

$\widetilde{\alpha_i^+}(t)$ ... decomposition variables of $\alpha_i^+(t)$ charging

$\widetilde{\alpha_i^-}(t)$ ... decomposition variables of $\alpha_i^-(t)$ discharging

$\widetilde{S}_i(t)$ ... decomposition variables of $S_i(t)$ SoC

Obviously, in the final feasible solution, decomposed variables have to be equal:

$$S_i(t) = \widetilde{S}_i(t), i \in B \quad \text{decomposition}$$
$$\alpha_i^+(t) = \widetilde{\alpha_i^+}(t), i \in B \quad \text{decomposition}$$
$$\alpha_i^-(t) = \widetilde{\alpha_i^-}(t), i \in B \quad \text{decomposition}$$

Note: Variables $P_i(t)$ at slack node i need not be duplicated as the variables $P_{k(i)}$ takes over the role of duplicated variables. However, we have to consider a small adaption, as the flow direction changes (i.e. we have to change signs):

$$P_i(t) = -P_{k(i)}(t), \text{ slack node } i \quad \text{decomposition}$$

Lagrangian Function

Variables q are the duplications of the variables p.

$$\begin{aligned} min_{x,p,q} \quad & \sum_t C^t(x^t, q^t) \\ s.t. \quad & (x^t, p^t) \in S^t \\ & q \in D \\ & p^t = q^t \end{aligned}$$

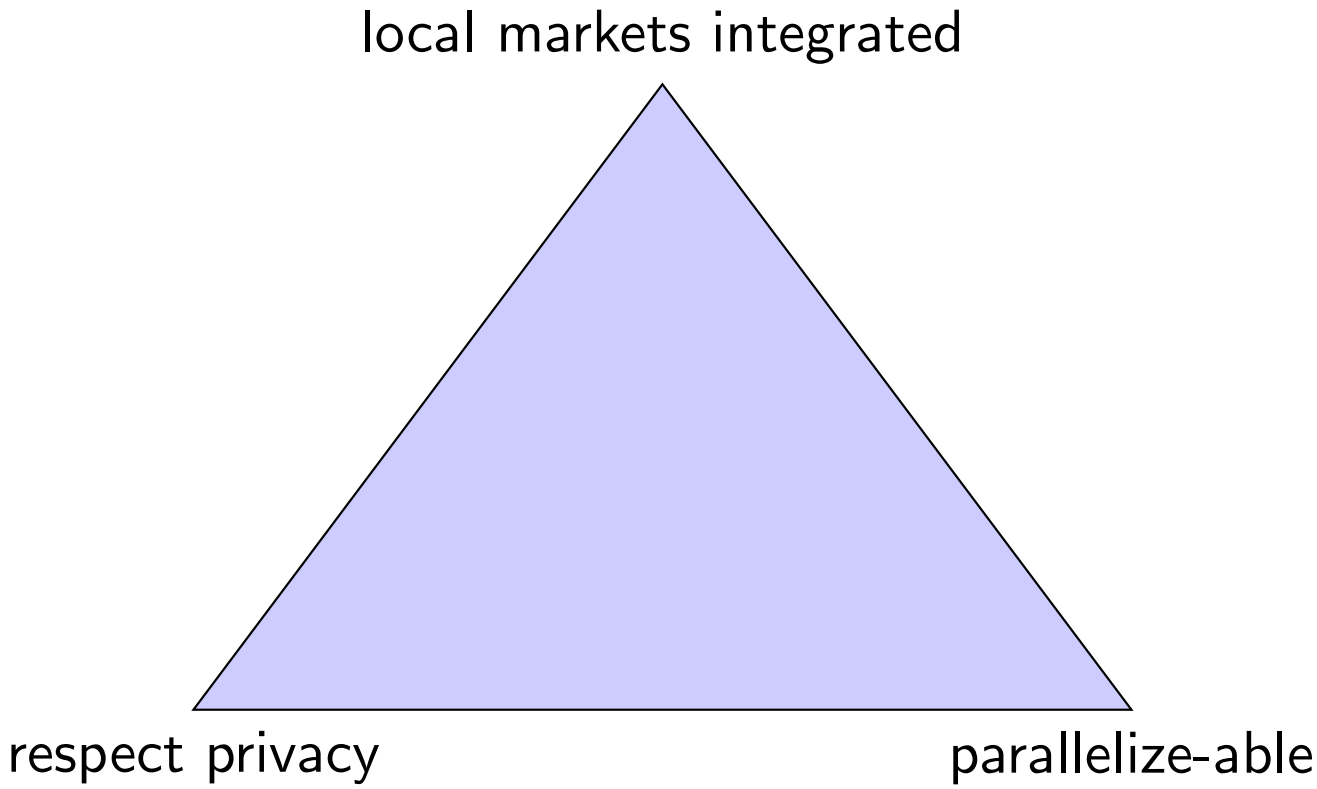
For each component of $p - q$, we define a shadow price and define a set $\mu = (\mu^1, ..., \mu^t)$ of dual variables (vectors)

$$L(x, p, q, \mu) = \sum_t C^t(x^t, q^t) + \sum_t \mu^t \cdot (p^t - q^t)$$

Dual function θ : $\theta(\mu) := min_{(x,p)\in S, q\in D} L(x, p, q, \mu)$,
Dual problem $max_\mu \ \theta(\mu)$.

Market algorithm - our findings

- Bundle Method
  - Linear approximation of dual function
  - Synchronization - Use Case 1
  - Had to limit shadow prices
- Bundle Method with step-size control
  - Quadratic penalty on step-size, Armijo like parameters etc
  - Use Case 2 extreme case: unfeasible - unbounded
  - Exit scenario - capped shadow prices
- Adding 1 step Newton-Rhapson for linearization
  - Use Case 3 and Use Case 4
  - Still no satisfactory performance
- ADMM (Alternating Direction Method of Multipliers)


local markets integrated
respect privacy
parallelize-able

Finally, my thanks to the Callia project partners

DSO: Stadtwerke Heidelberg, Bedas Istanbul

TSO: Transnet BW, Bedas Istanbul

Grid communication: Salzburg Research, REstore Antwerp, VITO Genk

RES: ISC Konstanz (PV)

Flex: REstore Antwerp (aggregator), Blue.sky (batteries), Bedas

Scientific: Salzburg Research, Univ. Stuttgart, TU Wien, VITO Genk

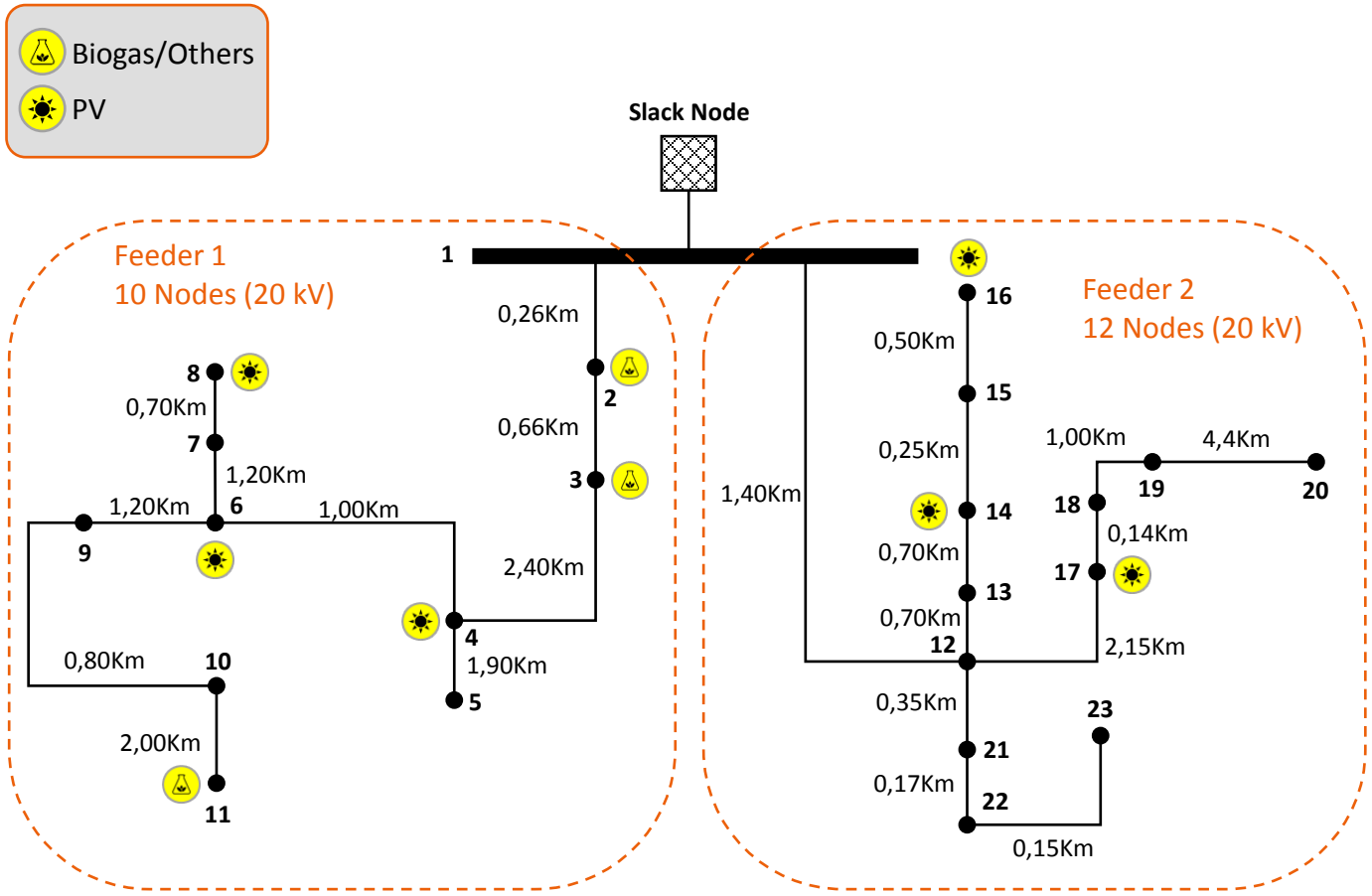
Power Electronics: Devolo, Pavotek

"Freedom, equality, democracy: blessings or chaos for energy markets? "

The Energiewende might cause chaos, freedom, equality and democracy is the chance to get the chaos under control. A system-wide grid-based welfare optimizing flexibility market might help to take this opportunity.

Thank you for your attention

23 Nodes Generic Grid Model



All Nodes have a load connected (Except Slack Node)

R' = 0,168 Ω/Km (For All Lines)
r' = 0,042 p.u/Km (20kV/100MVA Base)
Max Load per Line: 8 MW

Node	Load [KW]	Gen [kW]
1	0	0
2	28	782
3	28	740
4	462	103
5	145	0
6	338	0
7	261	0
8	80	113
9	4084	19
10	124	0
11	49	524
12	110	0
13	122	0
14	26	0
15	173	0
16	26	44
17	212	42
18	264	223
19	527	0
20	258	0
21	423	0
22	595	0
23	347	0
Sum	8683	2591


Hörsaal EI 6
Eckert
Gebäude Gußhaus, 4.OG
Gußhausstraße 25-25a
1040 Wien
U2
U4
U1
U1 U2 U4
Karlsplatz
U1 U2 U4
Karlsplatz,
Ausgang Resselpark
1 62
Karlsplatz
Resselpark
Karlsplatz
Bärenmühl-
durchgang
Resselgasse
Operngasse
Wiedner Hauptstraße
1 62
Resselgasse
Paniglgasse
Karlsgasse
Frankenberggasse
59A
Schleifmühlgasse
IV Wieden
Gußhausstraße
1 62
Paulanergasse
Favoritenstraße
Taubstummengasse
U1
Taubstummengasse
Floragasse
U1