



Smart TSO-DSO interaction schemes, market architectures and ICT
Solutions for the integration of ancillary services from demand side
management and distributed generation

SmartNet Project Meeting, Brussels | 20.06.2018

Pilot C

Endesa - Vodafone – ONE - Tecnalia



This project has received funding from the European Union's Horizon 2020
research and innovation programme under grant agreement No 691405







Vodafone
Base Stations

More than 400 units just in
Barcelona

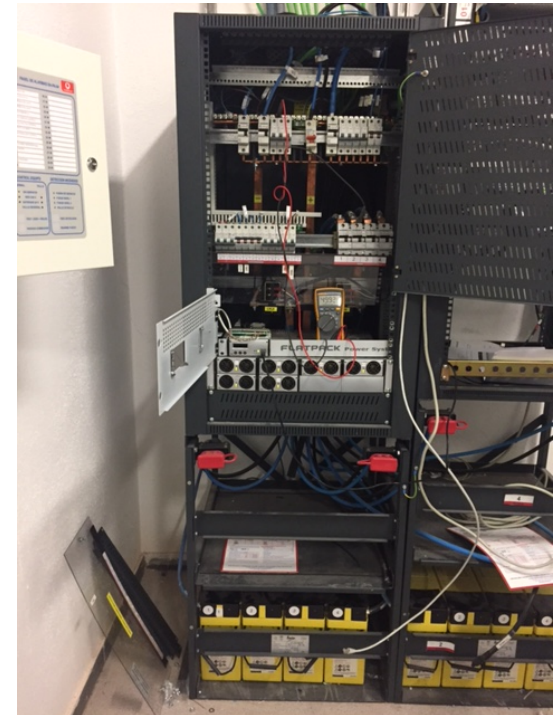
Contracted Power of each
one from
5kw to 15kw

Vodafone Base Stations



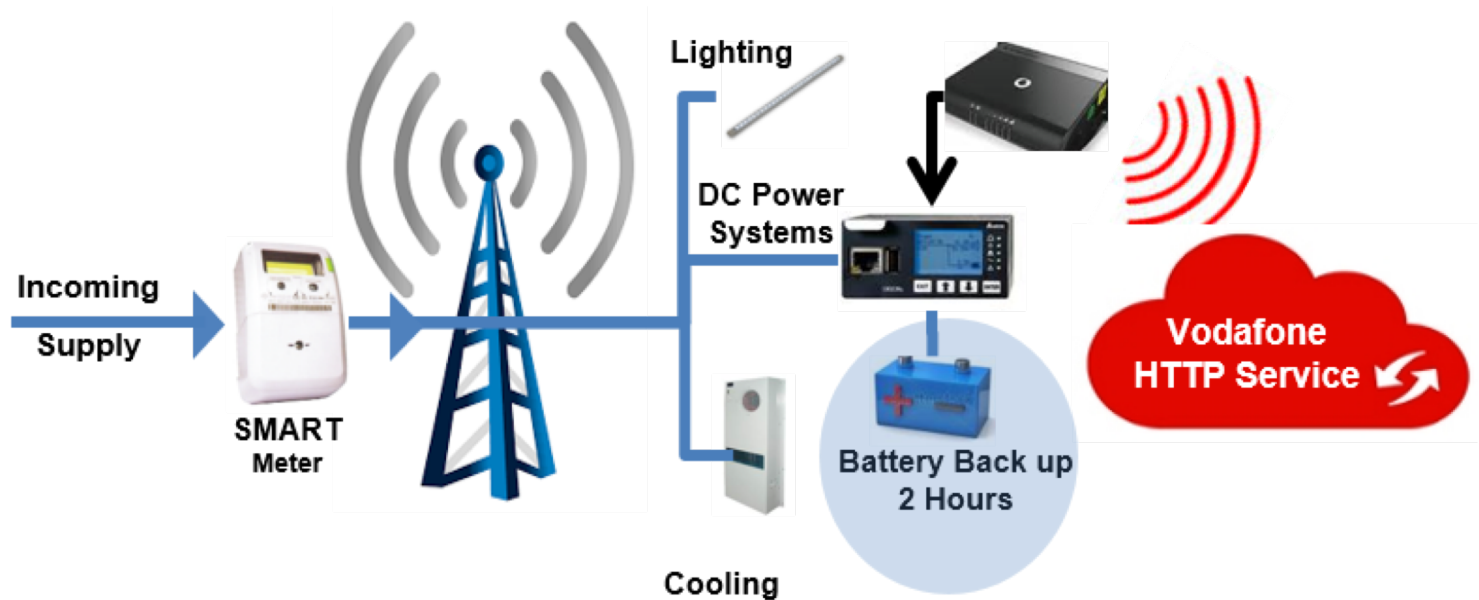
Flexibility by Storage Capacity

- Back Up Batteries - Base Station of Vodafone



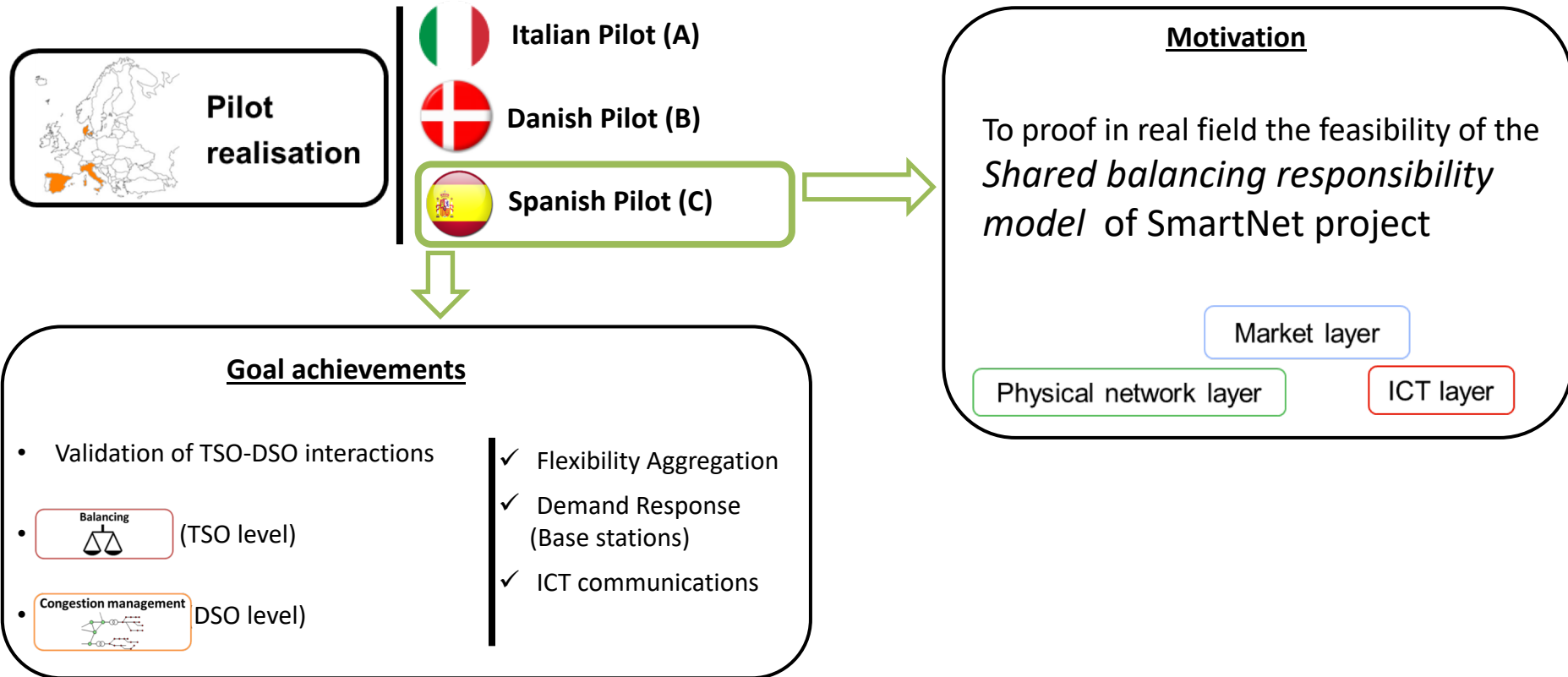
Spanish pilot

DER Owner side. Demand Response Technology over VF Base Stations



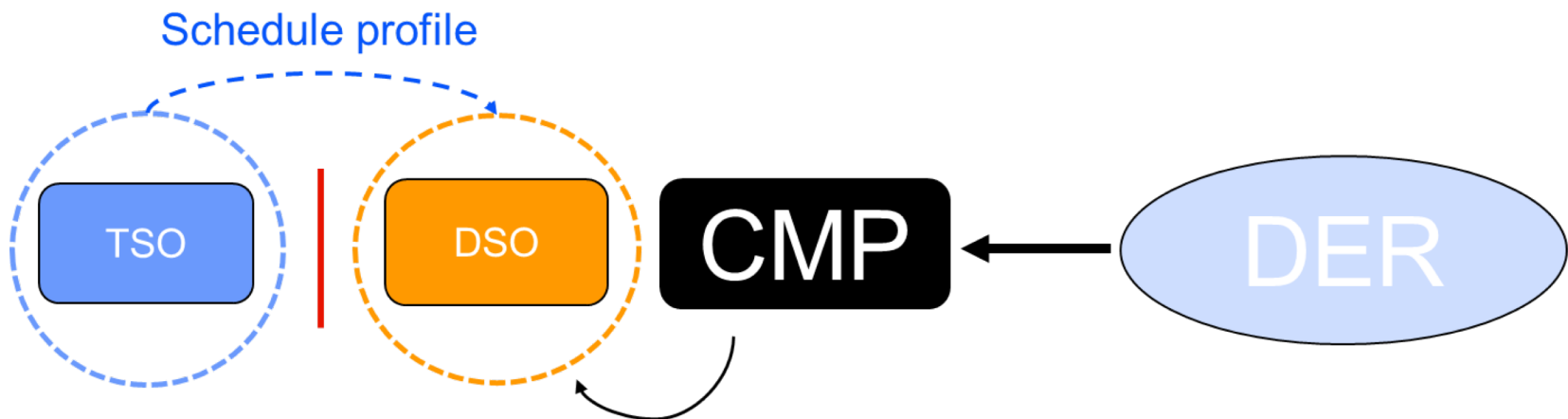
Pilot flexible aggregation capacity:
around 100 kW

Spanish pilot



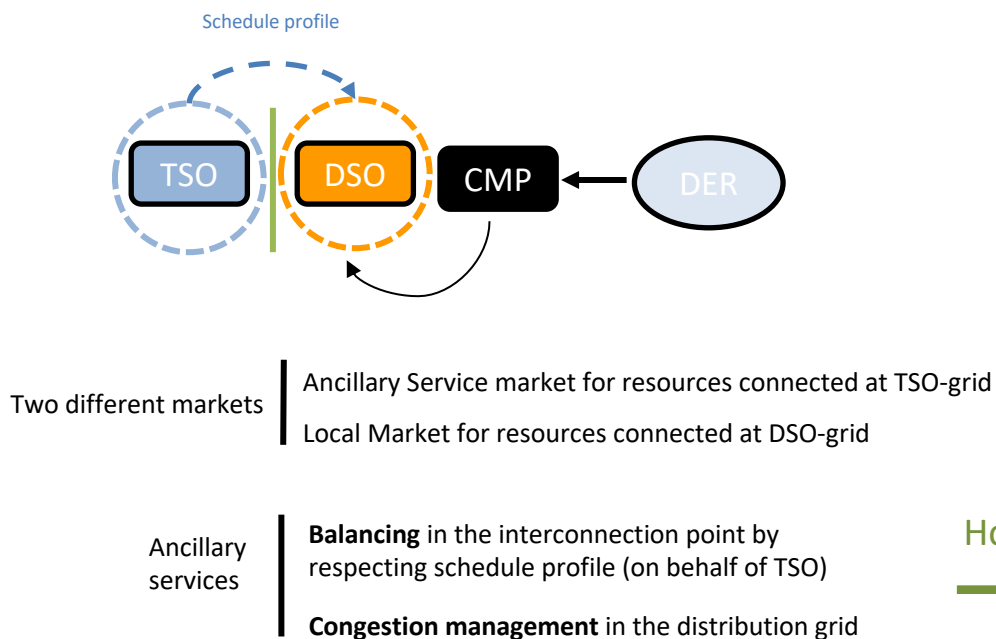
Coordination scheme

Shared balancing responsibility model

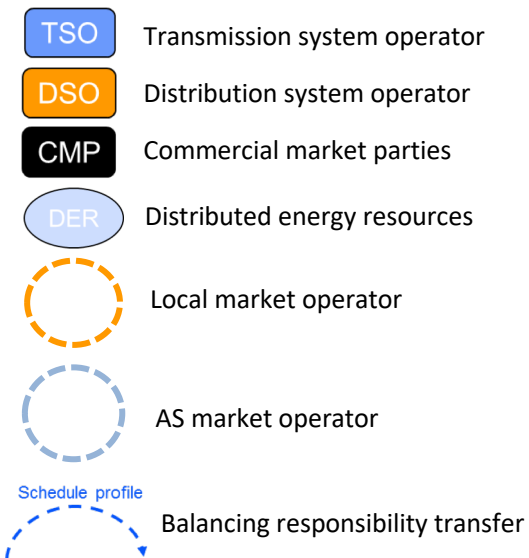


Coordination scheme

Shared balancing responsibility model







How?
→

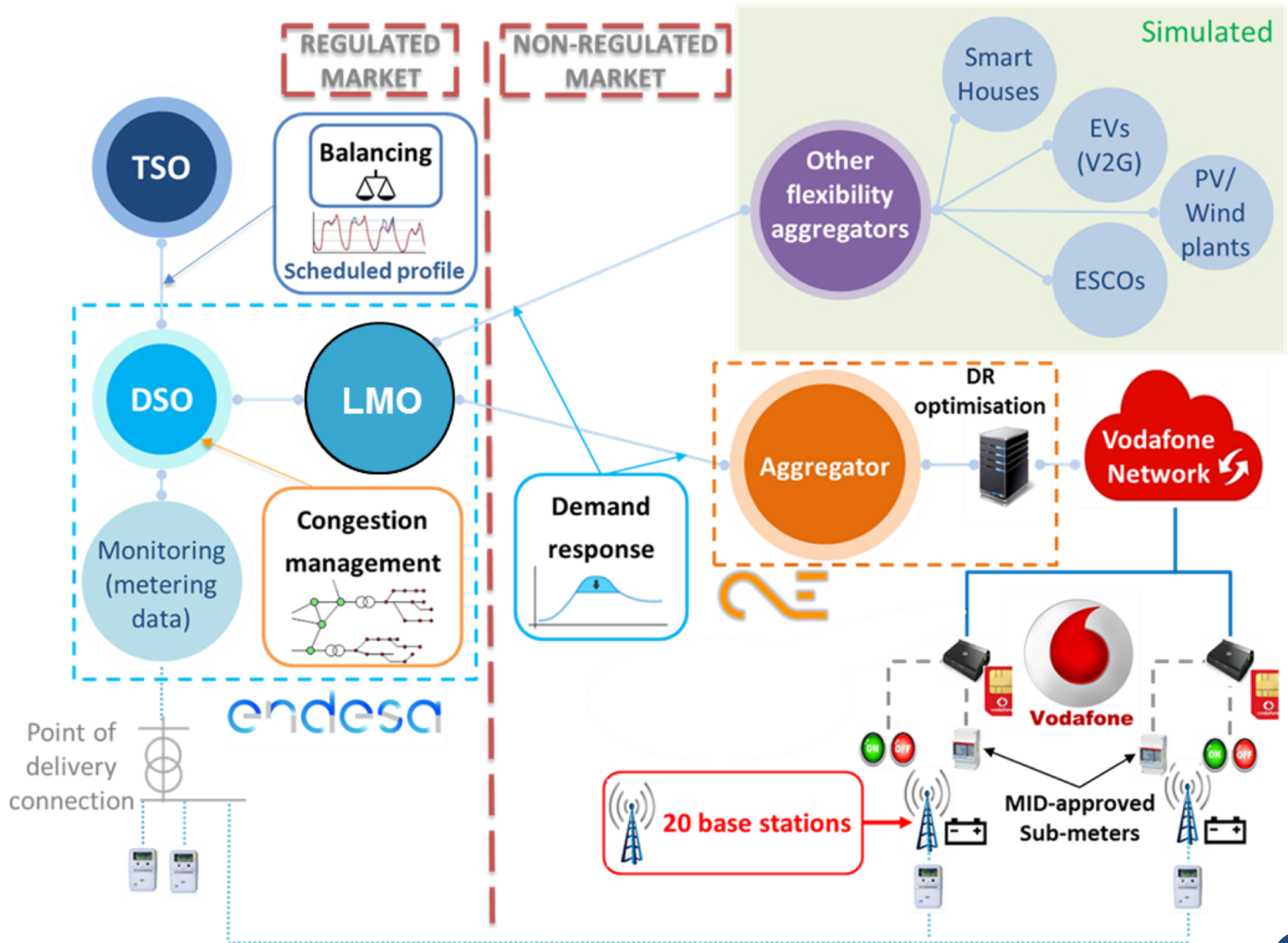


By using flexibility from DER owners through Commercial market parties

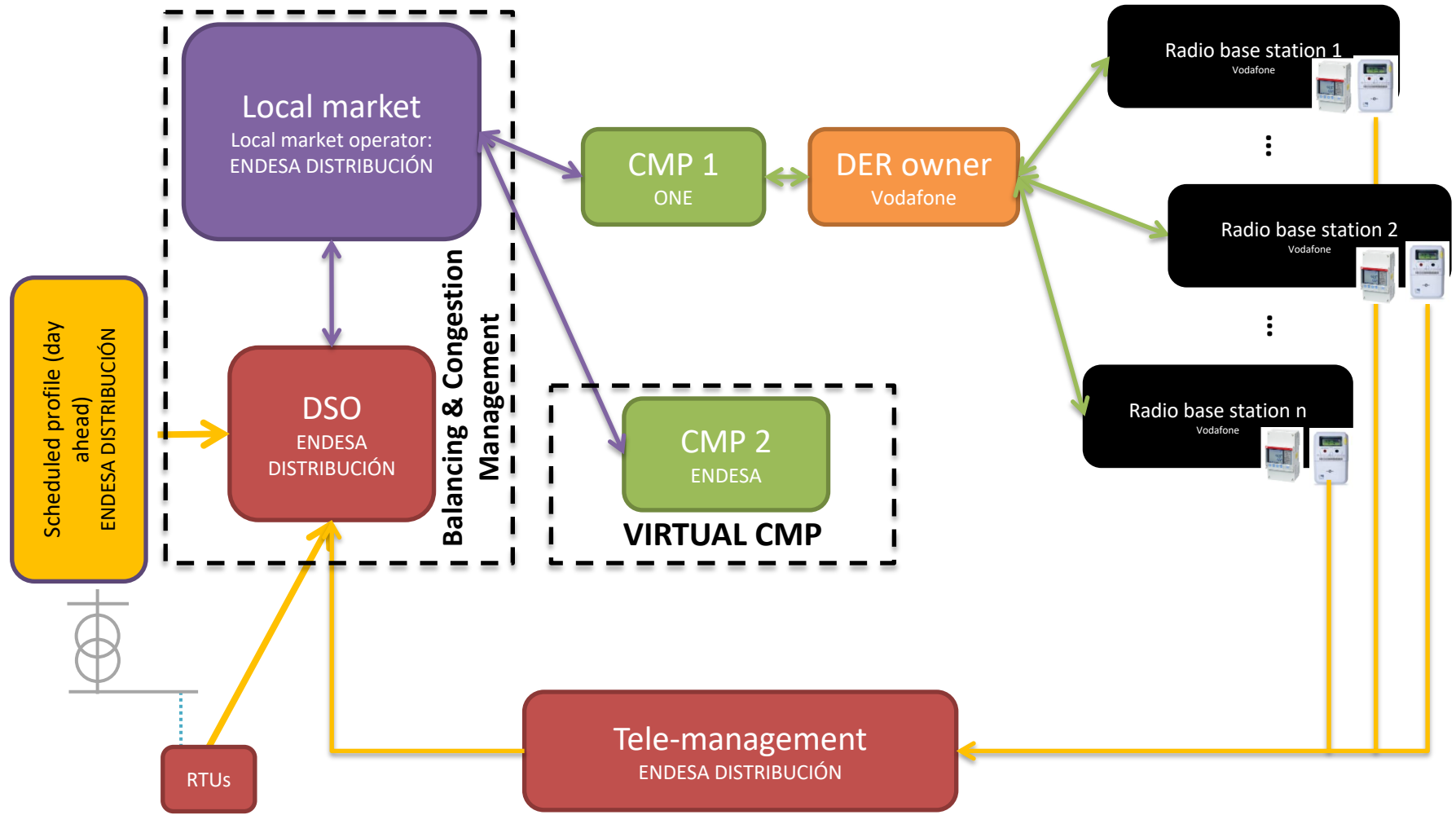
Roles in the project

	Transmission System Operator	Balancing at interconnection level Developing the TSO-DSO interaction
	Distribution System Operator	By doing congestion management services for itself at local network
	Commercial Market Party	Virtual nodes emulating other CMP's (Smarthouses, PV's, BSs)
	Market operator	Local market operation
	Commercial Market Party	Managing the portfolio of Vodafone radio base stations
	DER owner	Owner of the base stations (flexible resource) Provider of connectivity services to CMP's
	Consultant	DR providers





Pilot C: Setup

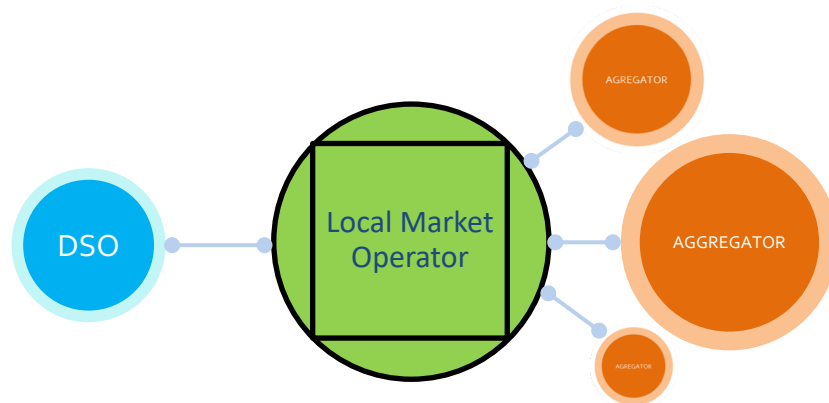


Pilot C: Local Market Operator

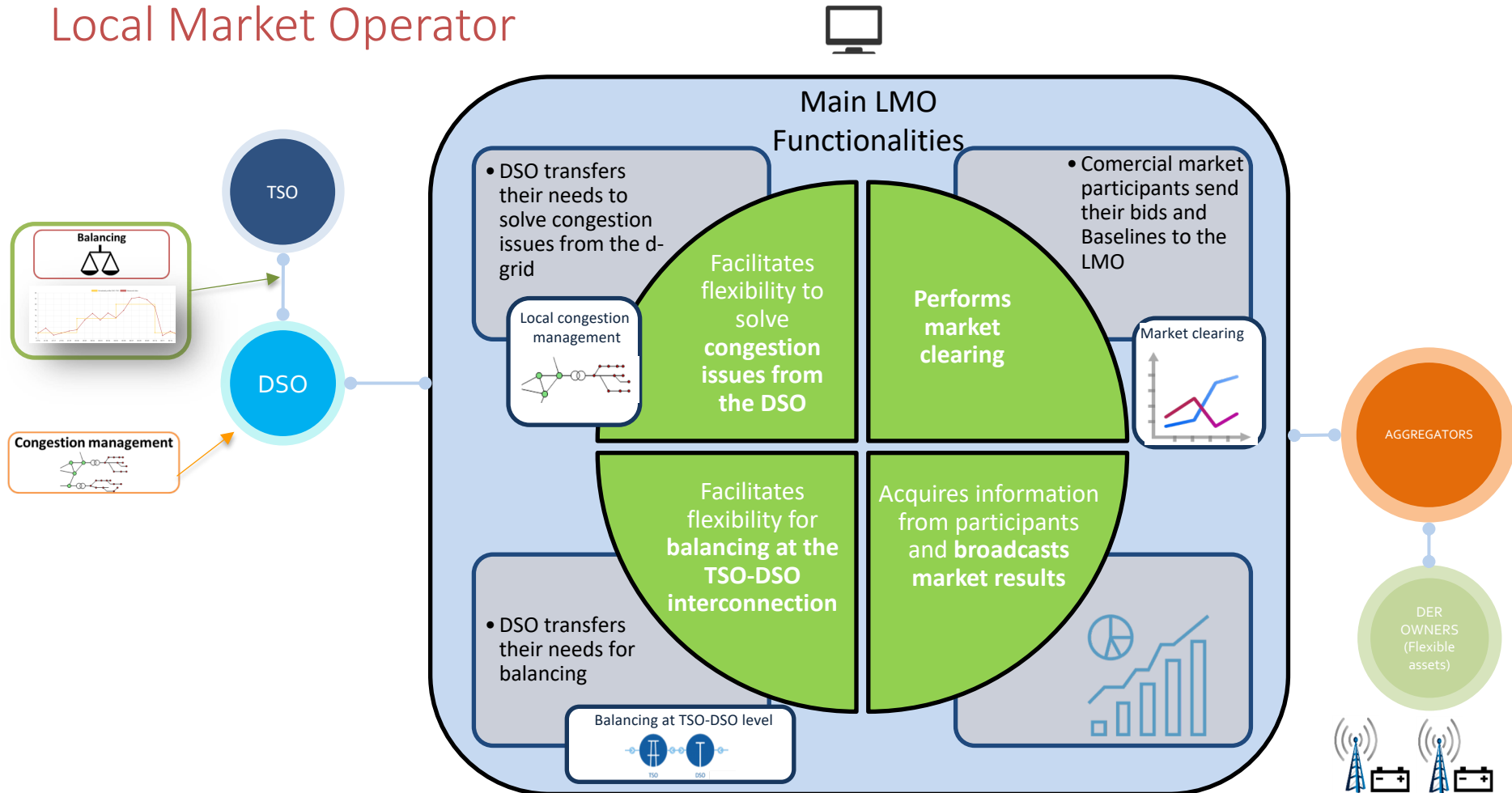
Endesa Distribución will play the **market operator** role at the local (distribution) level by means of the **market clearing algorithm**, which at the end is an OPF (Optimal Power Flow).

The OPF solves in the same optimization model both technical and market-related aspects of the balancing and congestion management services.

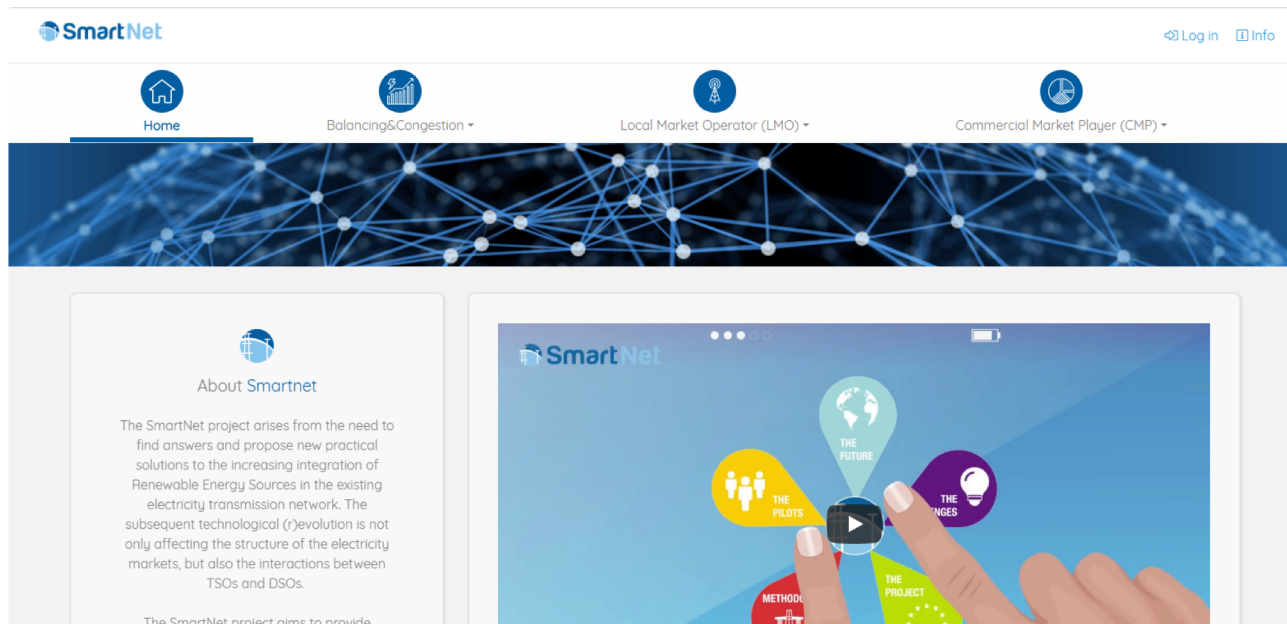
In other words, **technical constraints and bid prices are combined in the same optimisation problem**, which provides an optimal economical outcome.



Local Market Operator

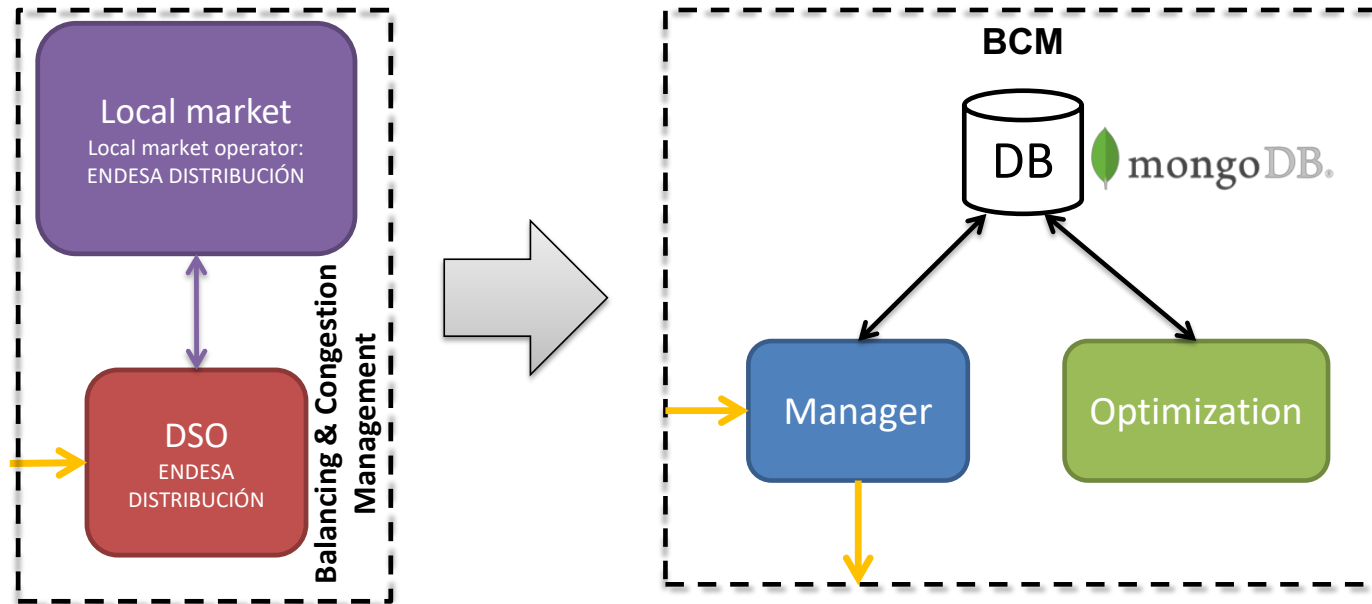


Web interface architecture



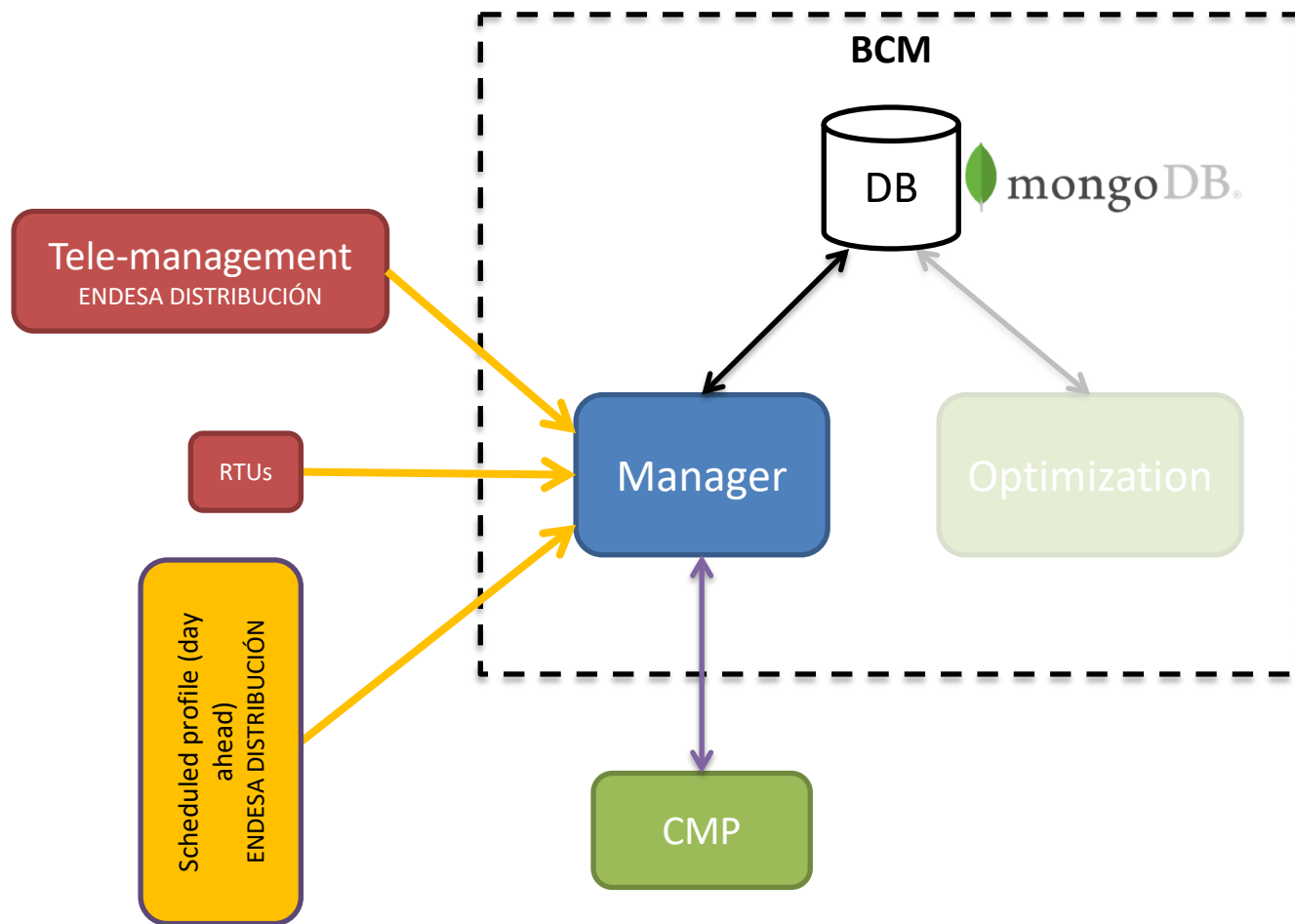
- Balancing and Congestion Management
 - Balancing
 - Network status
- Market
 - Market price
 - Flexibility
 - Market results
 - CMP bids
- CMP ONE (real)
- CMP TWO (virtual)
- CMP V2G (virtual)
 - Aggregated load (per CMP)

Pilot C: Balancing & Congestion Management

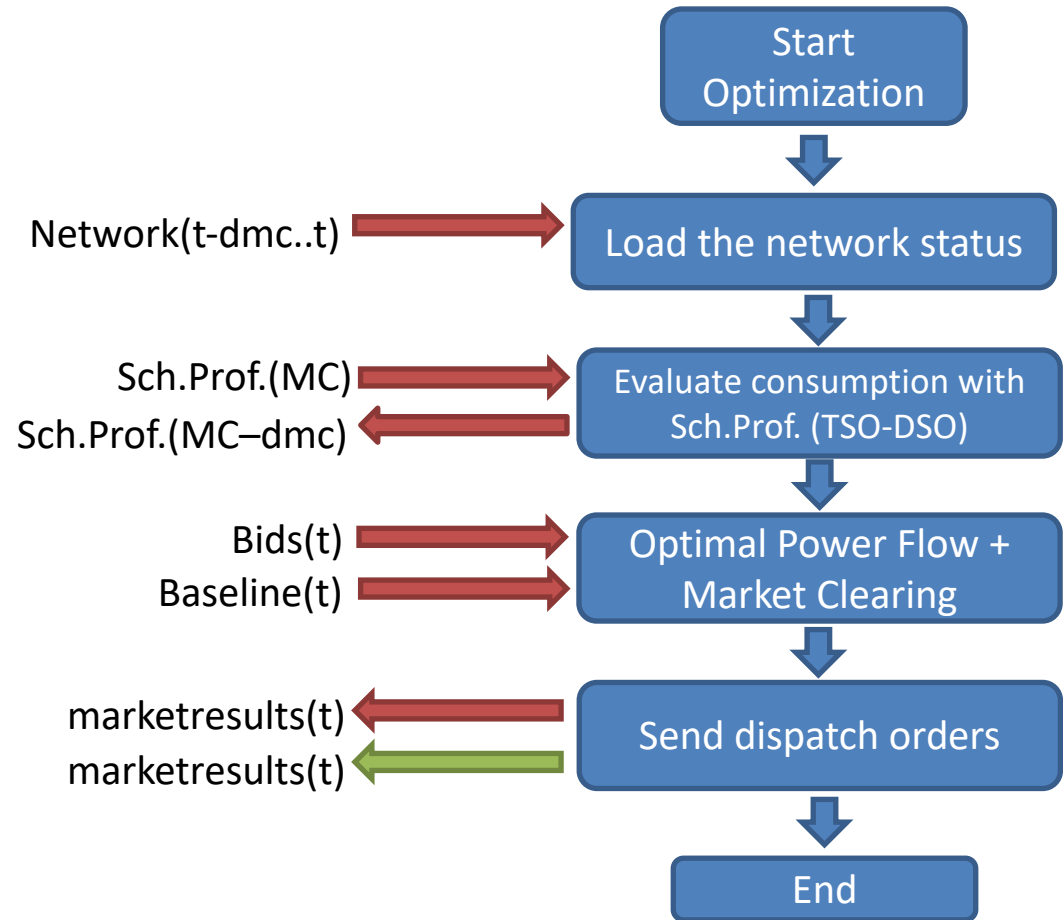
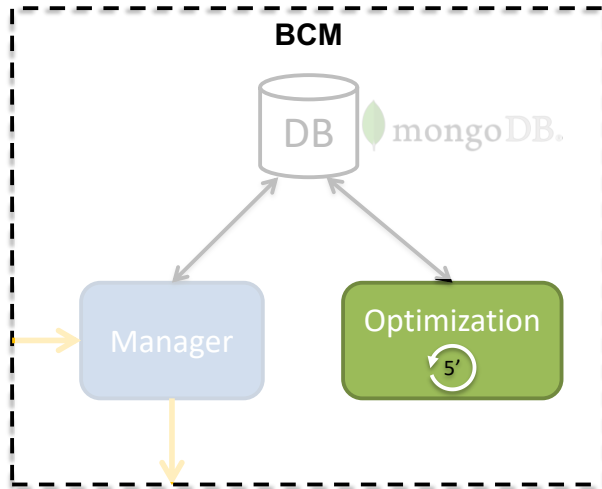


```
Information Process
=====
Active CMP:
ONE last bids: 2018-03-21T15:30:00Z
VCMP01 last bids: 2018-03-21T15:10:00Z
=====
Next calculations at: 2018-03-21T15:14:00Z
Next market at: 2018-03-21T15:15:00Z
=====
```



Pilot C: BCM - Manager




Pilot C: BCM - Optimization



MC = Market Clearing Time
dmc = 5 min

 Messages

 Connections to DB

Pilot C: BCM - Opt. – OPF + MarketClearing

$$\min \sum_{g \in G} \sum_{k \in K_g} lb_{gk}^+ P_{gk}^+ + \sum_{k \in K_{G_0}} lb_{0k}^- P_{0k}^- + \sum_{(i,j) \in \mathcal{L}} C_{ij}$$

s.t.

Power Flow technical constraints

Balancing constraints

Congestion constraints

Market Clearing constraints

Pilot C: BCM - Opt. – OPF + MarketClearing

Balancing

$$P_{0k}^- > 0 \quad \exists k \in K_{G_0}$$

Demand surplus

$$P_{0k}^+ > 0 \quad \exists k \in K_{G_0}$$

Insufficient generation

Congestion

$$C_{ij} > 0 \quad \exists (i, j)$$

Congestion in line (i, j)

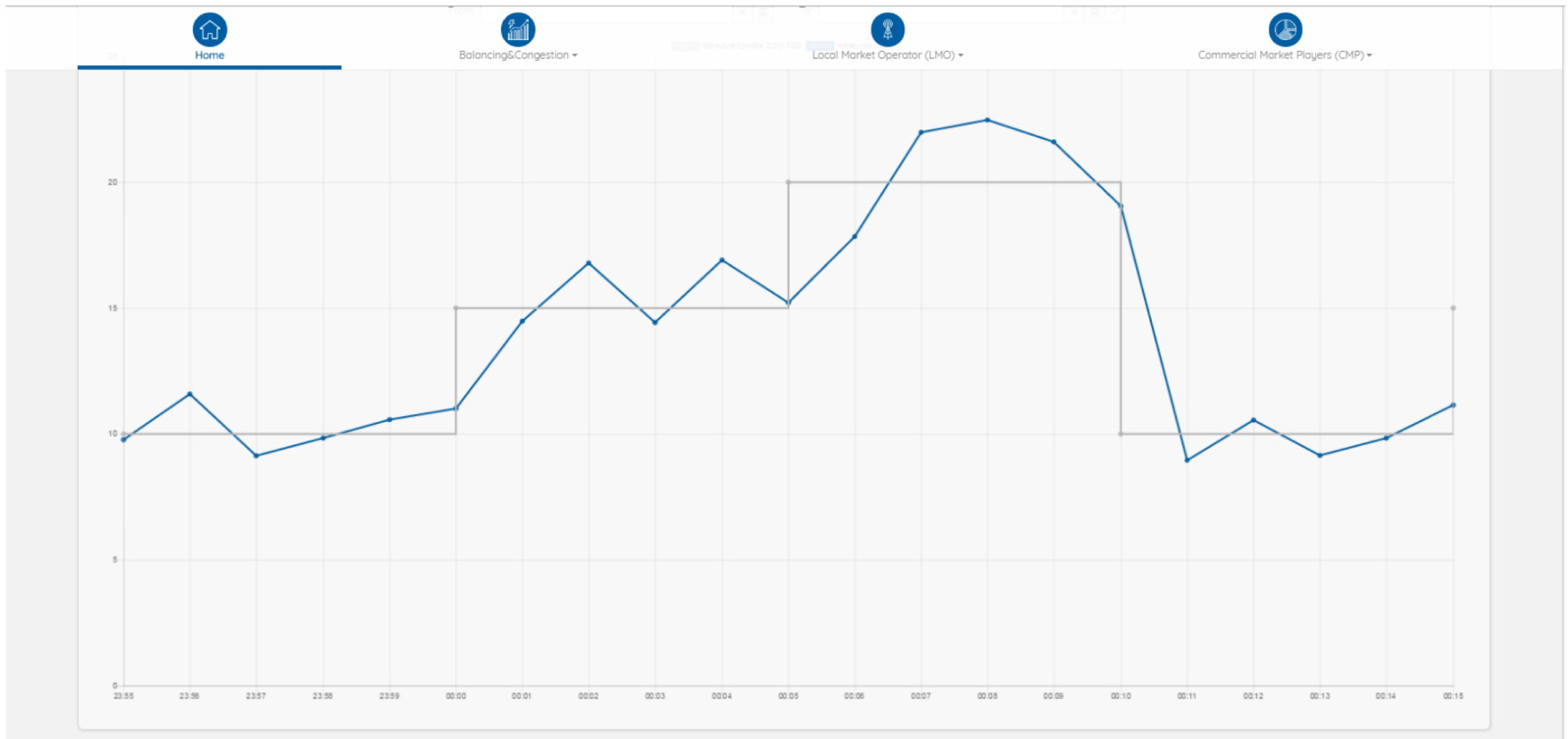
Market Clearing

$$k : \begin{cases} lb_{gk}^+ = 1 \\ lb_{gk+1}^+ = 0 \end{cases}$$

Price bid block $k \in K_g$
for generator g

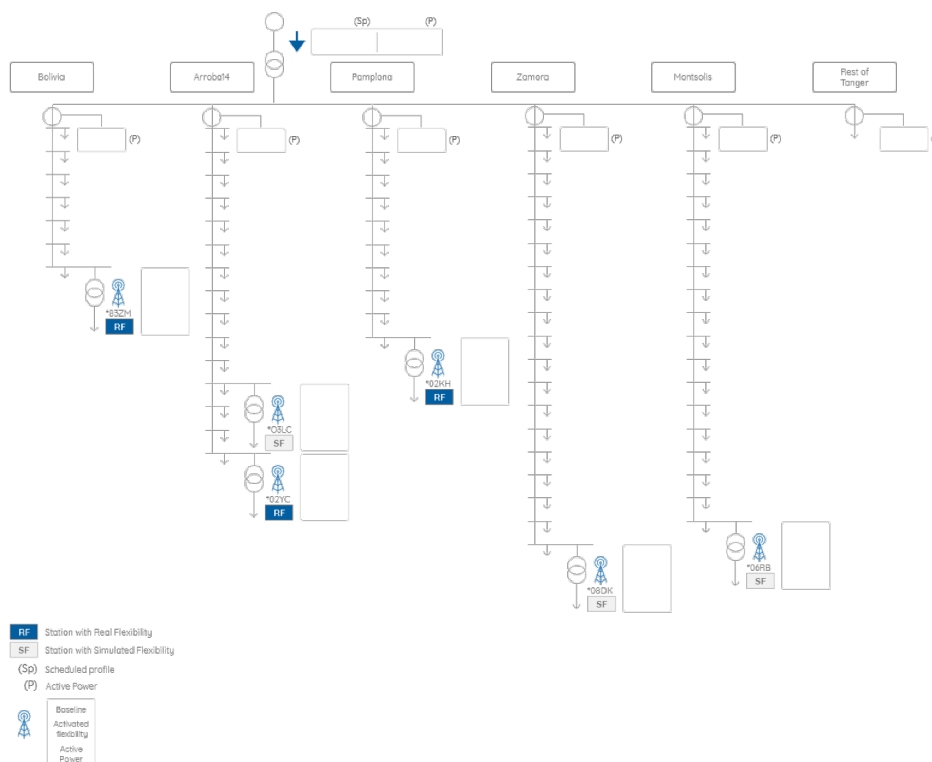
Balancing

- Time plot of active power exchanged at TSO-DSO interconnection points
 - Scheduled profile (MW)
 - Actual active power measured data (MW)
 - 1 plot per each TSO-DSO interconnection point in Pilot C
 - Adjustable time filter (window)



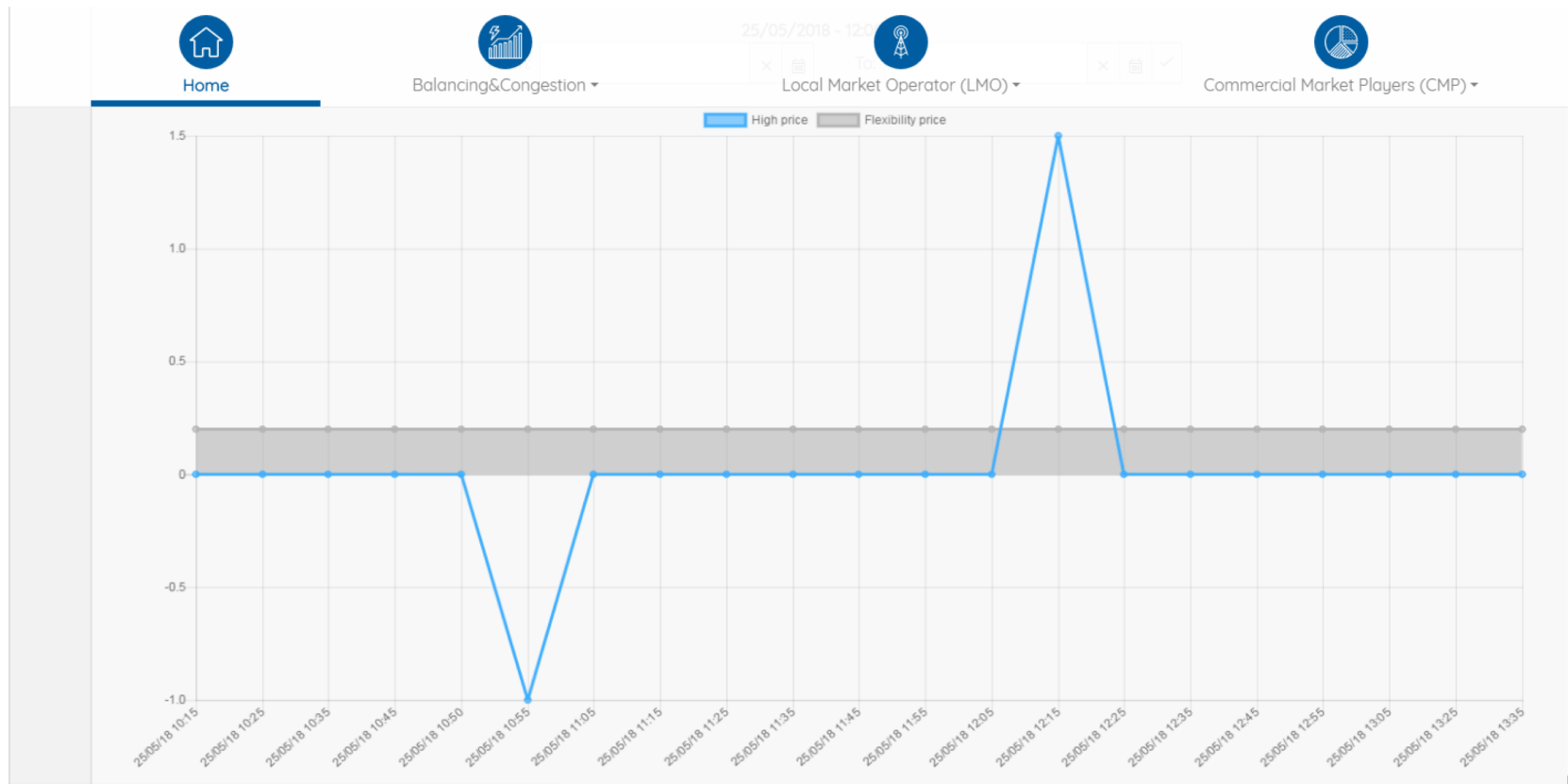
Network status

- Diagram of the distribution network downstream each TSO-DSO interconnection point
 - Voltage levels per node
 - Branch loadings (lines/cables, transformers)
 - Actual delivery of flexibility resources of the Pilot C (VODAFONE and virtual)
 - Updated every 1 minute



Market price

- Time plot of the clearing price per market session at each TSO-DSO interconnection point (cent/kWh)
 - 1 plot per each TSO-DSO interconnection point in Pilot C
 - Adjustable time filter (window)



Flexibility & Market results (dispatching)

- Flexibility:
 - Time plot of **total flexibility volumes** per market session at each TSO-DSO interconnection point (kW)
 - Dispatched flexibility
 - Available flexibility volumes
 - Time window with few recent market sessions
- Market results (dispatching):
 - Table of **dispatched flexibility volumes per CMP** per market session and node at each TSO-DSO interconnection point (kW)



LMO
Local Market Operator

Fusce sed bibendum ipsum. Nulla nulla nisl,
tempus eget interdum et, consectetur a nisl.
Fusce aliquet purus quis felis dignissim dapibus.
Nullam quis auctor quam.

Station	Flexibility price	High price	Market Flexibility
Tanger	0.18	0.20	145
Besòs	0.16	0.20	162
Vilanova	0.16	0.20	170
Maragall	0.18	0.20	155
Hostafranc	0.19	0.20	145

[Find out more](#)

CMP bids

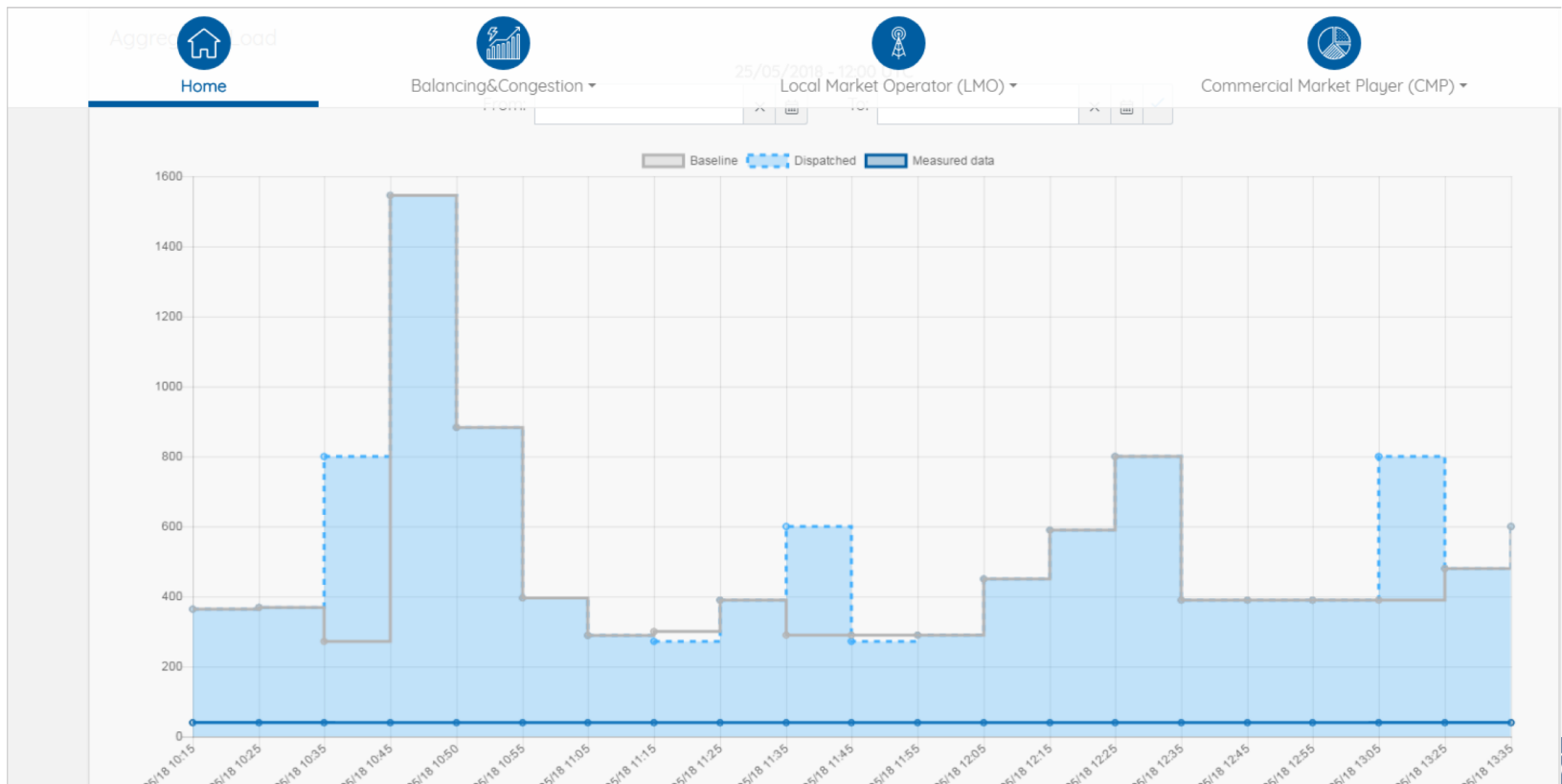
- Table of submitted flexibility bids per CMP per market session and node at each TSO-DSO interconnection point
 - Curtailable/non-curtailable bid blocks
 - Real/virtual CMP

CMP bids

CMP	Market time	Curtailable	Node	Price (€/kWh)	P (kW)	Virtual	
ONE	2017-02-13T23:55:00Z	no	6	0.32	2.5	No	^
TWO	2017-02-13T23:55:00Z	no	10	0.26	7.5	Yes	
V2G	2017-02-13T23:55:00Z	yes	7	0.28	50	Yes	
ONE	2017-02-14T00:00:00Z	no	6	0.32	2.5	No	
TWO	2017-02-14T00:00:00Z	no	10	0.26	7.5	Yes	
V2G	2017-02-14T00:00:00Z	yes	7	0.28	57	Yes	
V2G	2017-02-14T00:00:00Z	yes	7	0.28	-10	Yes	▼

CMPs (aggregated load)

- Time plot of aggregated load of customers' portfolio of each CMP
 - Baseline (yellow)
 - Dispatched power, i.e. (baseline + dispatched flexibility) (green)
 - Delivered (measured) power (brown)



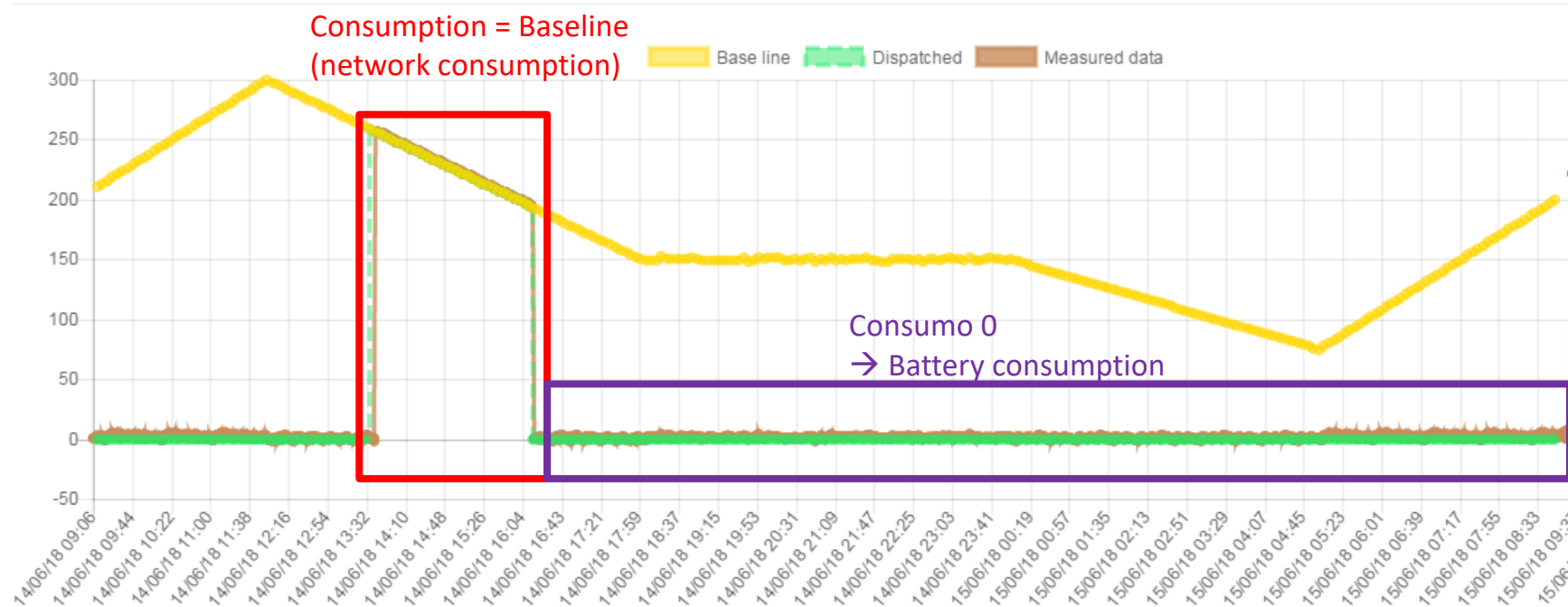
VCMP01

Sate: Running

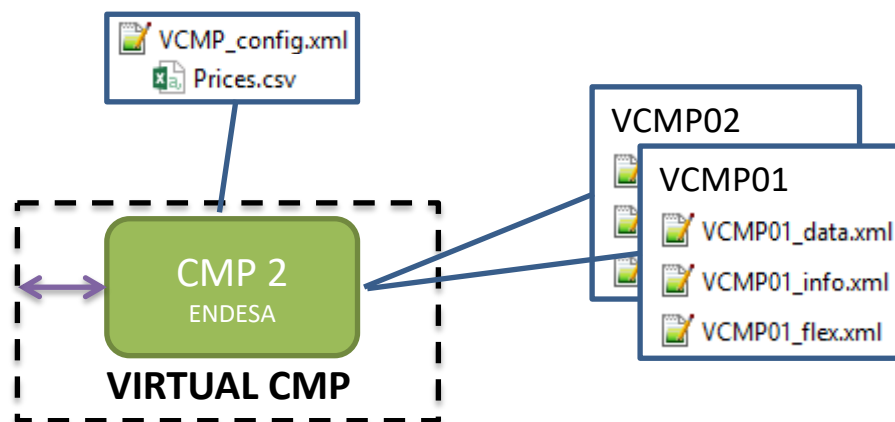
18/06/2018 06:52:21 UTC

Time Filter ▼

Aggregated Load

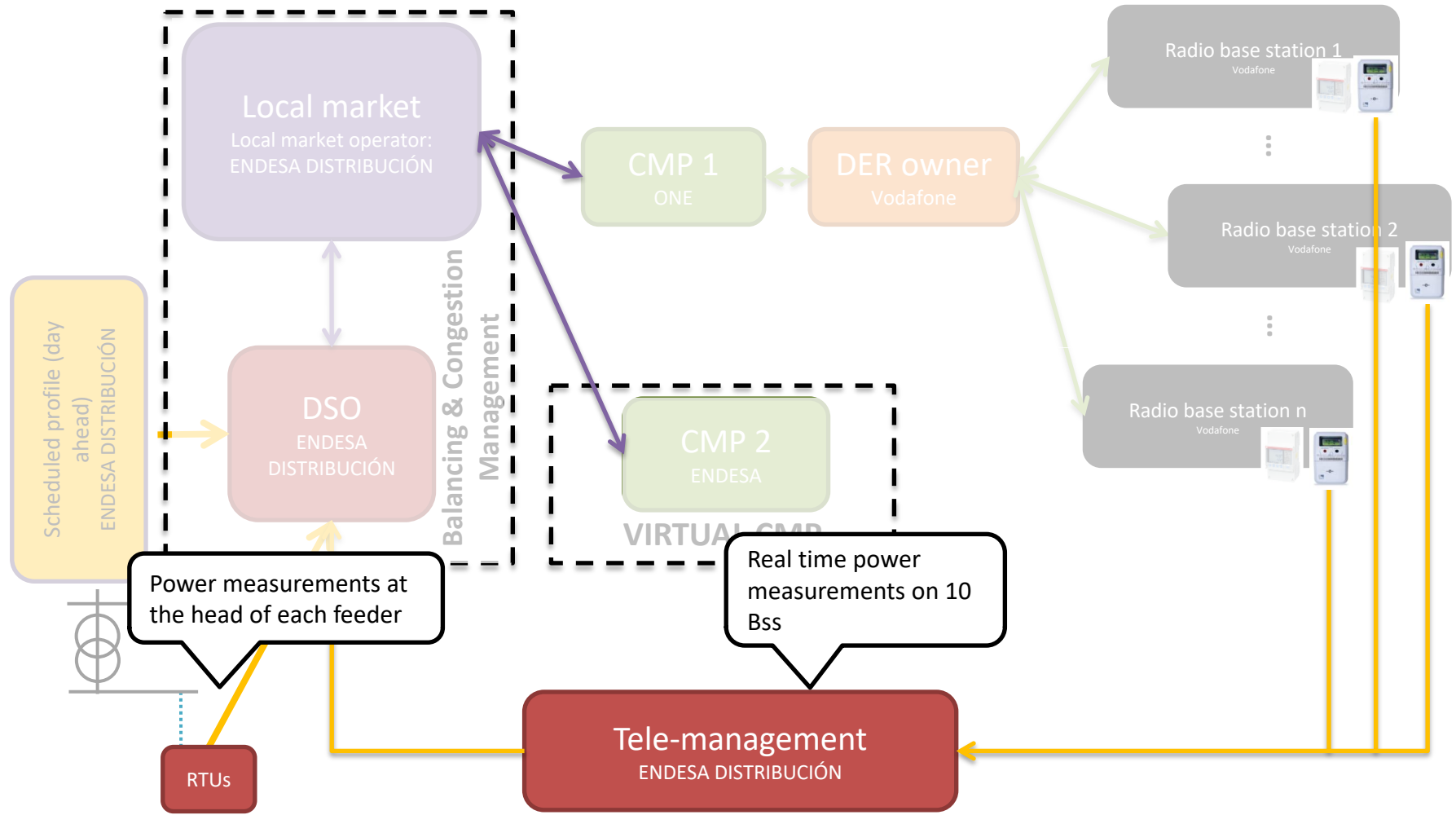


Pilot C: Virtual CMP

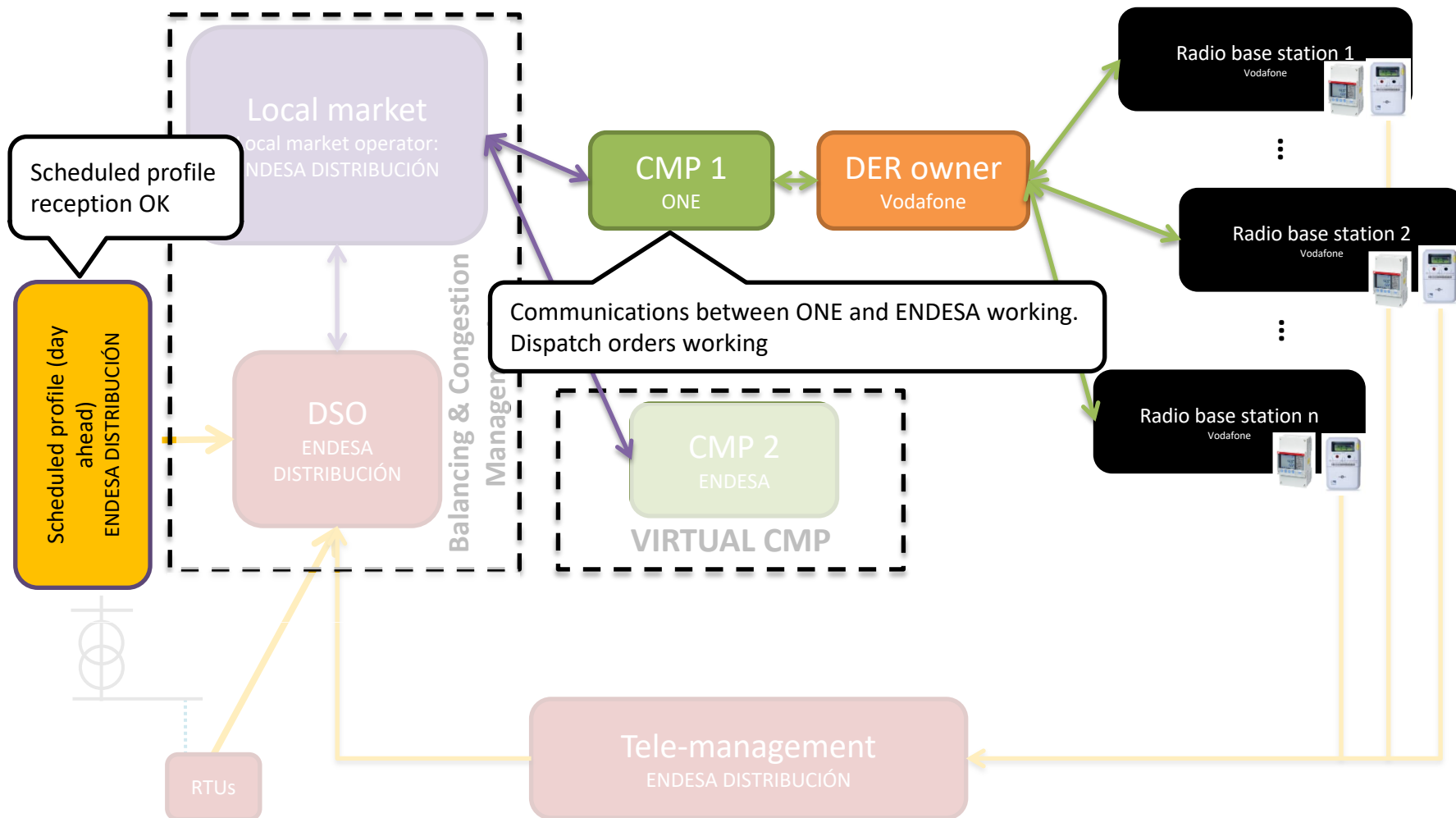


```
=====
Information Process Send virtual measurements 21-Mar-18 15:11:00 time now 21-Mar-18 15:11:00 processing message...
VCMP01 Information Process Loaded VCMP01_flex.xml
Information Process next measurements time at 2018-03-21T15:12:00Z
Information Process
=====
Available VCMPs
VCMP01 satus: run    next bid_baselines at: 2018-03-21T15:13:55Z
-----
Next virtual measures will be send at: 2018-03-21T15:12:00Z
```

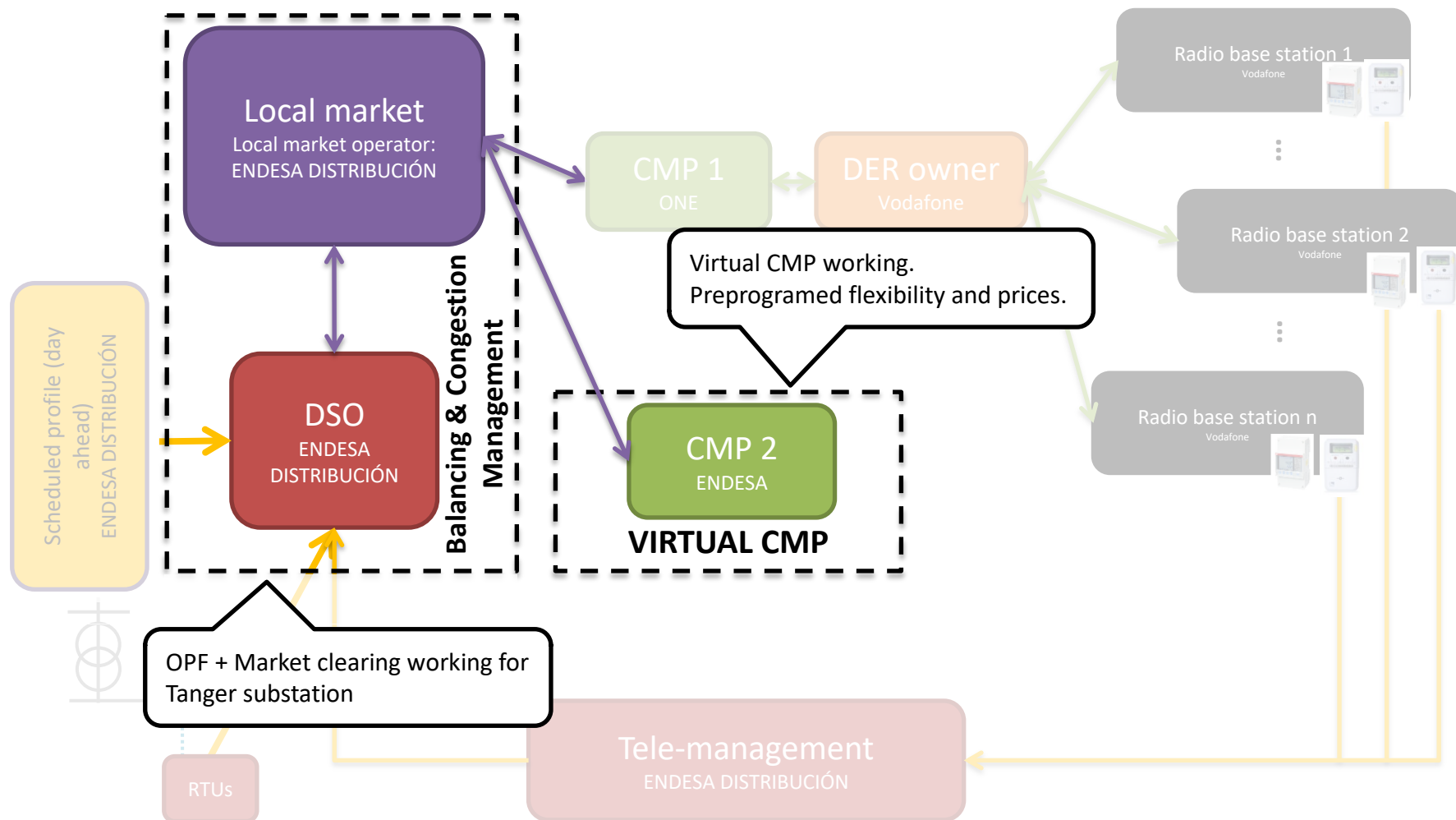

Progress so far



Progress so far



Progress so far



What has been done from the aggregation part

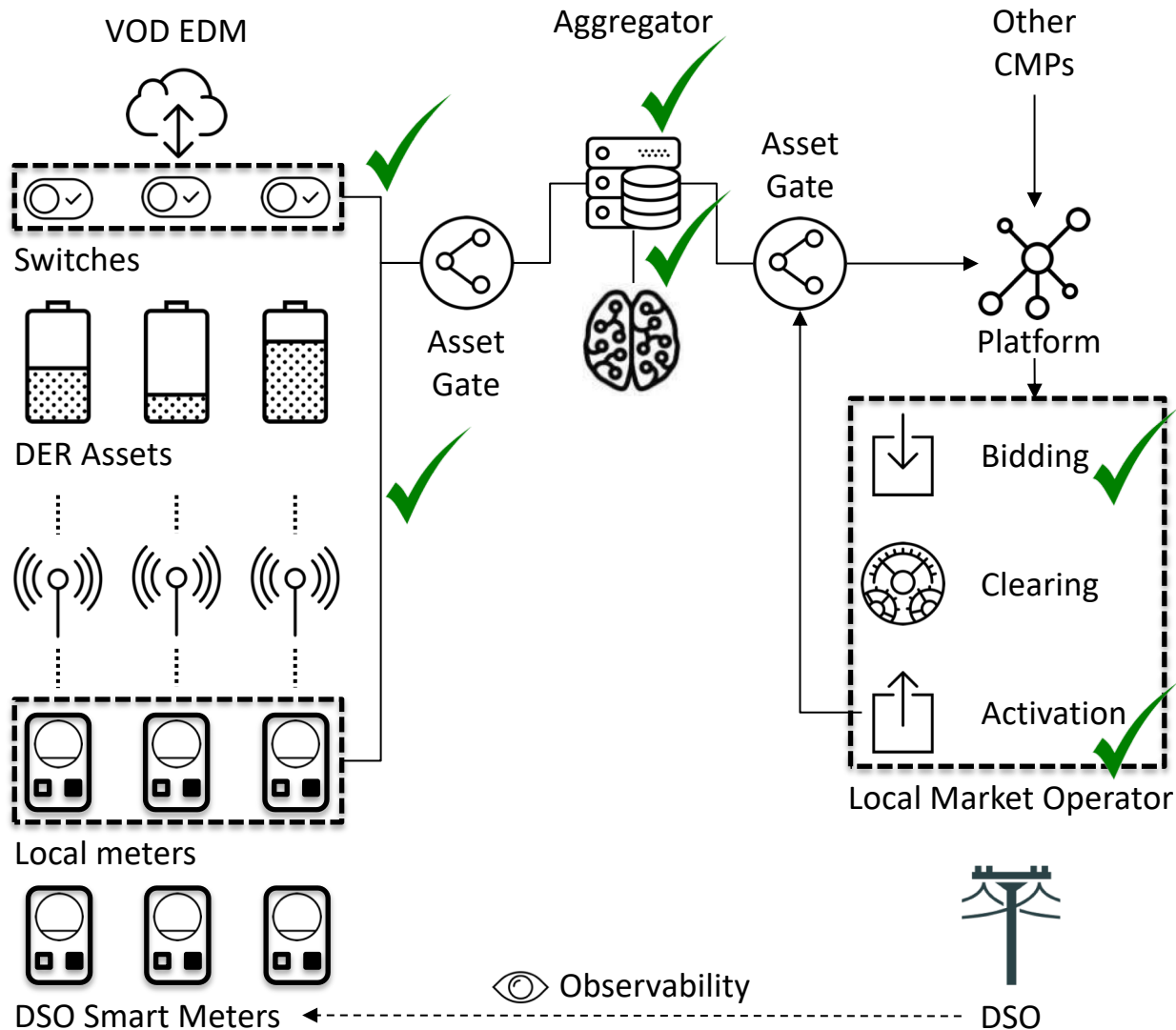
General WP5 tasks:

- AWS Server Maintenance
 - Memory increase
 - Execution time optimization
 - Latest Linux update
- Automatic clean up routines
- Database optimization
- Integration of market APIs
- Integration of REST server

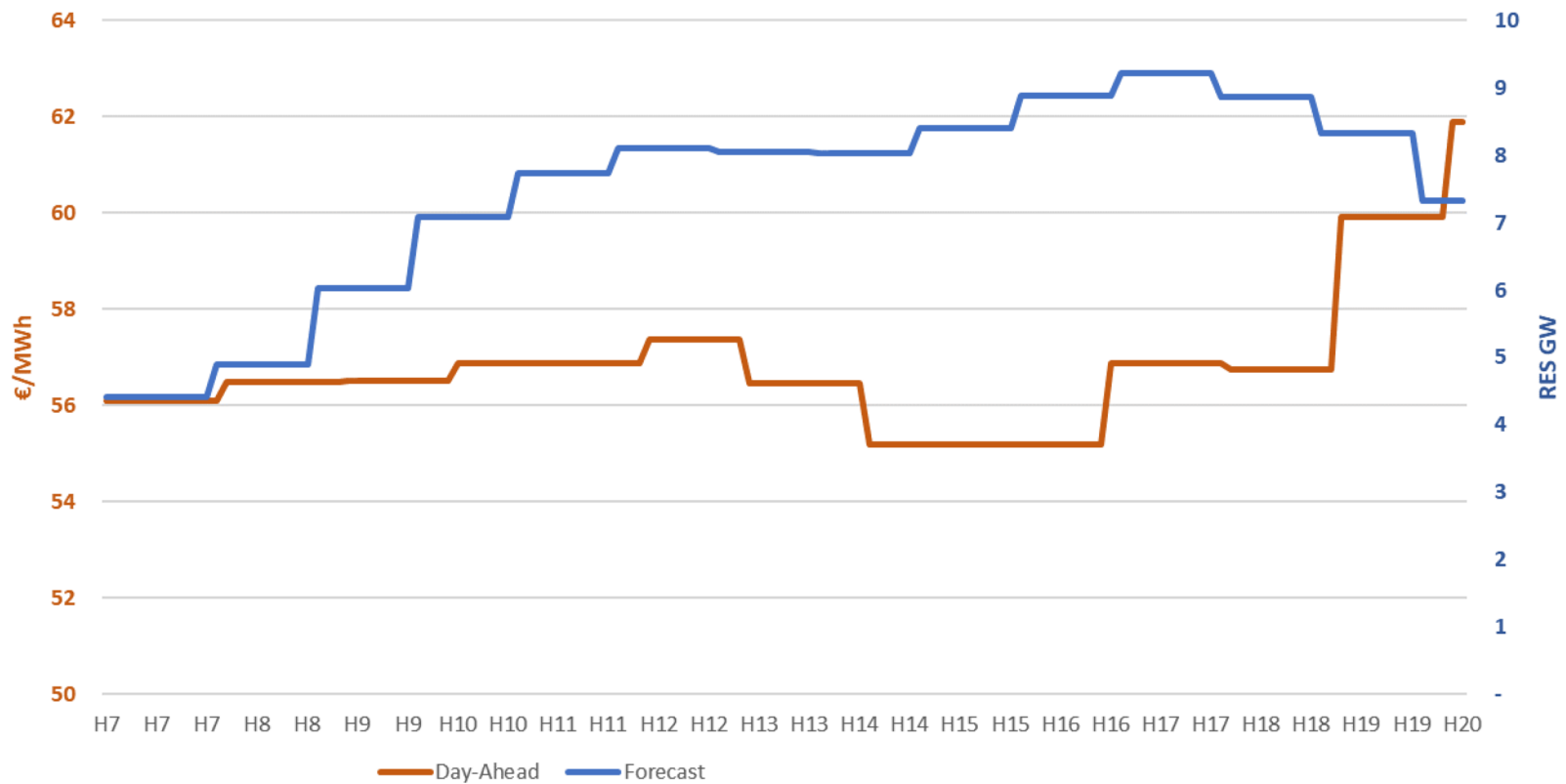
Pilot Specific:

- Update communication scripts
- Re-work scripts' to adapt to align with updated Pilot considerations
- Introduction of dynamic bidding strategy
- Script optimization
- Resolution of communication issues

Status

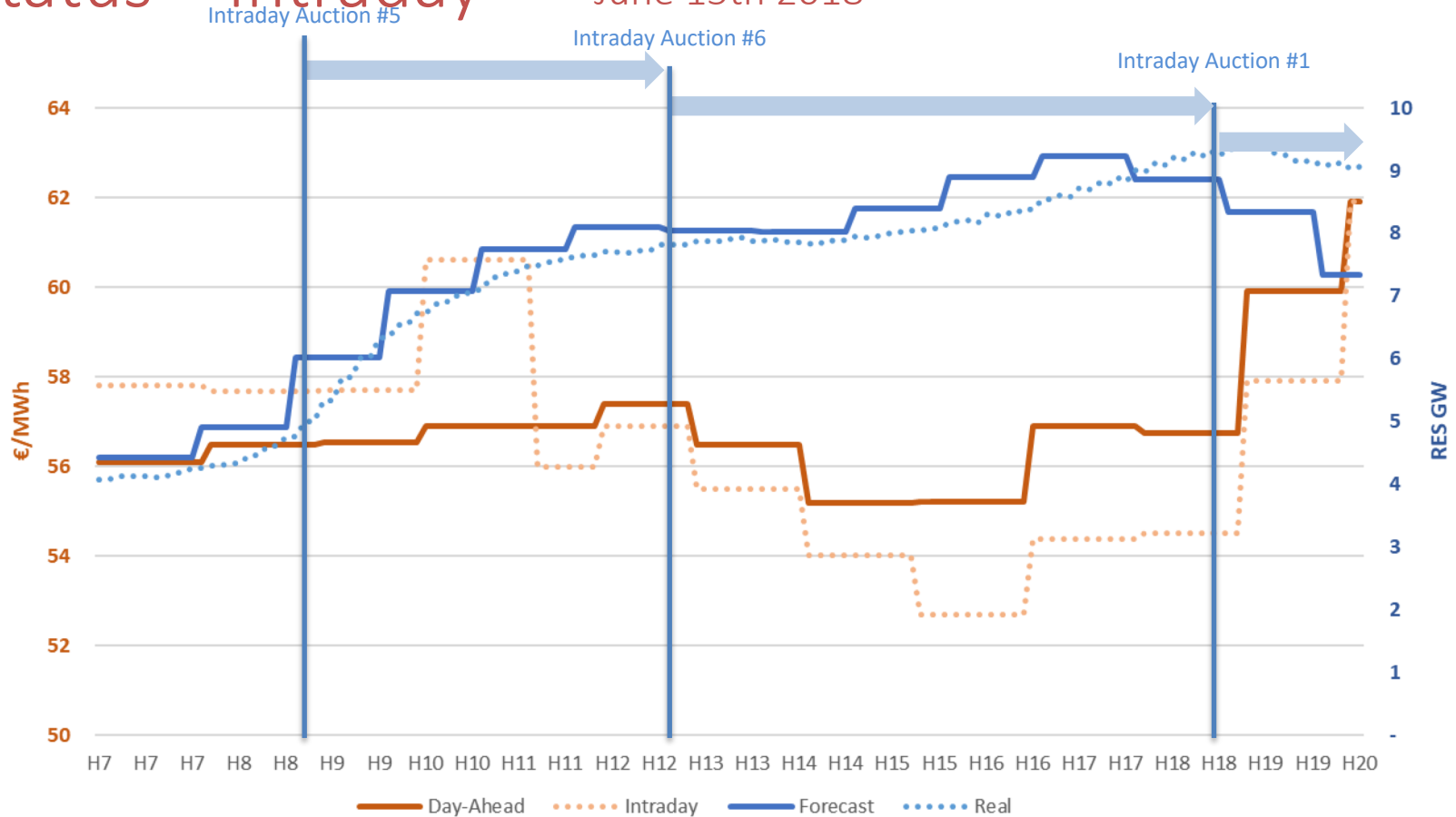


Status – Day Ahead June 15th 2018



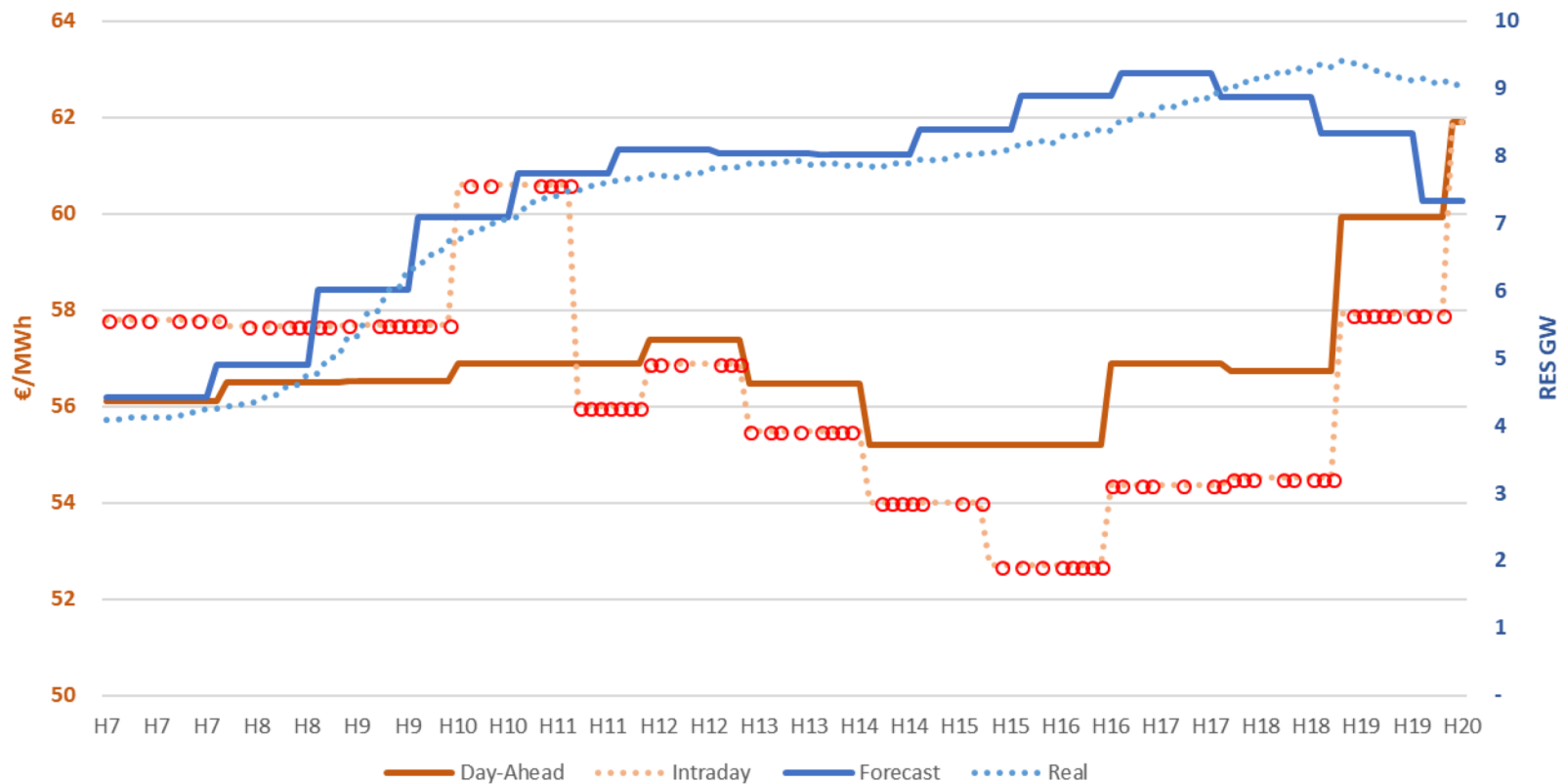
Status – Intraday

June 15th 2018



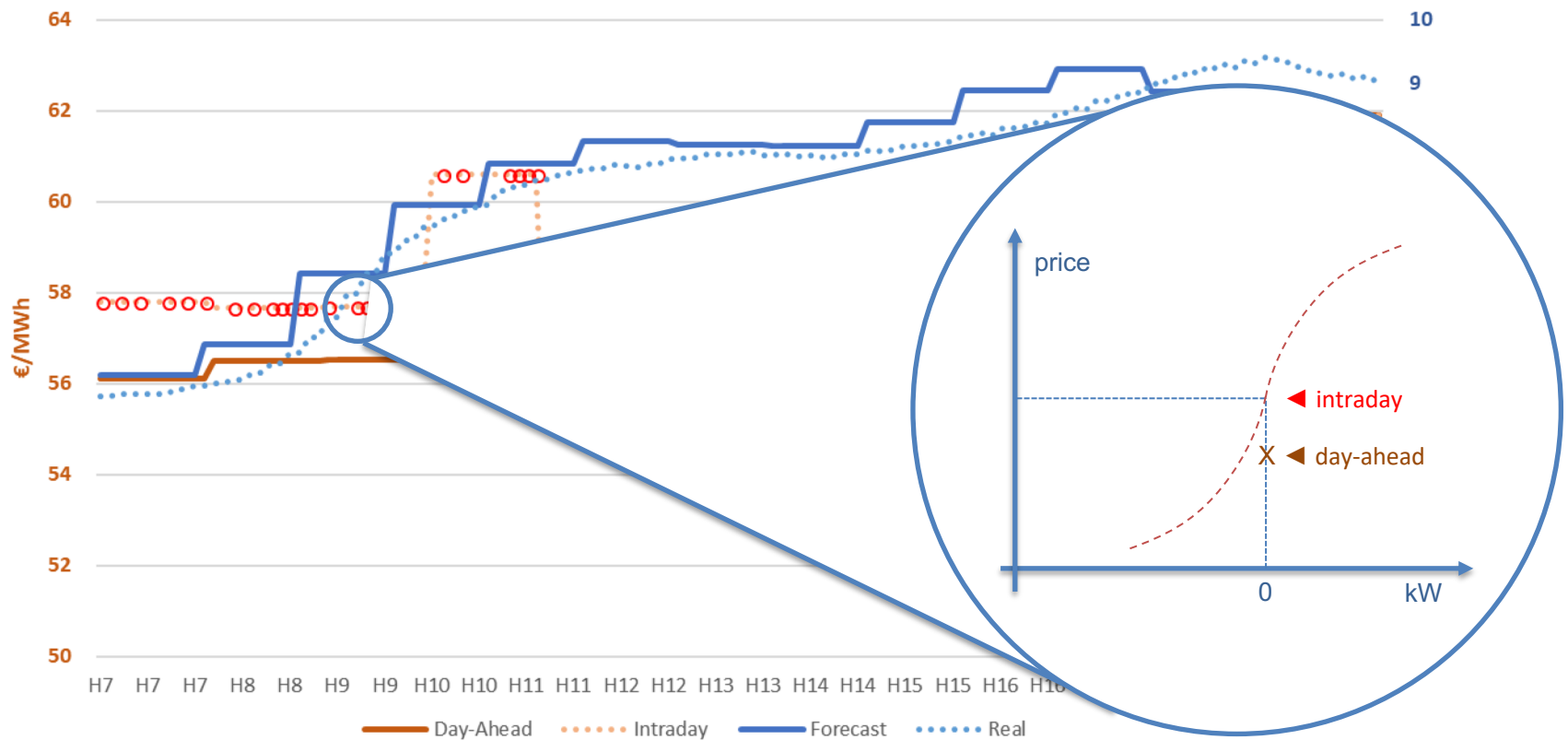
Status – Real Time

June 15th 2018



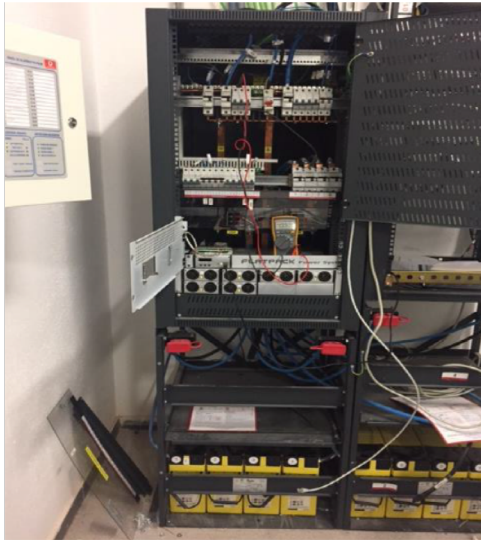
Status – Real Time

June 15th 2018

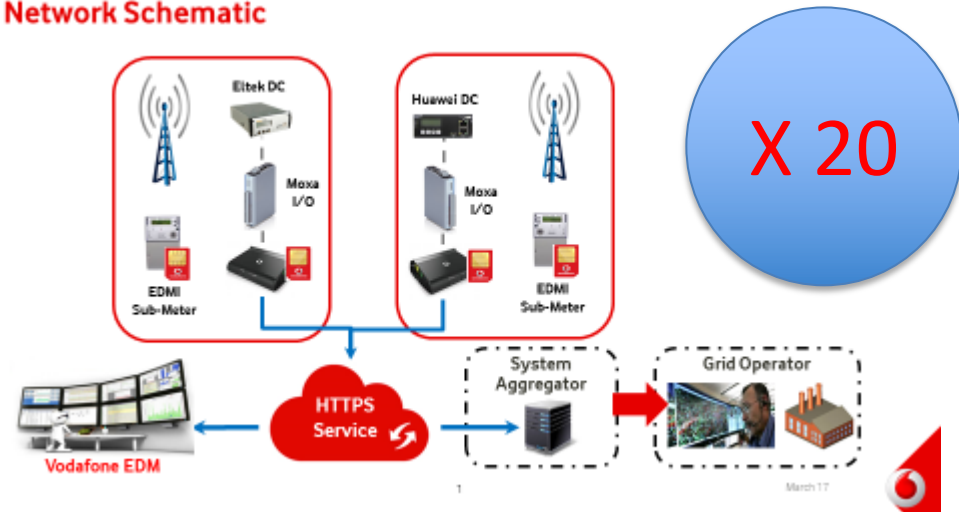


Pilot C - Physical Layer

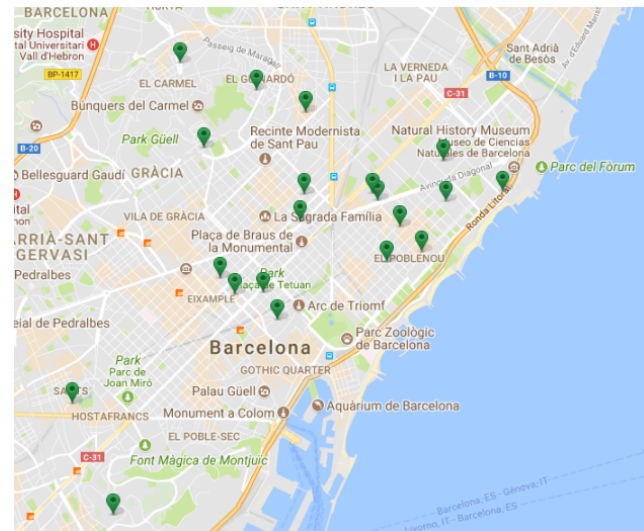
Vodafone BTS transformation into DER plants.



Network Schematic



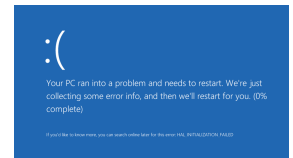
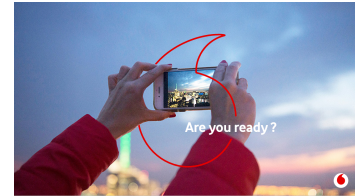
- **Curtailment principle** : integrate the remote battery test functionality to pilot the radio equipment switch to back up batteries on demand
- **Scenario**: 20 Radio Base stations equipped with
 - 48V controller SW: 2 brands – Eltek and Huawei
 - SNMP connection
 - Mobile Link 4G modem+ Moxa gateway
 - 4x12 V 100amph VRLA Batteries
 - 1 smart meter with 1mn slot readings



Test preparation – 12 months on a bumpy road....

Sensitive context to manage operation in 20 different locations

1. **Live business:** BTS's are delivering service to the public -> 0 impact rule
2. **Private location:** The BTS's are located on commercial or private premises -> logistic required for non permanent access authorization– e.g 6 months to get access for 48V cabin swap with cranes
3. **DER internal Quality of Sce:** Vodafone Network is submitted to freezing period for quality management - Regulator audits, Christmas period, etc ... - > no site access at all during 2 periods of 4 weeks within the last 6 months
4. **SW stability:** 48V controller software releases and unequal performances requiring unexpected manufacturers deep dive and solving patches delivery
5. **DER resource reliability:** Batteries back up requirement to be adjusted with pilot rules (95%) and obsolescence triggering physical change requests and potentially technology evolution from VRLA to Lithium batt. To follow-up
6. **Monitoring continuity:** Monitoring systems cabling sensitive requiring maintenance personal training and clear verification process.



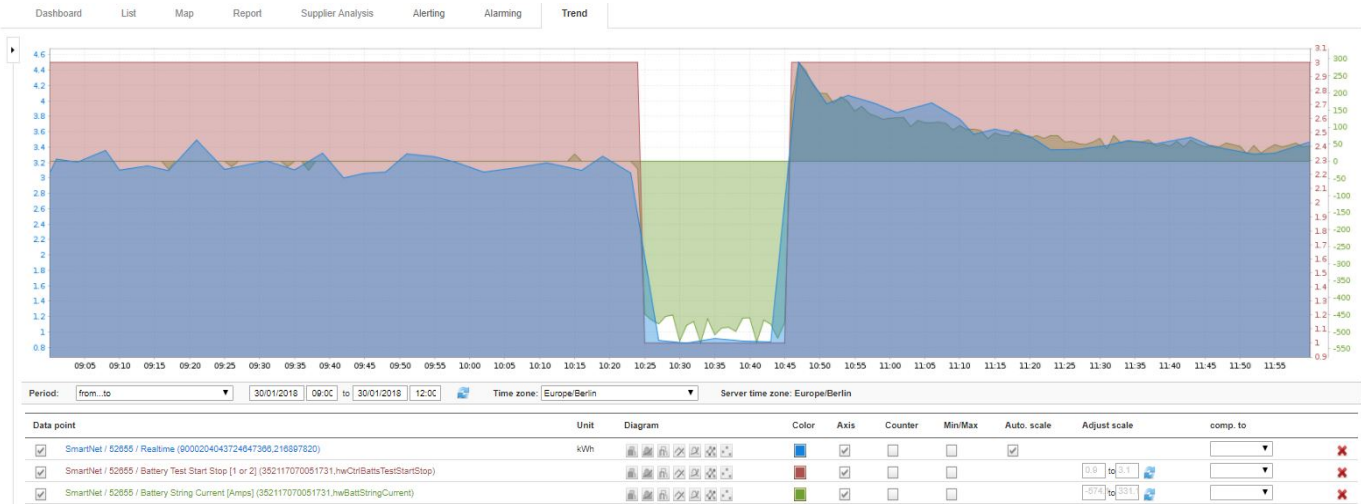
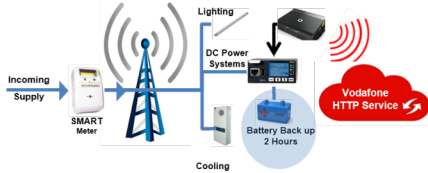
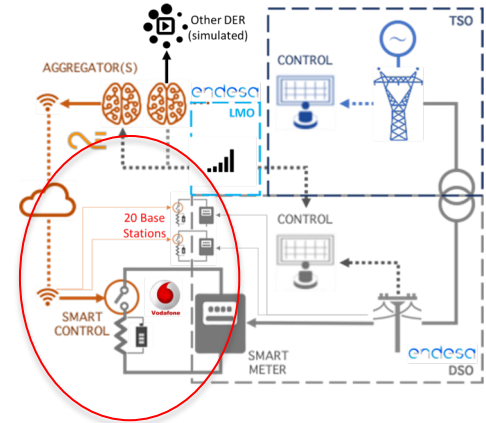
Field test: 80 to 95% operational

Feb 2018

Jun 2018: 90 to 100 Kw curtailable

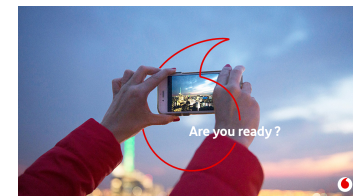
Selection	VF Site ID	Vodafone Name	PSU Type	Battery Status	Monitoring	Batt Test	Comment/Actions
POSTFRANC	618	B SANTS	Huawei	TBC	TBC	TBC	Cabinet swap 18th of Feb
TANCER	801	B PERU	Huawei	Good	Good	Working	Smart Meter Connectivity Issue
MARAGALL	801	B ERCILLA46	Eltek	Good	Good	Working	ok
VLARONDA	3208	B PALLARS	Eltek	TBC	TBC	TBC	Site Visit Required to Enable Remote Control
VLARONDA	3207	B CARTAGENA	Eltek	TBC	TBC	TBC	Site Visit Required to Enable Remote Control
SANLLEP	10946	B TOLRA51	Huawei	TBC	TBC	TBC	Cabinet swap 28th Jan
SANLLEP	11847	B MONTERRAT20	Eltek	Good	Good	Working	ok
VLARONDA	26435	B GRANVIAG653	Huawei	Good	Good	Working	ok
VLARONDA	28154	B TRAFALGAR21	Huawei	Good	Good	Working	ok
BEZOS	29424	B LLULL111	Eltek	Good	Good	Working	ok
VLARONDA	32652	B MALLORCA272	Huawei	Good	Good	Working	ok
BEZOS	52655	B DIAGONALMAR_U	Huawei	Good	Good	Working	ok
BEZOS	62806	B SANOFI SYNTHELABO AVENTIS_VPI	Eltek	Good	Good	Working	ok
VLARONDA	64936	B CN MONTJUICH	Eltek	Good	Good	Working	ok
VLARONDA	70903	B BAC DE RODA LLULL	Eltek	Good	Good	Working	ok
VLARONDA	76469	B BCNACTIVA	Eltek	Good	Good	Working	ok
MARAGALL	77879	B ARAGÀ_472	Huawei	Good	Good	Working	ok
MARAGALL	80263	B PS_MARAGALL74	Huawei	Good	Good	Working	ok
TANCER	85405	B LLACUNA_10	Eltek	Good	Good	Working	ok
VLARONDA	85407	B PALLARS_193	Eltek	Good	Good	Working	ok

VF Site ID	Vodafone Name	PSU Type	Battery Status	Monitoring	Batt Test	Comment/Actions
618	B SANTS	Huawei	Good	TBC	Good	Remote meter connectivity in test
621	B PERU	Huawei	Good	TBC	Good	Remote meter connectivity in test
801	B ERCILLA46	Eltek	Good	Good	Working	ok
3208	B PAUCULARIS	Eltek	Good	Good	Working	ok
5297	B CARTAGENA	Eltek	Good	Good	Working	ok
10048	B TOLRA51	Huawei	TBC	TBC	TBC	Coms issue on controller
11847	B MONTERRAT20	Eltek	Good	Good	Working	ok
26435	B GRANVIAG653	Huawei	Good	Good	Working	ok
28354	B TRAFALGAR21	Huawei	Good	Good	Working	ok
29424	B LLULL111	Eltek	Good	Good	Working	ok
52652	B MALLORCA272	Huawei	Good	Good	Working	ok
52655	B DIAGONALMAR_U	Huawei	Good	Good	Working	ok
62806	B SANOFI SYNTHELABO AVENTIS_VPI	Eltek	TBC	TBC	TBC	SNMP issue .
64936	B CN MONTJUICH	Eltek	TBC	LAG to repla	TBC	Replace ML4G
70903	B BAC DE RODA LLULL	Eltek	Good	Good	Working	ok
76469	B BCNACTIVA	Eltek	Good	Good	Working	ok
77879	B ARAGÀ_472	Huawei	Good	Good	Working	ok
80263	B PS_MARAGALL74	Huawei	Good	Good	Working	ok
85405	B LLACUNA_10	Eltek	Good	Good	Working	Equipment swap required
85407	B PALLARS_193	Eltek	Good	Good	Working	ok



Next: flexibility usage for the DER

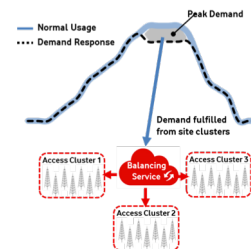
As many telecoms operators, Vodafone manages a vast technical and multi site estate, with installed energy backup to allow customer enjoying voice call and data speed in any circumstances.



In good grid conditions, the unused available capacity backup aggregated from Bases stations can be reused by the DSO for congestion management, and eventually avoiding costly ignition of thermic power plants. Vodafone by itself in EU could represent 250MW + of dispatchable load.



SmartNet benefits demonstration allowing a regulation change in the next years will help unlock the value of Vodafone small infrastructure power assets while contributing to the social welfare of European citizens.



SmartNet



SmartNet-Project.eu

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