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
To prove in real field the feasibility of the Shared balancing responsibility model of SmartNet project

Motivation

Goal achievements

- Validation of TSO-DSO interactions
  - Balancing (TSO level)
  - Congestion management (DSO level)
- Flexibility Aggregation
- Demand Response (Base stations)
- ICT communications
Coordination scheme

Shared balancing responsibility model
Coordination scheme

Shared balancing responsibility model

<table>
<thead>
<tr>
<th>Two different markets</th>
<th>Ancillary Service market for resources connected at TSO-grid</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Local Market for resources connected at DSO-grid</td>
</tr>
</tbody>
</table>

Ancillary services

Balancing in the interconnection point by respecting schedule profile (on behalf of TSO)

Congestion management in the distribution grid

How?

By using flexibility from DER owners through Commercial market parties
## Roles in the project

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

Main LMO Functionalities

- **DSO transfers their needs to solve congestion issues from the d-grid**
- **Comercial market participants send their bids and Baselines to the LMO**
- **Facilitates flexibility to solve congestion issues from the DSO**
- **Performs market clearing**
- **Facilitates flexibility for balancing at the TSO-DSO interconnection**
- **Acquires information from participants and broadcasts market results**

- **Local congestion management**
- **Performs market clearing**
- **Acquires information from participants and broadcasts market results**

**Balancing at TSO-DSO level**

**DER OWNERS (Flexible assets)**

**AGGREGATORS**
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

Local market
Local market operator: ENDESA DISTRIBUCIÓN

DSO
ENDESA DISTRIBUCIÓN

Balancing & Congestion Management

BCM

DB

Manager

Optimization

Information Process
------------------------------------------------------------------------------------------------------------------------
Active CMP:
ONE last bids: 2018-03-21T15:30:00Z
VEMP01 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

- Tele-management
- RTUs
- Scheduled profile (day ahead)

BCM

DB

mongoDB

Manager

Optimization

CMP
Pilot C: BCM - Optimization

Evaluate consumption with Sch.Prof. (MC – dmc)

Load the network status

Optimal Power Flow + Market Clearing

Send dispatch orders

End

MC = Market Clearing Time

MC = 5 min

dmc = 5 min

Messages

Connections to DB

Network(t-dmc..t)

Sch.Prof.(MC)

Sch.Prof.(MC–dmc)

Bids(t)

Baseline(t)

marketresults(t)

marketresults(t)
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

\[ P_{0k}^- > 0 \; \exists \; k \in K_g \]

Demand surplus

\[ P_{0k}^+ > 0 \; \exists \; k \in K_g \]

Insufficient generation

Congestion

\[ C_{ij} > 0 \; \exists \; (i, j) \]

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)
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

<table>
<thead>
<tr>
<th>CMP</th>
<th>Market time</th>
<th>Curtailable</th>
<th>Node</th>
<th>Price (€/kWh)</th>
<th>P (kW)</th>
<th>Virtual</th>
</tr>
</thead>
<tbody>
<tr>
<td>ONE</td>
<td>2017-02-13T23:55:00Z</td>
<td>no</td>
<td>6</td>
<td>0.32</td>
<td>2.5</td>
<td>No</td>
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<tr>
<td>TWO</td>
<td>2017-02-13T23:55:00Z</td>
<td>no</td>
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<td>0.28</td>
<td>7.5</td>
<td>Yes</td>
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<tr>
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<td>2017-02-13T23:55:00Z</td>
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<td>0.32</td>
<td>2.5</td>
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<td>yes</td>
<td>7</td>
<td>0.28</td>
<td>-10</td>
<td>Yes</td>
</tr>
</tbody>
</table>
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)
Consumption = Baseline (network consumption)

0 Consumption ⇒ Battery consumption
What has been done from the aggregation part
Status – Day Ahead

![Graph showing energy prices for Day Ahead and Forecast]
Status – Intraday

Intraday Auction

\(€/\text{MWh}\)

\(\text{RES GW}\)
Status – Real Time

BATTERY CHARGE

19:12:00 to 01:12:00

- 01EC
- 02DA
- 05RP
- 18RQ
- 22FR
- 60KC
- AVG
Pilot C - Physical Layer
Vodafone BTS transformation into DER plants.

- **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 100amp VRLA Batteries
  - 1 smart meter with 1mn slot readings
Field test: 90% operational

Feb 2018

Jun 2018: 90 to 100 Kw curtailable
Benefits of 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.
Thank You

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New Technologies & Innovation
Network Technology Iberia
Global Infrastructure & Networks

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