SmartNet Public Workshop
Showcase and debate on the results six month away from project end
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Simulation platform and preliminary results

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Introduction
Simulation activity in SmartNet

- Development of simulation software
- Definition of the reference scenario
  - Analysis of TSO-DSO coordination schemes
  - Definition of flexible devices profiles
  - Country-specific aspects and regulation
  - Network planning and operation
  - ICT specification and planning

- Cost Benefit Analysis
- Lab implementation of the simulation environment

Diagram:
- Physical layer
- Aggregation and bidding
- Market layer
- SQLite database

Software development and simulation environment

- Market layer
- Aggregation and bidding
- Physical layer
How the simulator works

Simulation based on three layers

Market layer

Bidding and dispatching layer

Physical layer

How the simulator works

Simulation based on three layers

Market layer

Bidding and dispatching layer

Physical layer
How the simulator works

Beginning of the simulation

The physical layer sends to aggregators:

- Current situation of devices
- Internal status of devices expected for the next time step
How the simulator works

How the bidding process is simulated

- Measurement of the devices status
- Evaluation of the available flexibility
- Construction of the flexibility bid
- Consideration of different markets

<table>
<thead>
<tr>
<th>time step $k$</th>
<th>time step $k+1$</th>
<th>time step $k+2$</th>
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<tr>
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How the simulator works

How the bidding process is simulated

Measurement of the devices status
(electric vehicle)

Current state of charge
Driver necessities
Mathematical model of EV

Optimization function

Total flexibility to sell

Measurement of the devices status
Evaluation of the available flexibility

Construction of the flexibility bid
Consideration of different markets

Consideration of different markets
Construction of the flexibility bid
Measurement of the devices status
How the simulator works

How the bidding process is simulated

Construction of the bid

- Optimization function
- Actual and forecasted cost of energy
- Eventual discomfort
- Bid reflecting the available flexibility and its cost

- Measurement of the devices status
- Evaluation of the available flexibility
- Construction of the flexibility bid
- Consideration of different markets

How the bidding process is simulated

- Construction of the bid
- Time step $k$
- Time step $k+1$
- Time step $k+2$
How the simulator works

How the bidding process is simulated

Market arbitrage

Market player → Flexibility bid → Real-time balancing market → Intra-day market

Intra-day market is not simulated, but its interference on the balancing market bidding is considered.

Consideration of different markets

- Measurement of the devices status
- Evaluation of the available flexibility
- Construction of the flexibility bid

Intra-day market is not simulated, but its interference on the balancing market bidding is considered.
How the simulator works
How the bidding process is simulated

Total flexibility of Electric Vehicles

- downward flexibility
- upward flexibility

23145 bids submitted
How the simulator works
How the bidding process is simulated

Flexibility cost of Electric Vehicles

- €/MWh
- time
- 06:00 09:00 12:00 15:00 18:00 21:00 00:00
- upward bid
- downward bid
How the simulator works

How the bidding process is simulated

Large power units (transmission system)
How the simulator works

How the bidding process is simulated

Total flexibility of Conventional Power Plants

30073 bids submitted
How the simulator works

How the bidding process is simulated

Flexibility cost of Conventional Power Plants

- €/MWh
- 06:00 09:00 12:00 15:00 18:00 21:00 00:00
- time
- upward bid
- downward bid
How the simulator works

How the bidding process is simulated

Distribution networks

Aggregator of curtailable generators

SmartNet
How the simulator works

How the bidding process is simulated

Distribution networks

Aggregator of curtailable generators

Aggregator of storage-based devices
How the simulator works

How the bidding process is simulated

Aggregator of curtailable generators

Aggregator of storage-based devices

Aggregator of thermally controlled loads

Aggregator of shiftable loads

Aggregator of dimmable loads
Total flexibility of Thermostatically Controlled Loads

- if aggregated per transmission node: 82848 bids submitted
- if aggregated per distribution node: 152020 bids submitted
How the simulator works

How the market process is simulated

- **Estimation of the network state at \( k+1 \)**
- **Collection of the bids from market players**
- **Market clearing process**
- **Communication of the accepted bids**
How the simulator works

How the market process is simulated

Estimation of the network state at $k+1$

The most updated status of the network is communicated from the physical layer.

Forecasting error is simulated assuming that it is decreasing in time.

Estimation of network imbalance and congestion status at $k+1$

Collection of the bids from market players

Market clearing process

Communication of the accepted bids
Simulation of the forecasting error
(exchange power profile in one primary substation)
How the simulator works

How the market process is simulated

Collection of the bids and market clearing

- Bids from transmission system devices
- Bids from distribution system devices

Market clearing process

- Market clearing algorithm
- Model of the transmission system
- Model of the distribution system

Estimation of the network state at $k+1$

Collection of the bids from market players

Communication of the accepted bids

Collections of bids

Market clearing process

Model of the transmission system

Model of the distribution system

Estimation of the network state at $k+1$
How the simulator works

How the market process is simulated

Collection of the bids and market clearing

- Bids from transmission system devices
- Bids from distribution system devices

Market clearing algorithm

Model of the transmission system
Model of the distribution system

Estimation of the network state at \( k+1 \)

Collection of the bids from market players

Market clearing process

Communication of the accepted bids

\[ \text{time step } k \]
\[ \text{time step } k+1 \]
\[ \text{time step } k+2 \]
How the simulator works

Collection of the bids and market clearing

- Bids from transmission system devices
- Bids from distribution system devices

Market clearing algorithm

Model of the transmission system
Model of the distribution system

Estimation of the network state at \( k+1 \)

Collection of the bids from market players

Market clearing process

Communication of the accepted bids

How the market process is simulated

TSO
DSO

Time steps:
- Time
- Time step \( k \)
- Time step \( k+1 \)
- Time step \( k+2 \)
How the simulator works

Communication of the market directives

- Network operations aimed at accommodating the activations

Estimation of the network state at $k+1$

Collection of the bids from market players

Market clearing process

Communication of the accepted bids
How the simulator works
How the market process is simulated

Bids submitted and accepted for Electric Vehicles

- **Blue line**: proposed quantity
- **Red line**: accepted quantity

MW

06:00 09:00 12:00 15:00 18:00 21:00 00:00

SmartNet
How the simulator works

How the market process is simulated

Bids submitted and accepted for Conventional Power Plants

- Blue line: proposed quantity
- Red line: accepted quantity

Legend:
- proposed quantity
- accepted quantity
How the simulator works
How the market process is simulated

Bids submitted and accepted for Curtailable Generation/Load

![Graph showing proposed and accepted quantities over time.](image-url)
How the simulator works

How the dispatching process is simulated

- Measurement of the devices status
- Evaluation of the available flexibility
- Optimal repartition of the activation signal

Physical layer

time

- time step $k$
- time step $k+1$
- time step $k+2$
How the simulator works

How the dispatching process is simulated

Measurement of the devices status

(Photovoltaic power plants)

- Maximum power
- Reactive power flexibility
- Maintenance costs
- Subsidies

Evaluation of the available flexibility

Optimal repartition of the activation signal

Optimization function

Available flexibility of each device

Measurement of the devices status

Maximum power

Reactive power flexibility

Maintenance costs

Subsidies
How the simulator works
How the dispatching process is simulated

Optimal repartition of the activation signal
(disaggregation)

- 100%
- 75%
- 10%
- 90%
- 50%

Measurement of the devices status
Evaluation of the available flexibility
Optimal repartition of the activation signal
How the simulator works

How the physical layer is simulated

- **Time step \( k + 1 \)**
  - Physics simulation of controllable devices
  - Network simulation
  - Low-level operations on network asset
  - Automatic Frequency Restoration (aFRR)

Diagram:
- **Market layer**
- **Physical layer**
- **Bidding and dispatching layer**

Timeline:
- Time
- Time step \( k \)
- Time step \( k + 1 \)
- Time step \( k + 2 \)
How the simulator works

How the physical layer is simulated

Thermostatically Controlled Load

- Environmental temperature
- Customers’ comfort and behavior
- Building thermal model
- Air conditioning system

Dynamic model

- Aggregator
- Temperature set-point

Active power consumption

Physics simulation of controllable devices

Network simulation

Low-level operations on network asset

Automatic Frequency Restoration

aFRR

time step \( k \)

time step \( k+1 \)

time step \( k+2 \)
How the simulator works

How the physical layer is simulated

**Distribution Network Simulation**
- Collection of the power exchange of each device
- Power flow of the distribution network

**Transmission Network Simulation**
- Power exchange of large devices and distribution networks
- Power flow of the transmission network

**Network simulation**
- Low-level operations on network asset
- Automatic Frequency Restoration
- Physics simulation of controllable devices

**time step \( k \)**

**time step \( k+1 \)**

**time step \( k+2 \)**
How the simulator works

Simulation results of a distribution network (no local market for congestion management)

High PV production determines voltage limits violations
How the simulator works

How the physical layer is simulated

Low-level network management operations

Network management in case of critical situations

- Automatic response of network asset
- Overvoltage and/or overloading of network buses and lines management
- Control of **Reactive Power**
- Control of **Active Power**
- Unwanted measures aimed at maintaining the safe grid operation

Time steps:
- Time
- Time step $k$
- Time step $k+1$
- Time step $k+2$
How the simulator works

How the physical layer is simulated

Unwanted Measure: Emergency curtailment of PV production
How the simulator works

How the physical layer is simulated

Unwanted Measures **with**/**without**

**local market** for distribution congestion management

![Graph showing MW over time with and without local market](image)
How the simulator works

How the physical layer is simulated

Unwanted measures cause imbalance

Unwanted measures

Imbalance caused by unwanted measures
How the simulator works

How the physical layer is simulated

**Automatic Frequency Restoration (aFRR)**

In case of imbalance, automatic controllers promptly activate reserves in order to mitigate it.

(the reserves will be restored later by balancing market)

- **Instantaneous imbalance level calculation**
- **Activation of resources by means of a control signal**
- **Re-simulation of the network**

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**Time step $k$**

- Physics simulation of controllable devices
- Network simulation
- Low-level operations on network asset
- **Automatic Frequency Restoration (aFRR)**

**Time**

**time step $k$**

**time step $k+1$**

**time step $k+2$**

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How the simulator works
How the physical layer is simulated

activated aFRR

MW

0

12:00

15:00

18:00

21:00

06:00

09:00

12:00

15:00

18:00

21:00

00:00

0

2000

4000

-2000

-4000

upward aFRR

downward aFRR
The simulated scenario has a time resolution of 15 minutes. The balancing market is simulated with a frequency of 60 minutes. It is supposed to have a latency of 15 minutes.
The simulated scenario has a time resolution of **15 minutes**. The balancing market is simulated with a frequency of **60 minutes**. It is supposed to have a latency of **15 minutes**.
Introduction
Simulation activity in SmartNet

SmartEST

Devices controllers
ICT equipment
SCADA/DMS SW and HW

Tests on physical equipment for TSO-DSO interactions

Software simulation
Market
bidding
dispatch

Real world

Lab implementation of the simulation environment
Laboratory activity
Distribution SCADA and Power Plant Controller

SmartNet simulator

Market

Bidding A

Dispatch A

Italian network

Bidding B

Dispatch B

PV inverter & RT network simulator

Power Plant controller

Distribution SCADA
Laboratory activity
Distribution SCADA and Power Plant Controller
Laboratory activity

Summer houses swimming pools in Denmark

SmartNet simulator

Market

Bidding A

Dispatch A

Danish network

Absorbed power

Summer houses swimming pools

Price signal

Swimming pools heaters aggregator

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Laboratory activity

Flexibility from battery backups of radio base stations

SmartNet simulator

Market

Bidding A

Dispatch A

Spanish network

interface

Absorbed power

Battery charge controller of radio base stations

Control signal

Radio base stations aggregator