European Utility Week

3 - 5 October 2017
RAI Amsterdam, The Netherlands

SmartNet

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

European Utility Week - October 2017 - Amsterdam

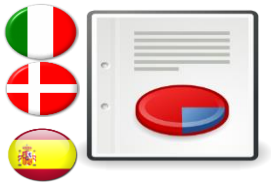
A simulation environment for analyzing ancillary services from distribution grids

Marco Rossi (RSE)

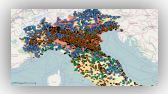
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691405

A simulation environment for analyzing ancillary services from distribution grids

SmartNet

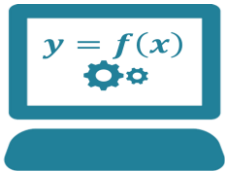


Development of realistic 2030 scenarios for the three reference countries



Italian case presented as example

Development of a simulation platform for the comparison of TSO-DSO coordination schemes

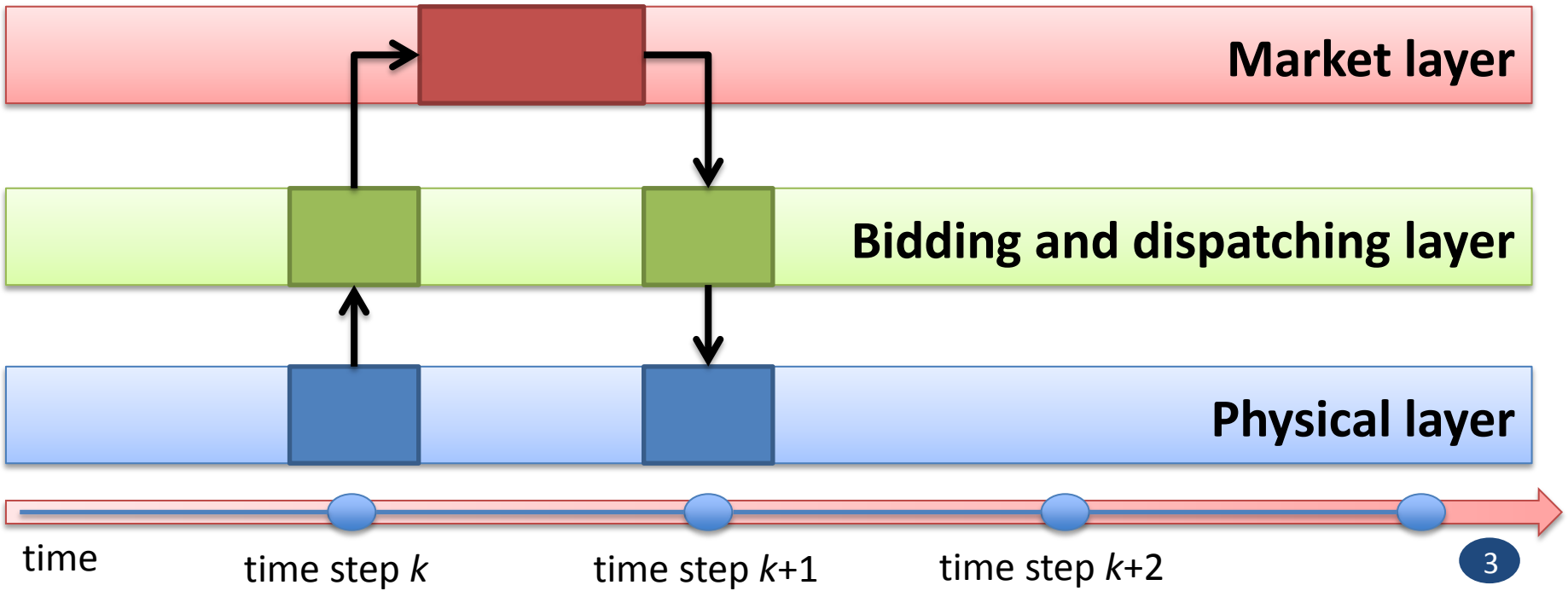


Presentation of the simulator working principles

Simulation of the potential distribution system contribution to ancillary services

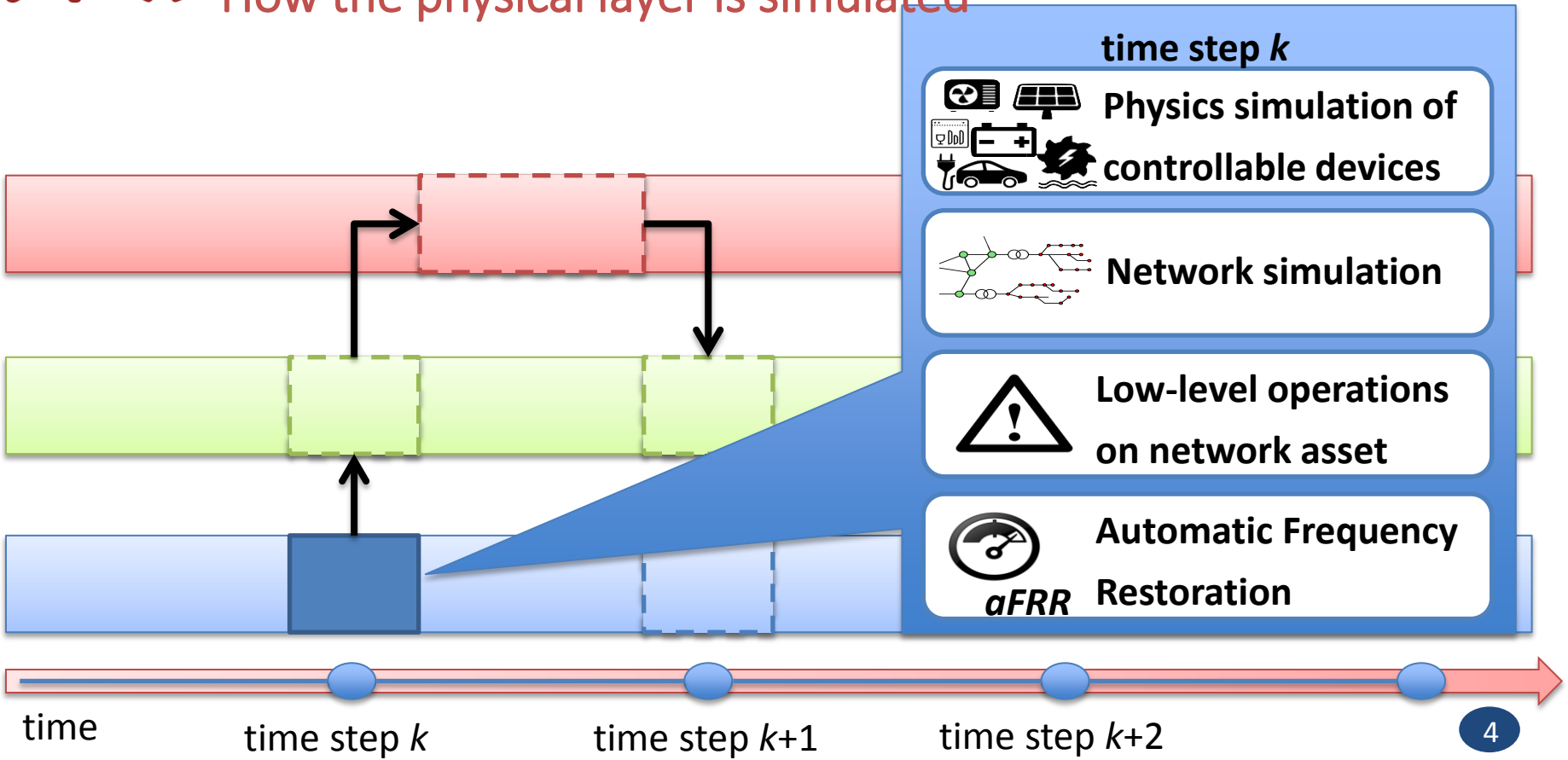
Simulation of real-time balancing market and congestion management

How the simulator works
Simulation based on three layers



How the simulator works

How the physical layer is simulated



How the simulator works

How the physical layer is simulated

Thermostatically Controlled Load

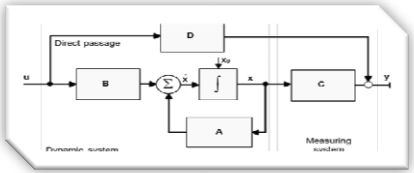
Environmental temperature

Customers' comfort and behavior

Building thermal model

Air conditioning system

Dynamic model



Active power consumption

Aggregator

Temperature set-point

time step *k*

Physics simulation of controllable devices

Network simulation

Low-level operations on network asset

aFRR Automatic Frequency Restoration

time

time step *k*

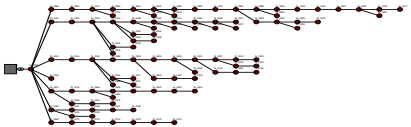
time step *k*+1

time step *k*+2

How the simulator works
How the physical layer is simulated

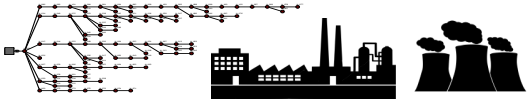
Distribution Network Simulation

Collection of the power exchange of each device

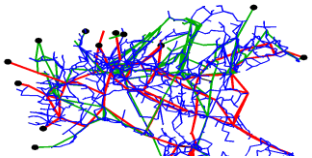


Power flow of the distribution network

Transmission Network Simulation



Power exchange of large devices and distribution networks



Power flow of the transmission network

time step *k*

Physics simulation of controllable devices

Network simulation

Low-level operations on network asset

aFRR

Automatic Frequency Restoration

time

time step *k*

time step *k*+1

time step *k*+2

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
- Network topology reconfiguration
- Failure of a device and/or network component (trip of protections)
- Overvoltage and/or overloading of network buses and lines

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

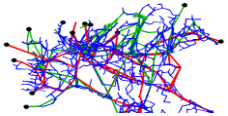
How the simulator works
How the physical layer is simulated

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

time step *k*

Physics simulation of controllable devices

Network simulation

Low-level operations on network asset

Automatic Frequency Restoration

aFRR

time

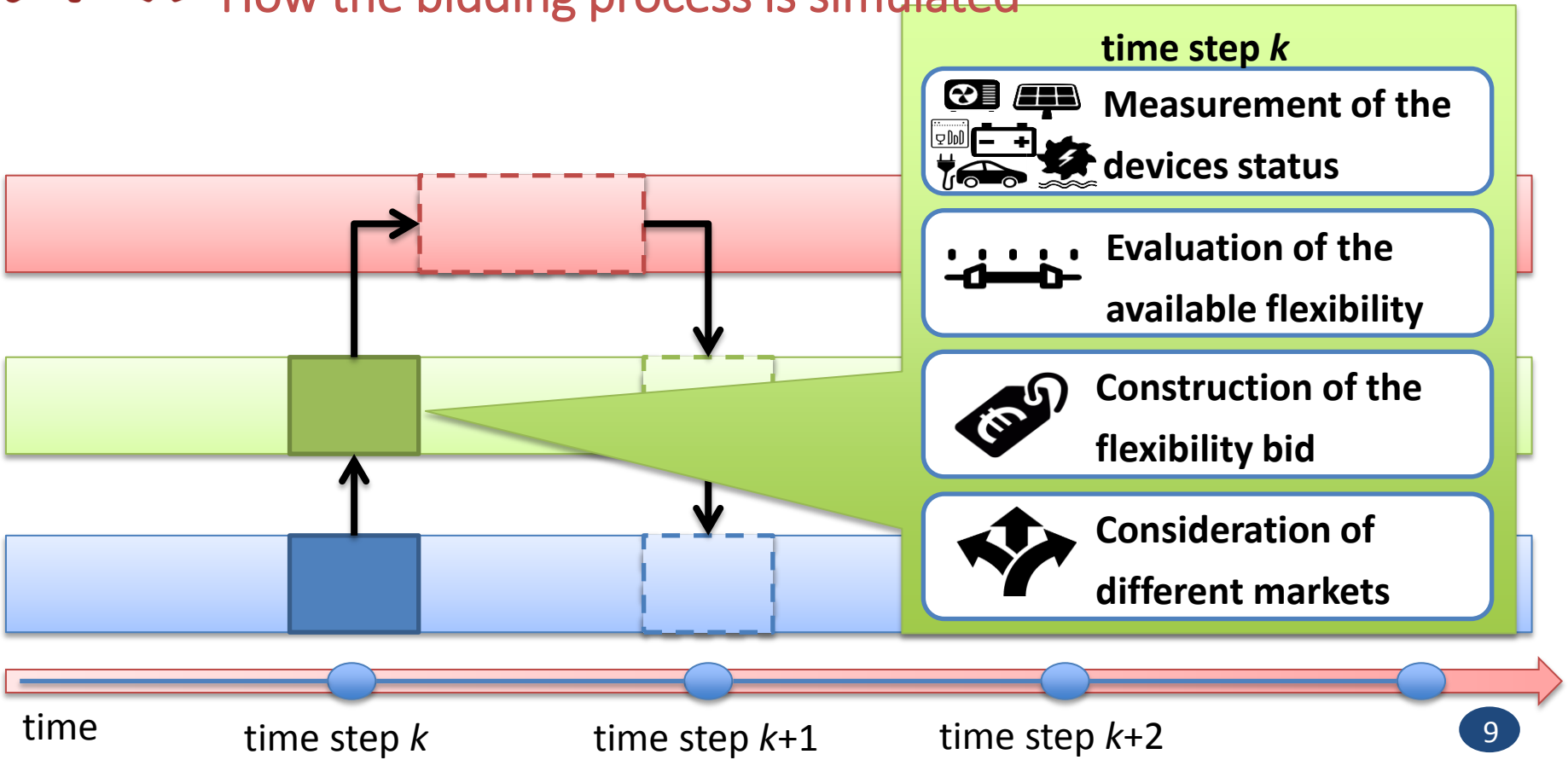
time step *k*

time step *k*+1

time step *k*+2

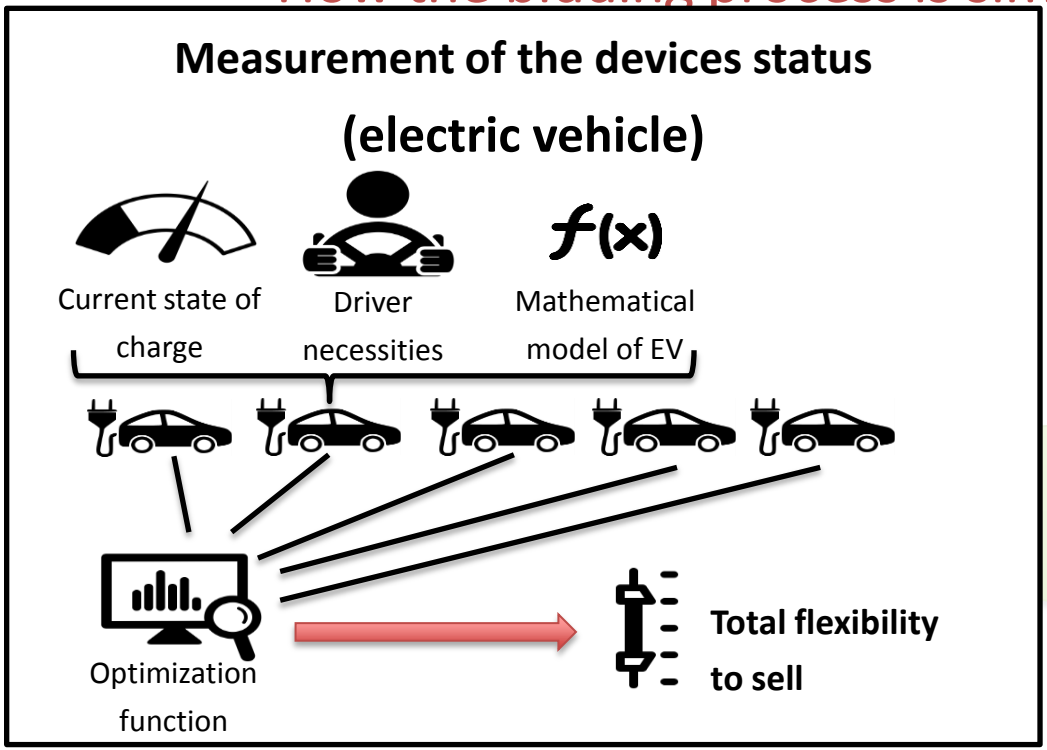
How the simulator works

How the bidding process is simulated



How the simulator works

How the bidding process is simulated



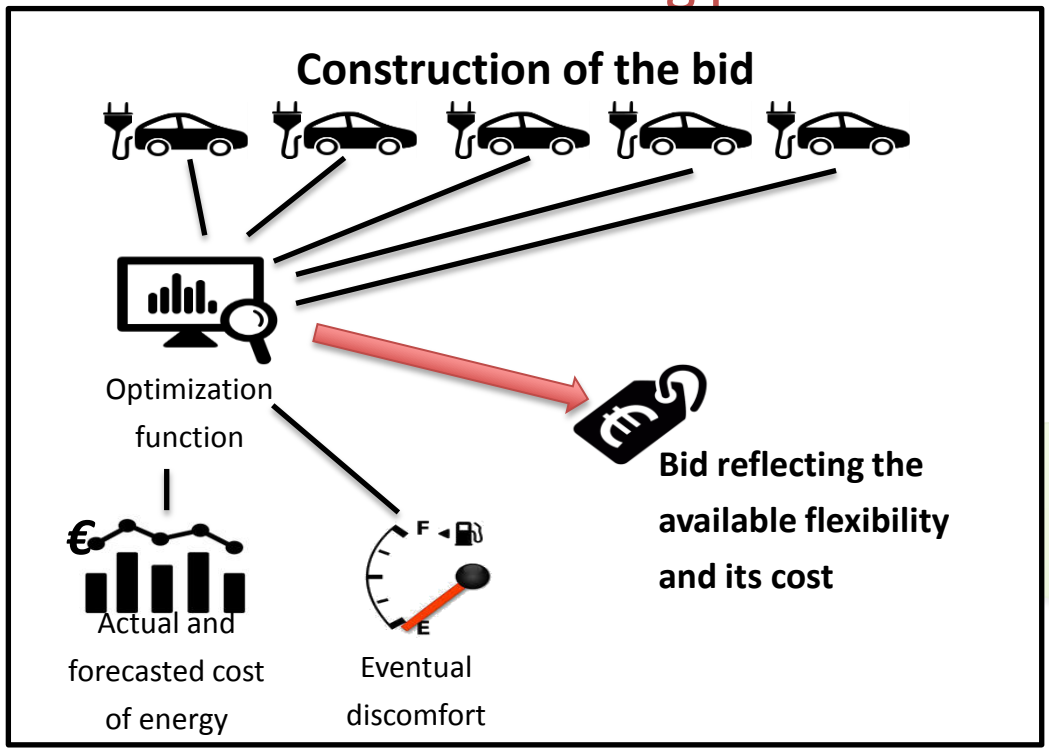
time step *k*

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

time | time step *k* | time step *k*+1 | time step *k*+2

How the simulator works

How the bidding process is simulated



time step *k*

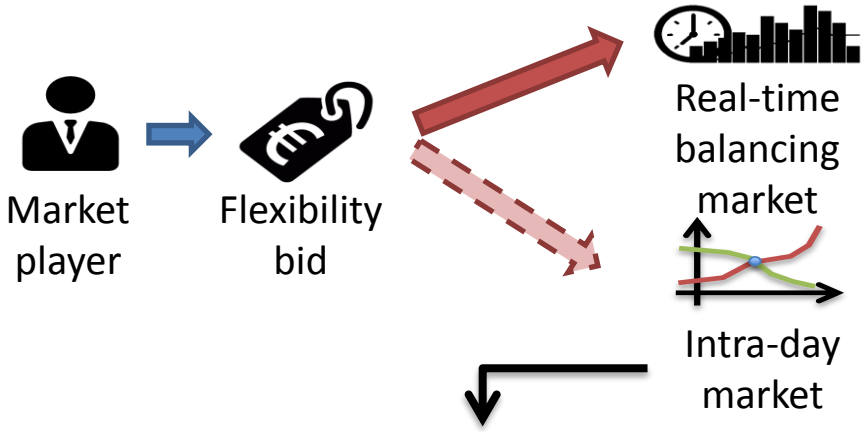
- Measurement of the devices status
- Evaluation of the available flexibility
- **Construction of the flexibility bid**
- Consideration of different markets

time | time step *k* | time step *k*+1 | time step *k*+2

How the simulator works

How the bidding process is simulated

Market arbitrage



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

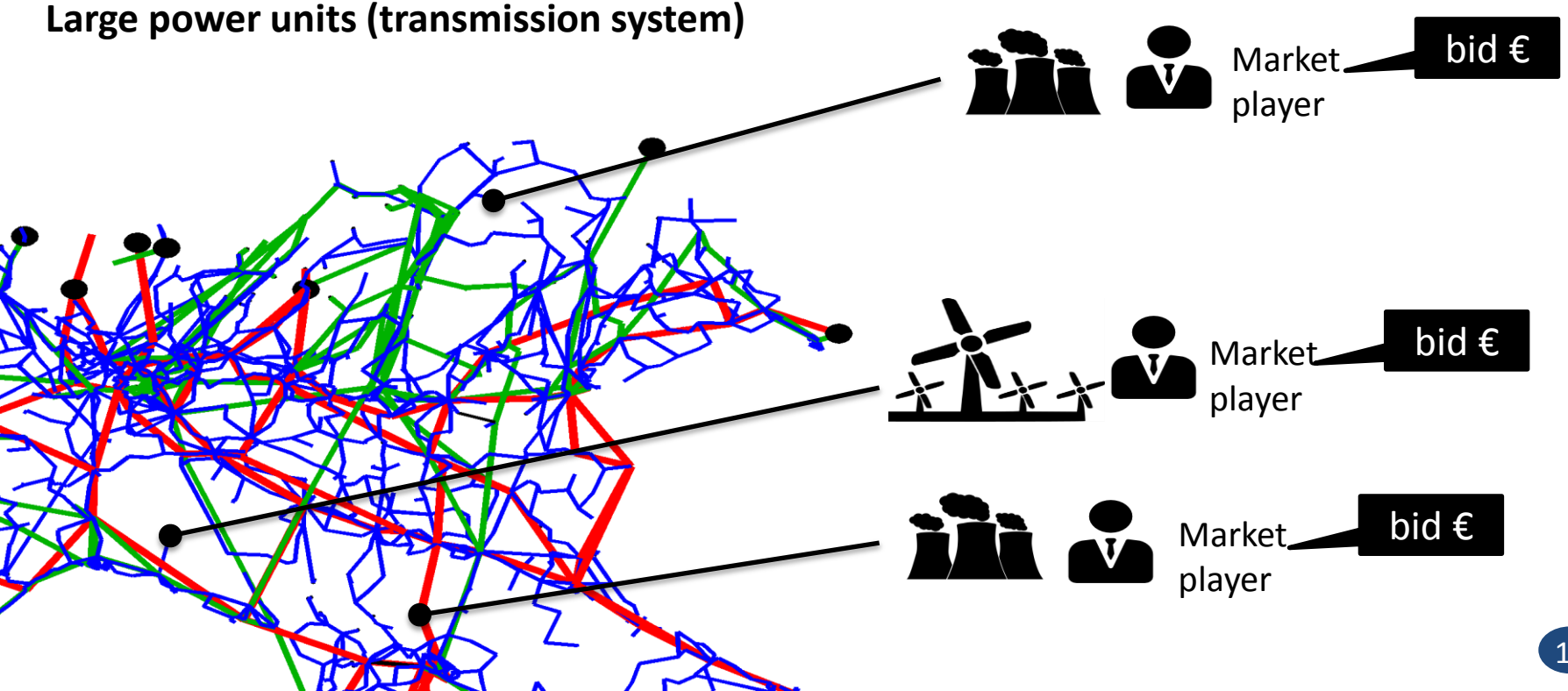
time step *k*

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

time | time step *k* | time step *k*+1 | time step *k*+2

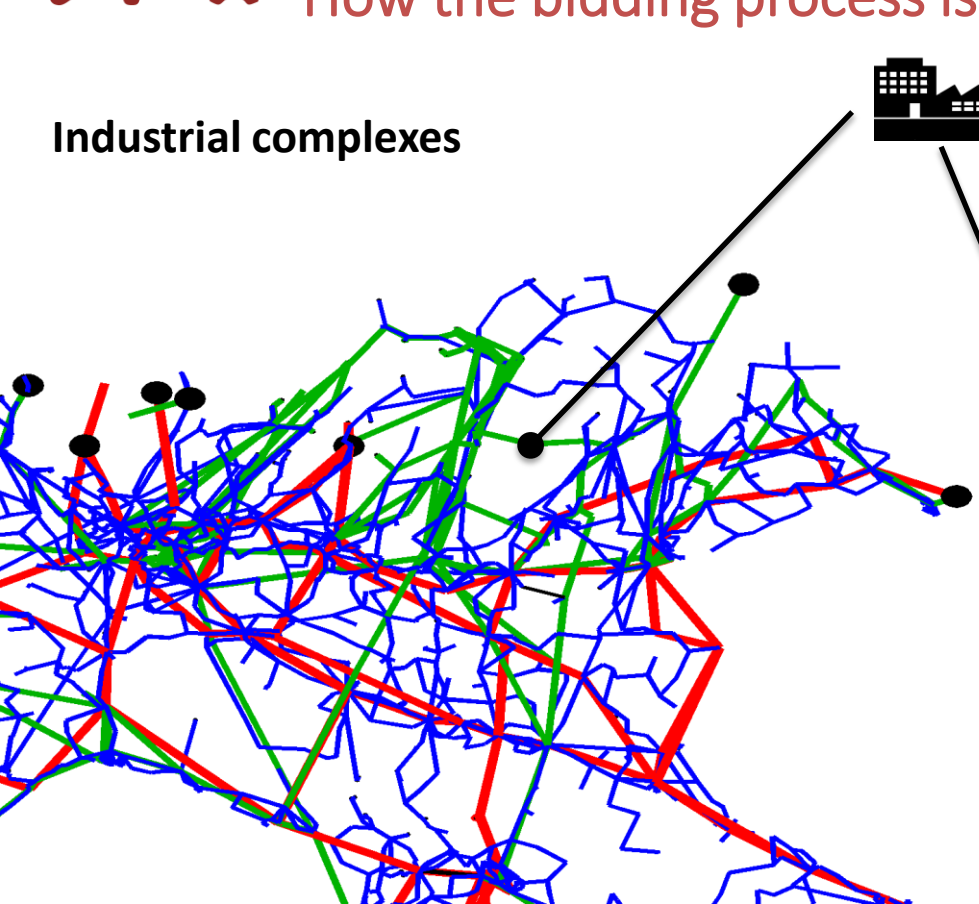
How the simulator works
How the bidding process is simulated

Large power units (transmission system)



How the simulator works
How the bidding process is simulated

Industrial complexes



Aggregator of dimmable loads — bid €

Aggregator of thermally controlled loads — bid €

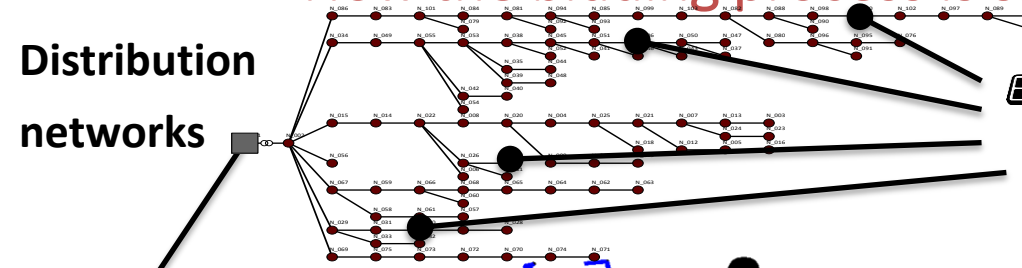
Aggregator of shiftable loads — bid €

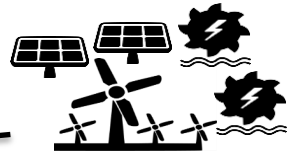
Aggregator of storage-based devices — bid €

How the simulator works

How the bidding process is simulated

Distribution networks





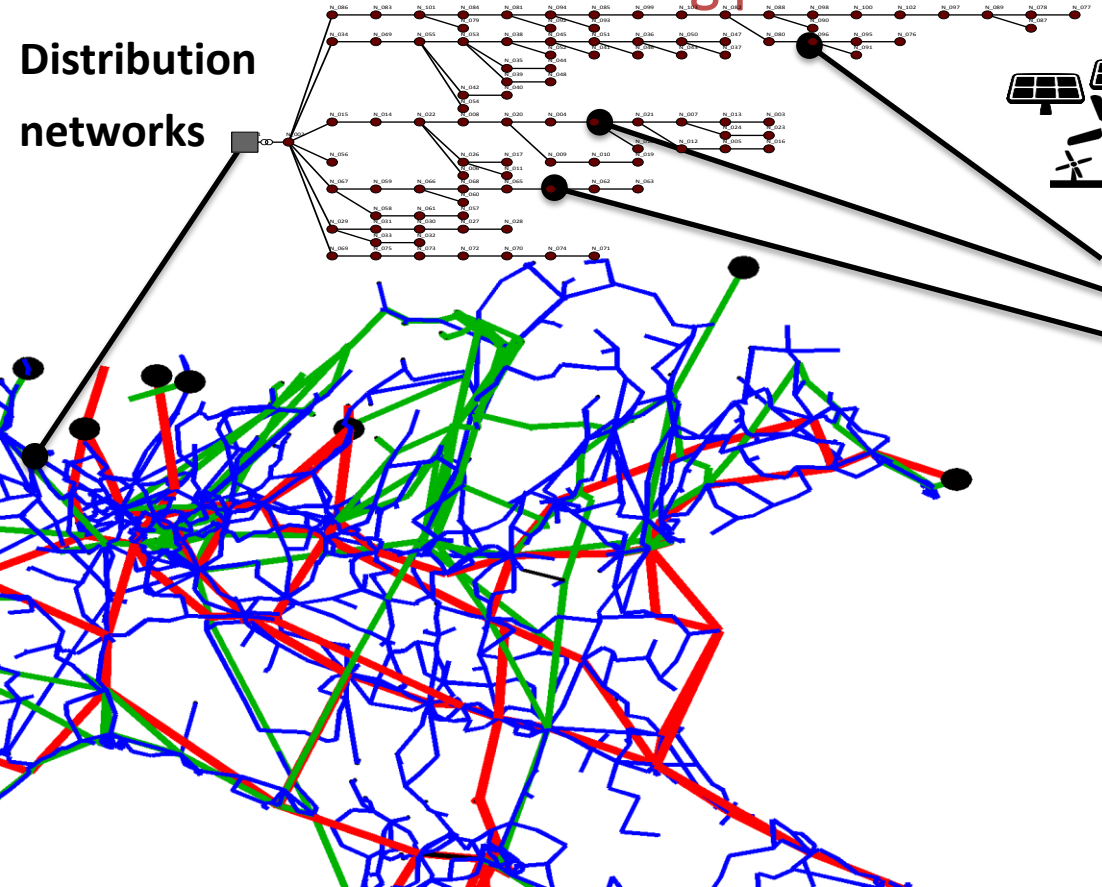
Aggregator of curtailable generators

bid €

How the simulator works

How the bidding process is simulated

Distribution networks



Aggregator of curtailable generators

bid €

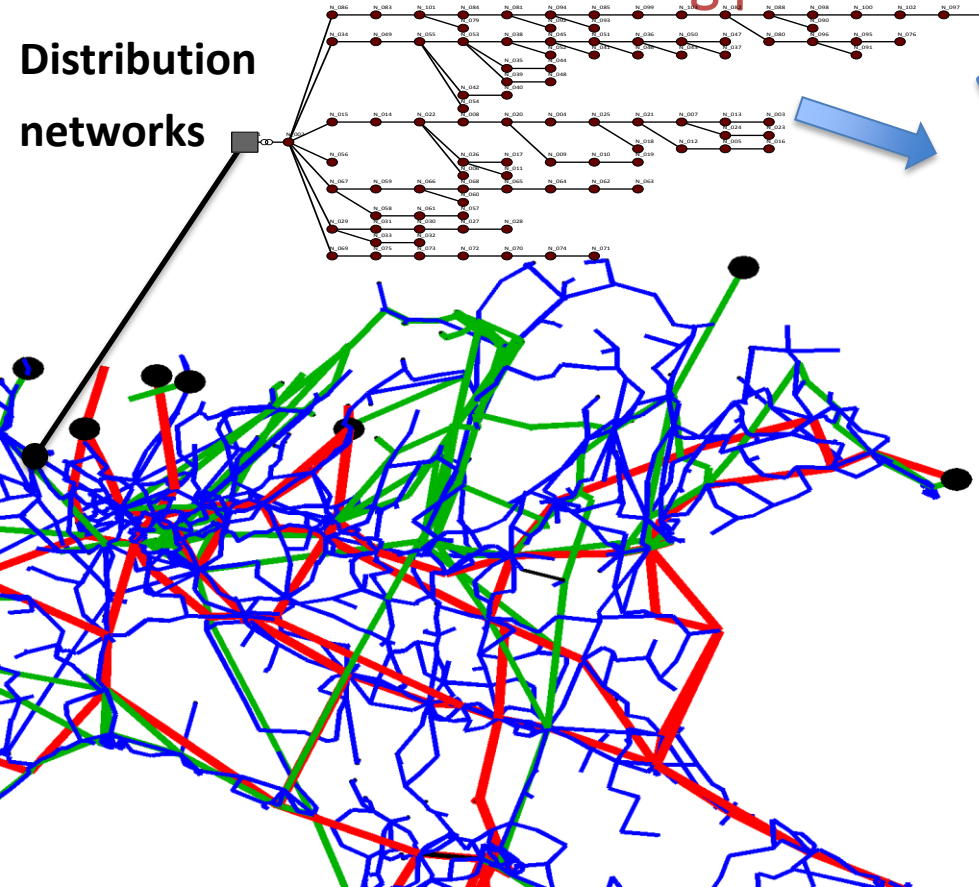
Aggregator of storage-based devices

bid €

How the simulator works

How the bidding process is simulated

Distribution networks



Aggregator of curtailable generators — bid €

Aggregator of storage-based devices — bid €

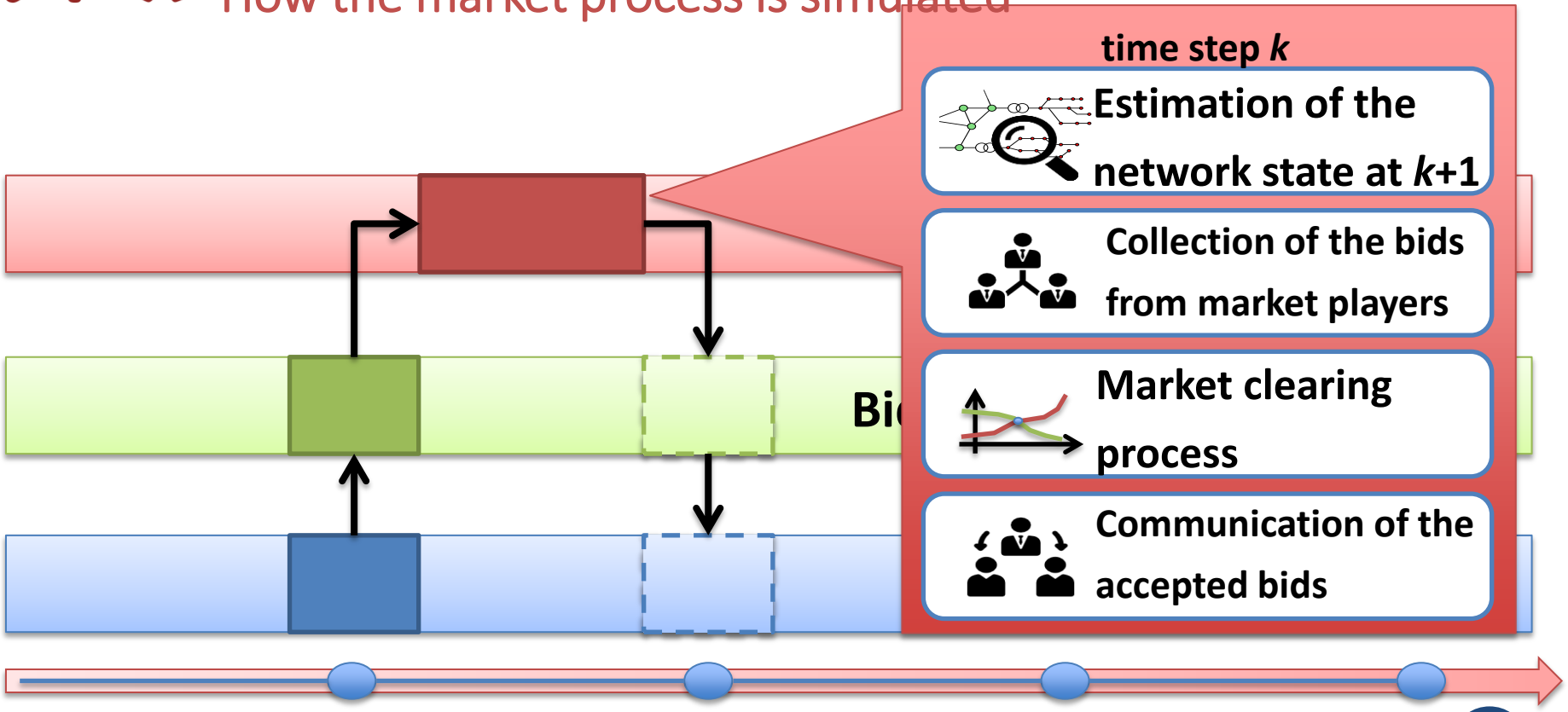
Aggregator of thermally controlled loads — bid €

Aggregator of shiftable loads — bid €

Aggregator of dimmable loads — bid €

How the simulator works

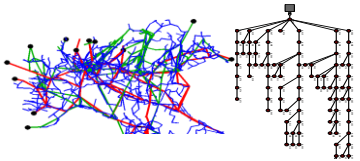
How the market process is simulated



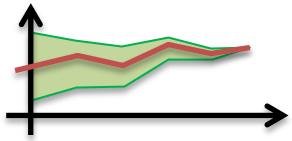
How the simulator works

How the market process is simulated

Estimation of the network state at *k*+1

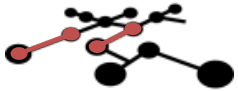


The most updated status of the network is communicated from the physical layer

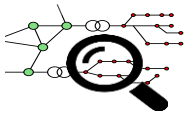


Forecasting error is simulated assuming that it is decreasing exponentially

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



time step *k*



Estimation of the network state at *k*+1

Collection of the bids from market players

Market clearing process

Communication of the accepted bids

time

time step *k*

time step *k*+1

time step *k*+2

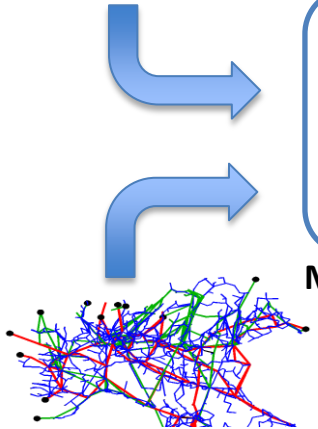
How the simulator works

How the market process is simulated

Collection of the bids and market clearing

Bids from transmission system devices

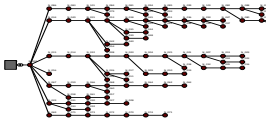
Bids from distribution system devices



Market clearing algorithm

Model of the transmission system

Model of the distribution system



time step *k*

Estimation of the network state at *k*+1

Collection of the bids from market players

Market clearing process

Communication of the accepted bids

time

time step *k*

time step *k*+1

time step *k*+2

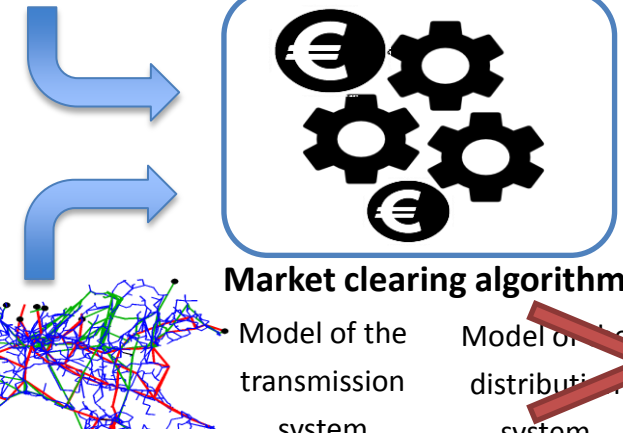
How the simulator works

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

time step *k*

Estimation of the network state at *k*+1

Collection of the bids from market players

Market clearing process

Communication of the accepted bids

time

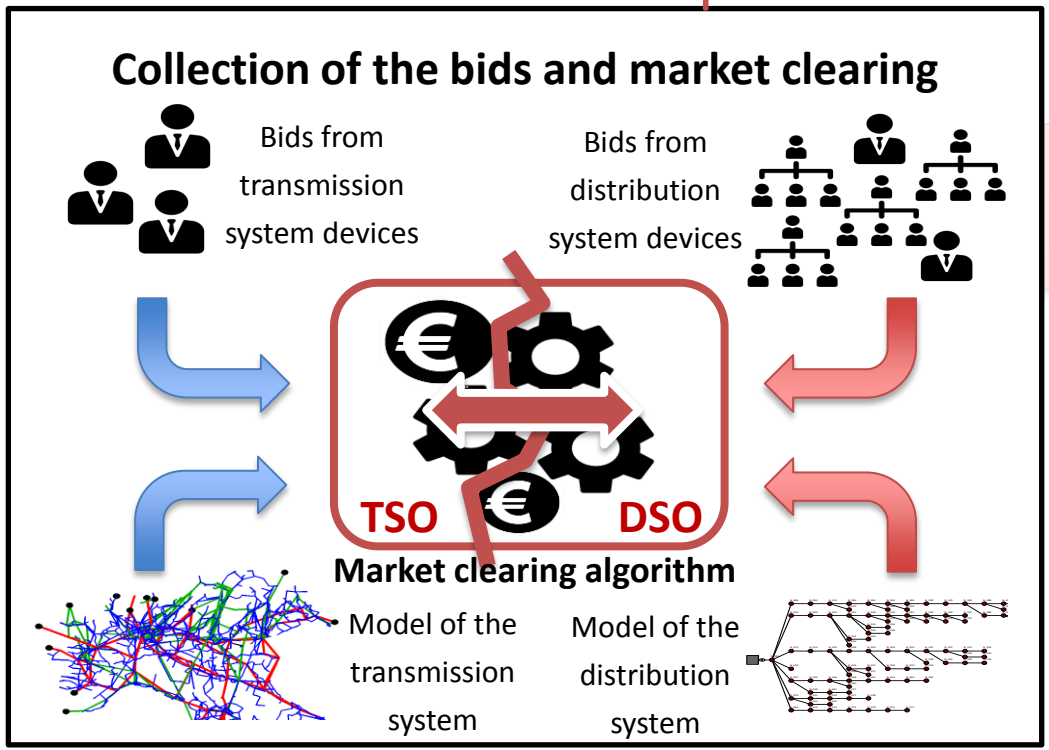
time step *k*

time step *k*+1

time step *k*+2

How the simulator works

How the market process is simulated



time step *k*

Estimation of the network state at *k*+1

Collection of the bids from market players

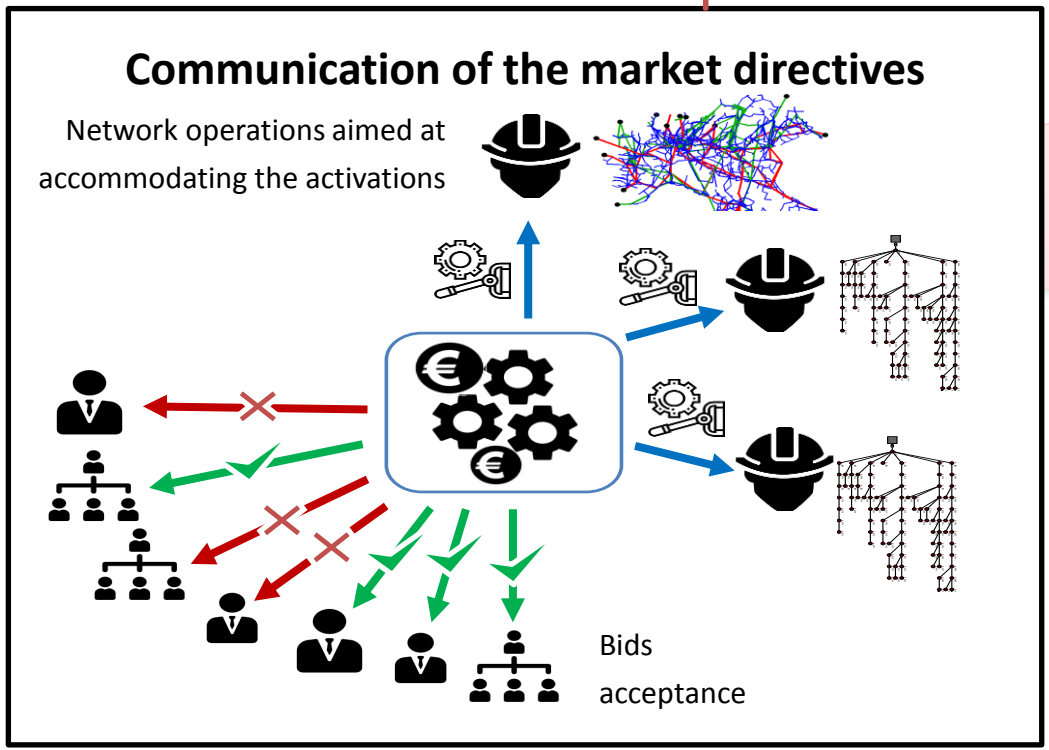
Market clearing process

Communication of the accepted bids

time | time step *k* | time step *k*+1 | time step *k*+2

How the simulator works

How the market process is simulated



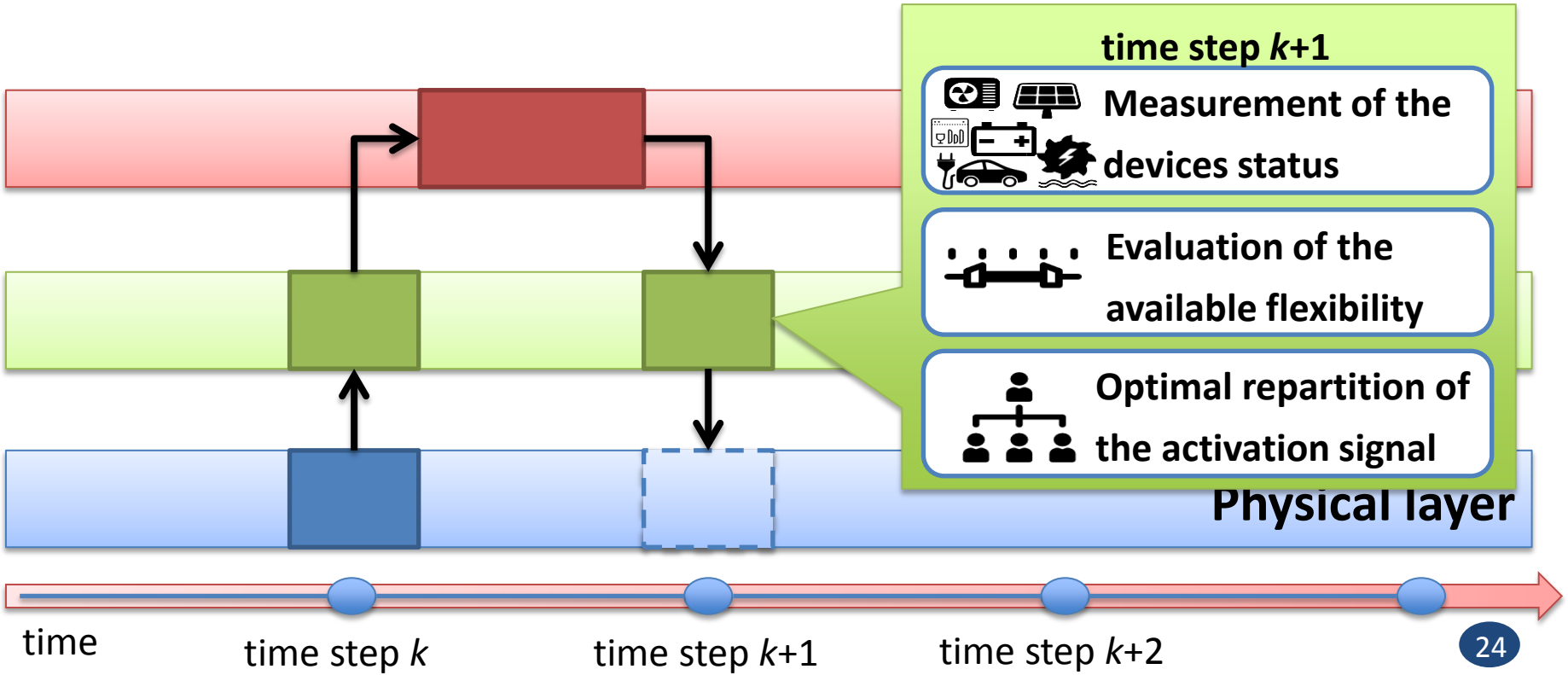
time step *k*

- Estimation of the network state at *k*+1
- Collection of the bids from market players
- Market clearing process
- **Communication of the accepted bids**

time | time step *k* | time step *k*+1 | time step *k*+2

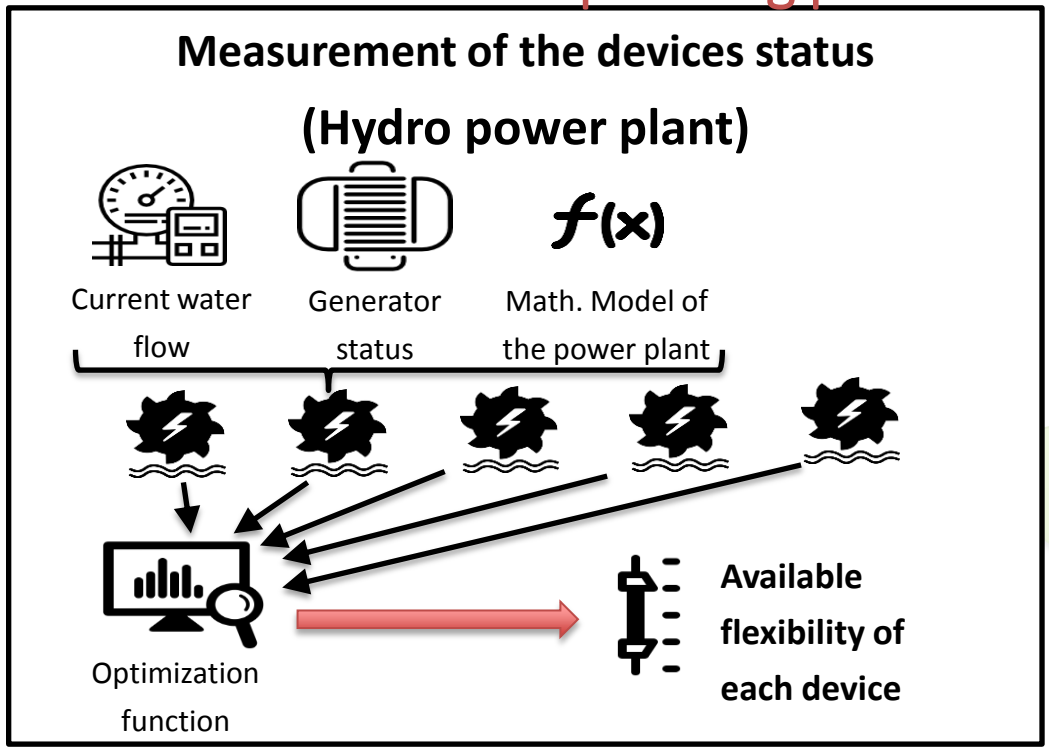
How the simulator works

How the dispatching process is simulated



How the simulator works

How the dispatching process is simulated



time step *k*+1

Measurement of the devices status

Evaluation of the available flexibility

Optimal repartition of the activation signal

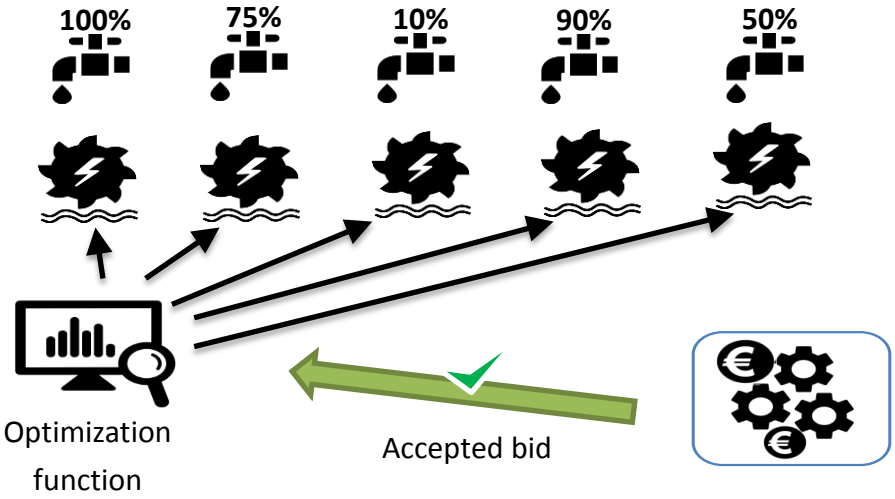
time | time step *k* | time step *k*+1 | time step *k*+2

How the simulator works

How the dispatching process is simulated

Optimal repartition of the activation signal

(disaggregation)



time step *k*+1

Measurement of the devices status

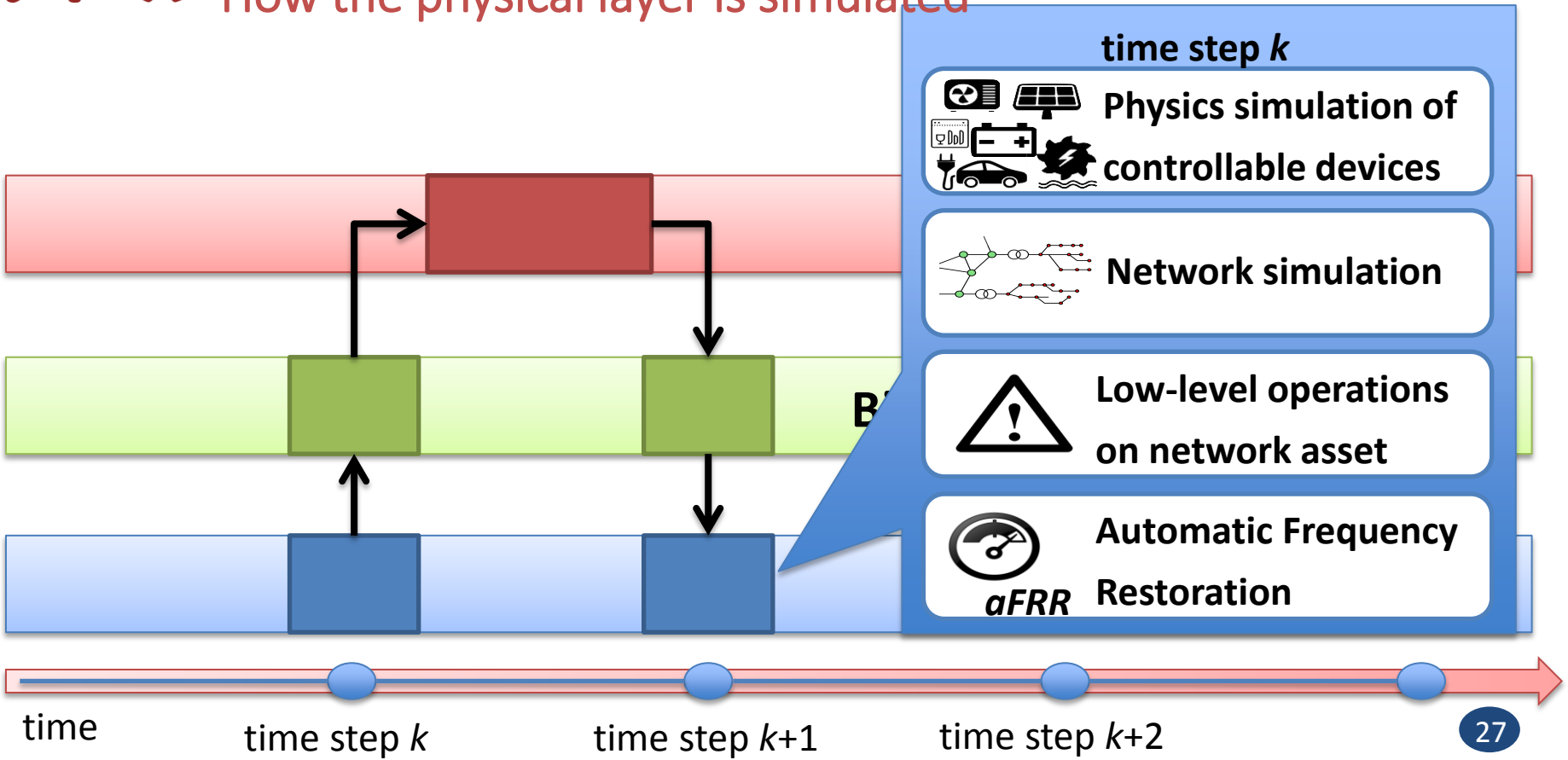
Evaluation of the available flexibility

Optimal repartition of the activation signal

time | time step *k* | time step *k*+1 | time step *k*+2

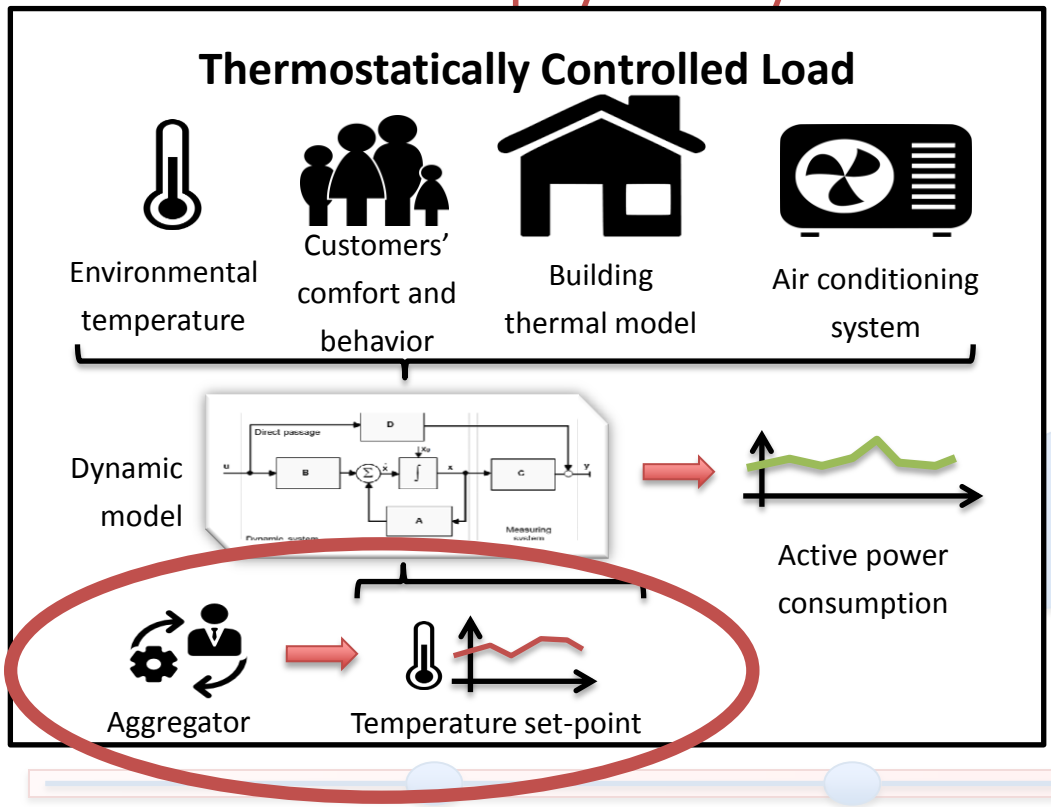
How the simulator works

How the physical layer is simulated



How the simulator works

How the physical layer is simulated



time step *k*

Physics simulation of controllable devices

Network simulation

Low-level operations on network asset

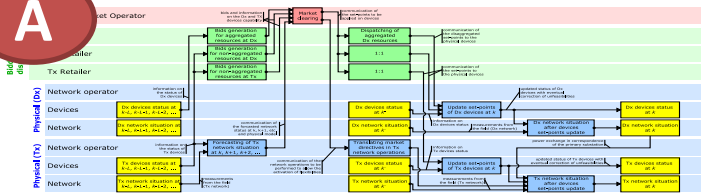
Automatic Frequency Restoration

aFRR

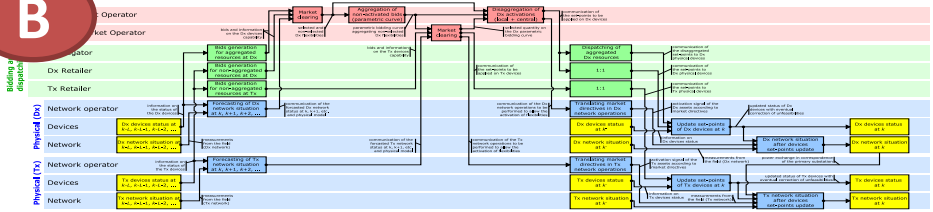
time | time step *k* | time step *k*+1 | time step *k*+2

Simulation diagrams

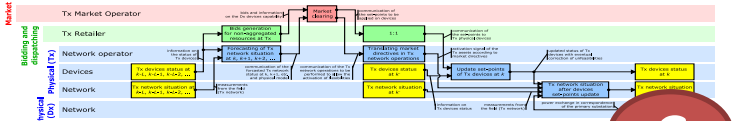
A

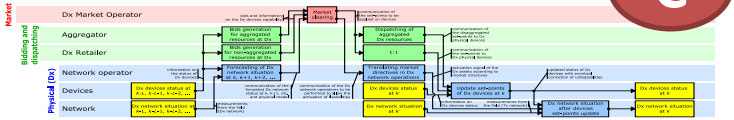


B

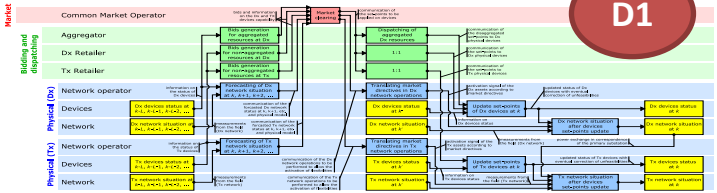


C

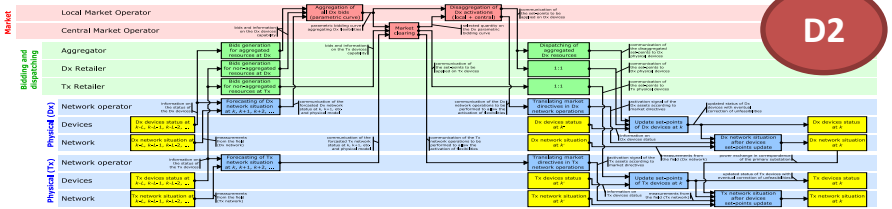




D1

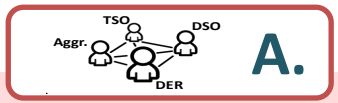


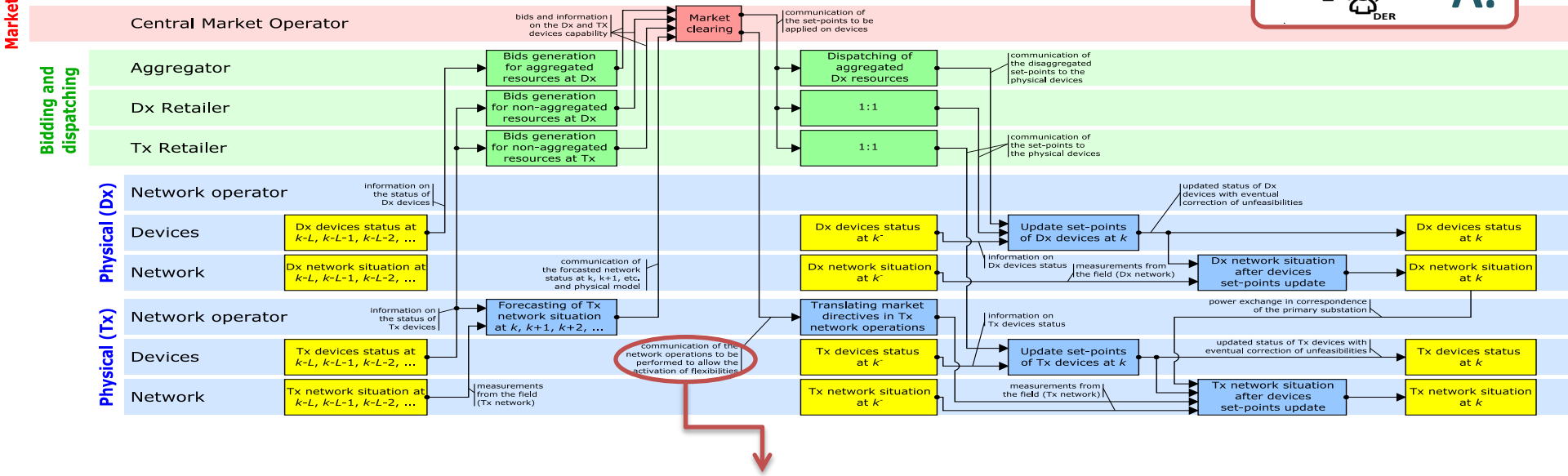
D2



Simulation diagrams

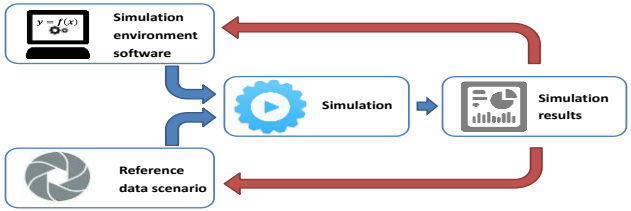
Coordination schemes with **common market** in which <u>transmission</u> and <u>distribution</u> resources participate





Details on the exchanged information: used for the design of the **ICT network** and calculation of ICT costs (processed later by CBA)

Key products

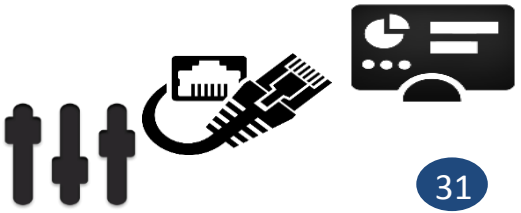


Validated simulation environment (software modules + scenarios)

Dedicated Cost Benefit Analysis approach

Best TSO-DSO interaction patterns for each considered national case

Guidelines on hardware utilization within the considered TSO-DSO schemes



Thank You

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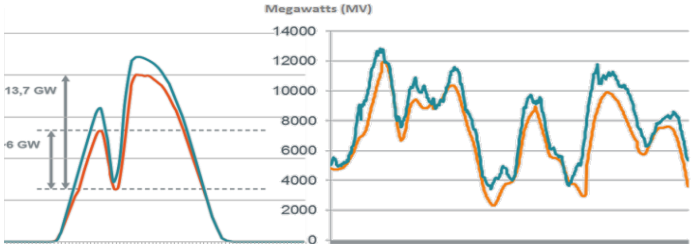
European Utility Week

3 - 5 October 2017
RAI Amsterdam, The Netherlands

How the simulator works

How imbalance and congestions are simulated

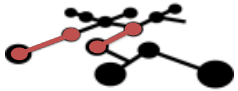


A **forecasting error** is introduced in order to model

- deviations in electricity production from RES
- load stochastic behavior
- power plants/network failures
- non-accepted bids in previous markets

Consequences of these deviations:

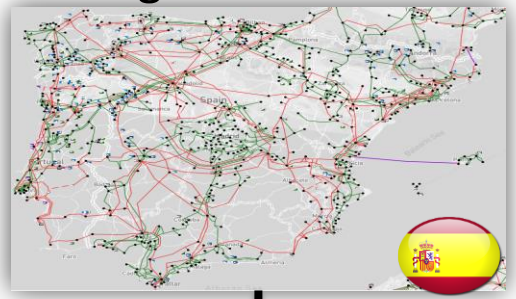
- **Transmission system imbalance**
- **(Distribution system imbalance)**

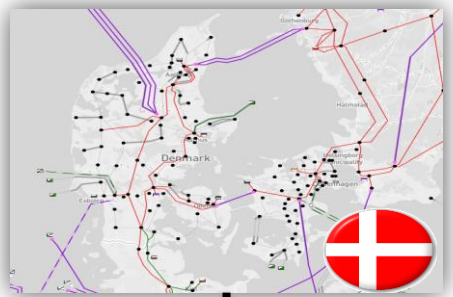


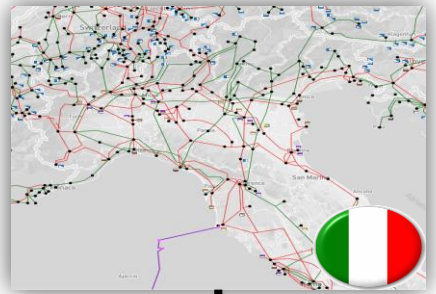
- **Congestions on transmission network**
- **Congestions on distribution network**

2030 Scenario Data

European reference scenarios are processed in order to generate the system configurations and data to be used in simulation and laboratory studies



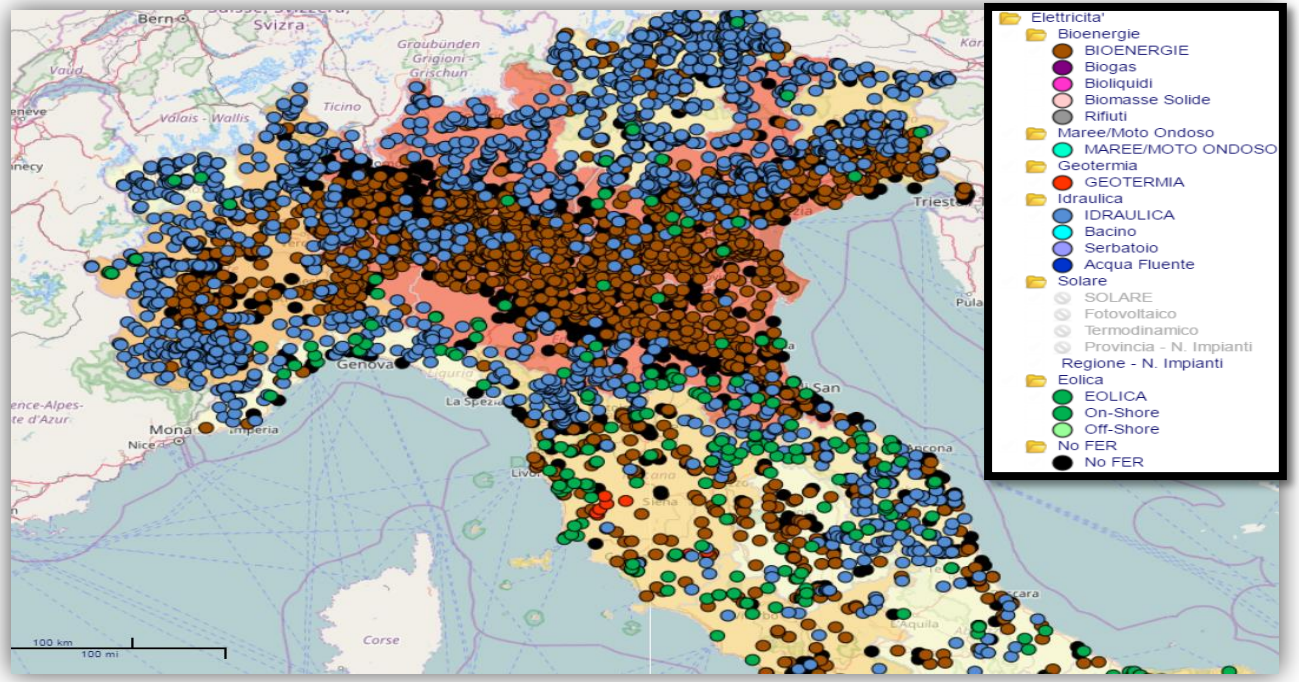




Scenario 1	Scenario 2	Scenario 3	Scenario 4
RES **lower** than required to fulfil 2030 emissions targets	RES **lower** than required to fulfil 2030 emissions targets	RES **equal to or higher** than required to fulfil 2030 emissions targets	RES **equal to or higher** than required to fulfil 2030 emissions targets
Good cross-border interconnections	**Poor** cross-border interconnections	**Good** cross-border interconnections	**Poor** cross-border interconnections

2030 Scenario Data

Geographical allocation of the energy resources expected for 2030



Population growth

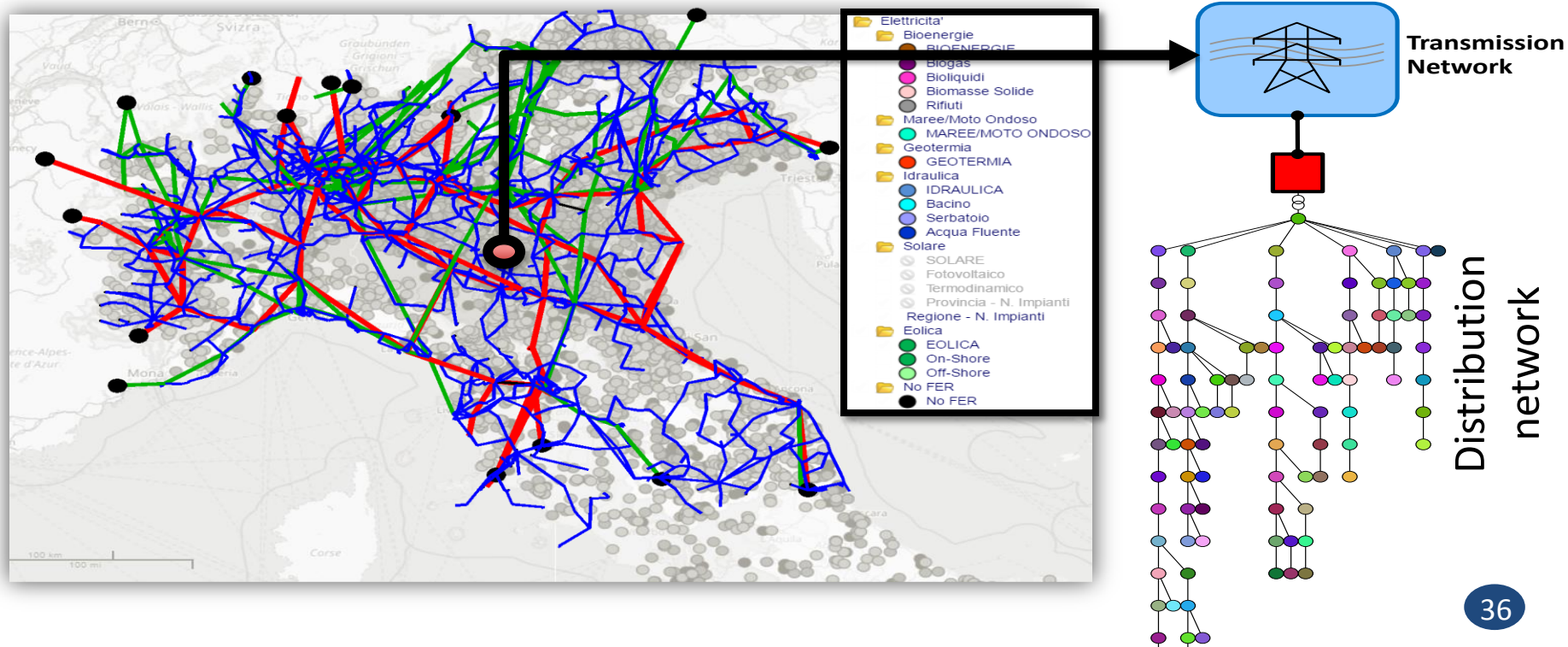
Renewables expansion

Exploitation of new electrical devices

Industrial development

2030 Scenario Data

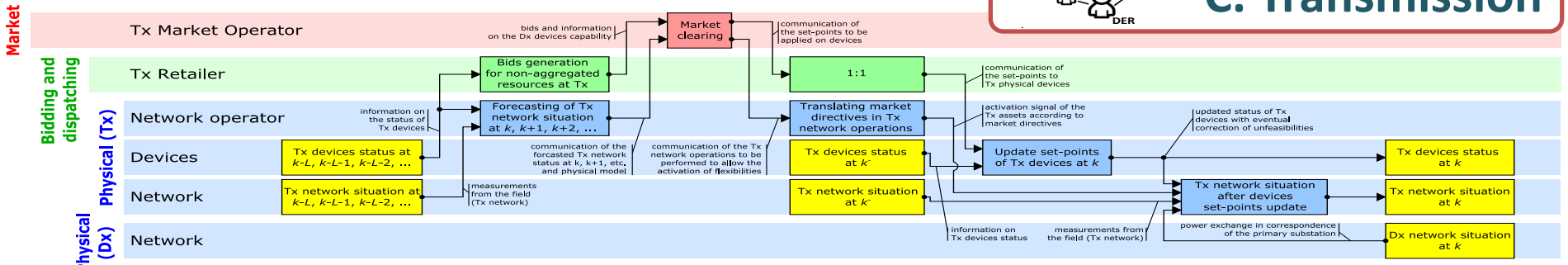
Mapping of the geographical information on the electricity network



Simulation diagrams

Coordination schemes with **separated markets:** one for <u>transmission</u> and one for <u>distribution</u> resources

C. Transmission



C. Distribution