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

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SmartNet: A European research project to study TSO-DSO coordination for ancillary services provision from distribution networks

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Agenda

- General project overview

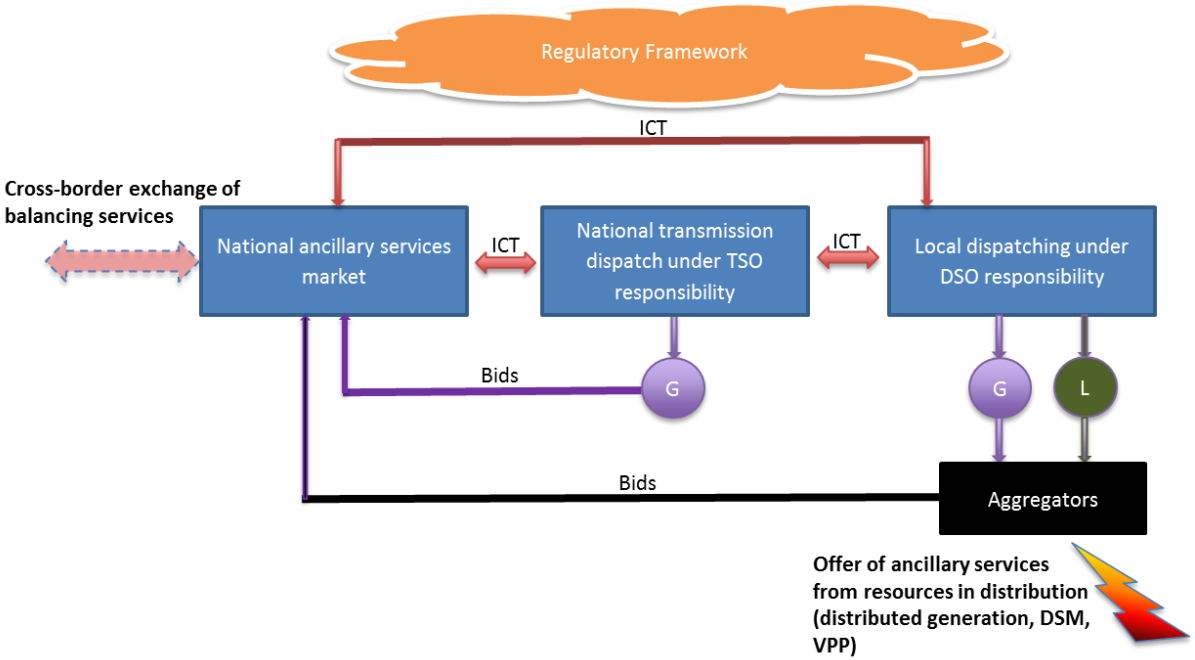
- Five coordination schemes
- Ancillary services market set-up
- Bidding strategies
- Aggregation algorithms

- Three physical pilots

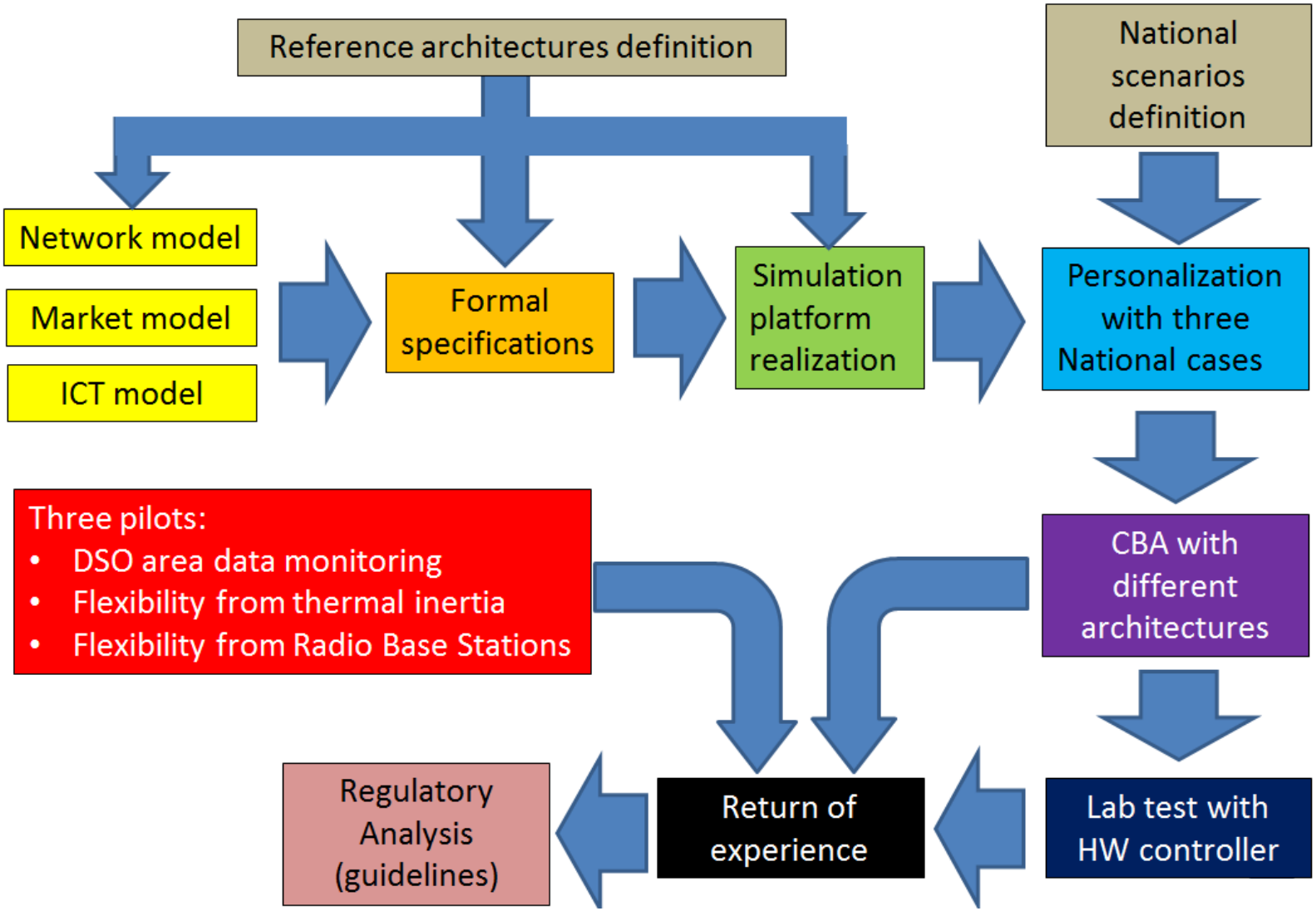
The SmartNet project

http://SmartNet-Project.eu

- **architectures for optimized interaction between TSOs and DSOs** in managing the purchase of ancillary services from subjects located in distribution.
- **three national cases** (Italy, Denmark, Spain);
- *ad hoc* **simulation platform** (physical network, market and ICT)
- **CBA** to assess which TSO-DSO coordination scheme is optimal for the three countries.
- Use of **full replica lab** to test performance of real controller devices.
- **Three physical pilots** are also developed to demonstrate capability to monitoring and control distribution by the TSO and flexibility services that can be offered by distribution (thermal inertia of indoor swimming pools, distributed storage of radio-base stations).



Overall project layout



Comparison of the national cases in a simulation environment and laboratory testing

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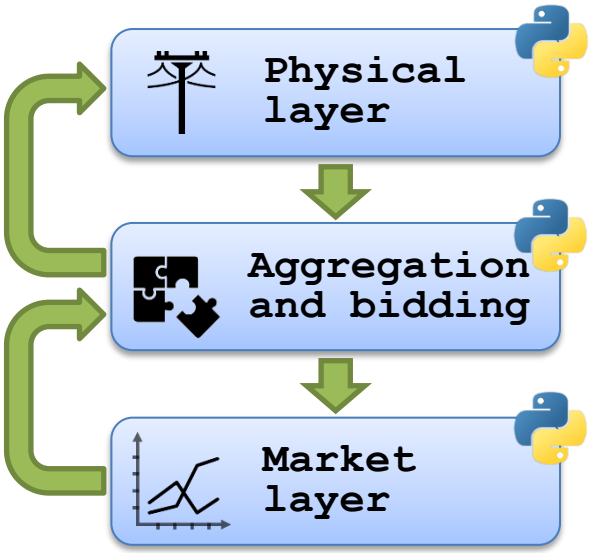
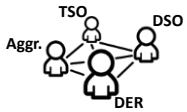
Development of simulation software



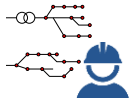
Definition of the reference scenario



Analysis of TSO-DSO coordination schemes

Definition of flexible devices profiles

Country-specific aspects and regulation



Network planning and operation

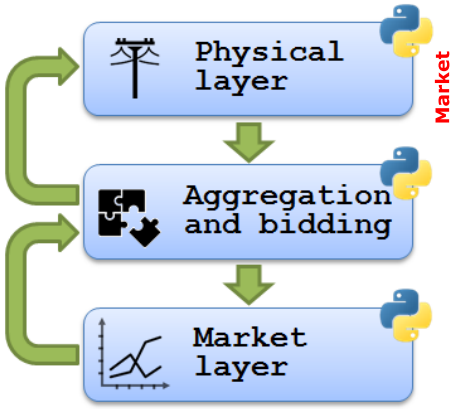
ICT specification and planning

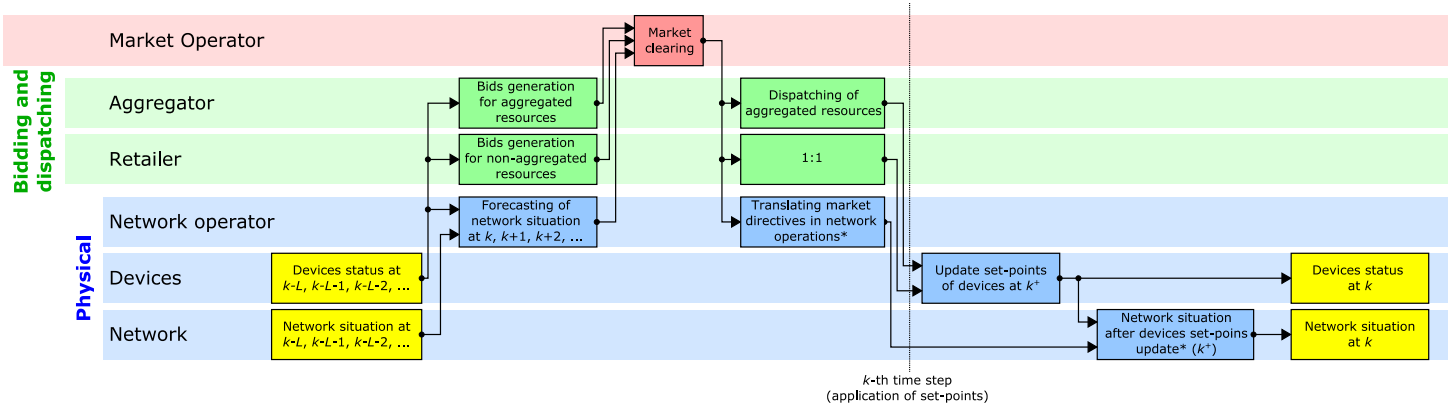
Simulation

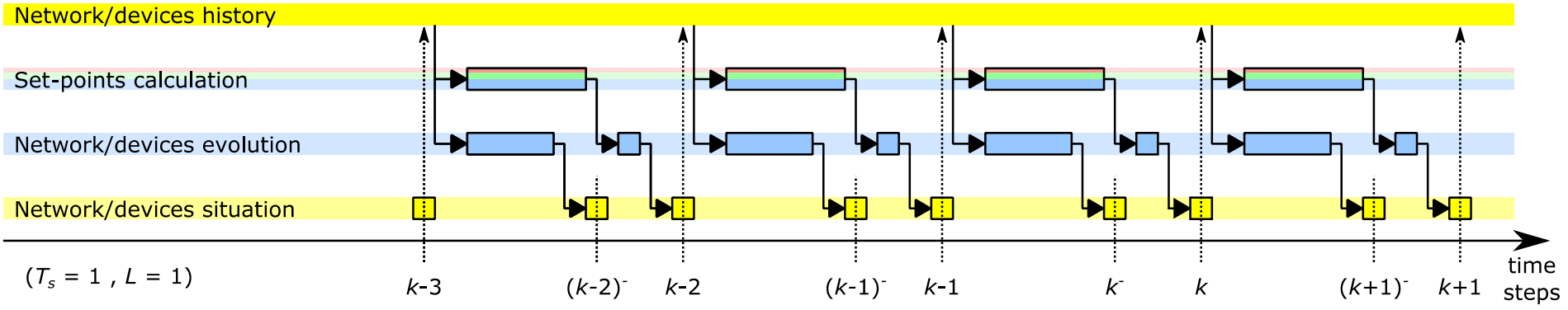
Cost Benefit Analysis

Lab implementation of the simulation environment

Interaction between the three layers







Survey of present AS in EU Countries

Country	Frequency control services		
	Primary	Secondary	Tertiary
Austria	FCR	aFRR	mFRR
Belgium	FCR-R1	FRR-R2	R3-Production
			R3-Dynamic profile
			R3 ICH-Interruptible users
Denmark*	FCR (DK1)	aFRR (DK1)	mFRR (DK1 and DK2)
	FCR-N (DK2 normal op.)		
	FCR-D (DK2 disturbance)		
Finland	FCR-N normal operation	aFRR	--
	FCR-D disturbance	mFRR	
Italy	Primary frequency control	Secondary frequency control	Tertiary frequency control
Norway	FCR-N normal operation	aFRR	mFRR
	FCR-D disturbance		
Spain	FCR	FRR	RR

Country	Voltage control services
Austria	Voltage control
Belgium	Primary control
	Centralised control
Denmark	Voltage control
Finland	Voltage control
Italy	Primary voltage control
	Secondary voltage control
Norway	Voltage control
Spain	Voltage control – Transmission network
	Voltage control – Distribution network

Country	Other ancillary services
Austria	Grid losses compensation
Belgium	Black start
	Grid losses compensation
	Strategic reserves for generation (SGR) and demand (SDR)
Denmark	Black start
Finland	Peak load capacity reserves
Italy	Interruptible load
	Black start
	Real time balancing
Norway	Interruptible load
	"Smoothed" production
Spain	Interruptible load
	Deviation management
	Black start
	Technical restriction resolution (day-ahead, intraday, real-time)

Future AS from DER in the EU (2030)

	A AS Widespread Today	B Emerging AS	C Future DER AS
Ancillary services for frequency control	FCR FRR RR		Fast frequency reserve: Inertia emulation Ramp margin: Ramp control
Ancillary services for voltage control	Congestion management through voltage control	Primary Voltage Control Secondary Voltage Control Tertiary Voltage Control	Fault ride-through capability
Ancillary services for power quality improvement			Injection of negative sequence voltages Damping of low-order harmonics Mitigation of flicker Damping of power system oscillations
Other ancillary services		Black start capability Compensation of power losses	Power factor control

Ancillary services that are currently widespread implemented, but only provided by conventional generation. These novel services will be supplied by the DER/DSM that appear as new market participants in the time horizon considered in SmartNet (2030).

Ancillary services that are considered as "new" because they are not widely deployed.

New functions implemented in DER will allow them to contribute to existing services (e.g. a wind turbine with fault ride-through capability contribute to restore voltage during a fault by supplying reactive power for primary voltage control). Others constitute a new ancillary service, e.g. the ones for power quality improvement.

TSO-DSO coordination schemes

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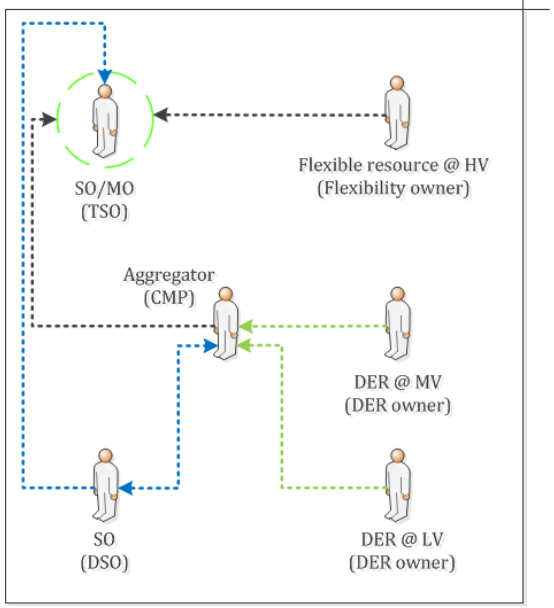
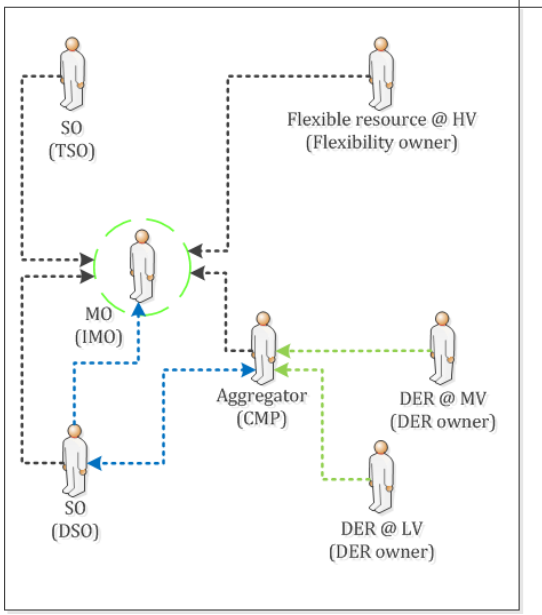
5 possible coordination schemes TSOs & DSOs for AS by distributed flexibility resources

- Centralized AS market model
- Local AS market model
- Shared balancing responsibility model
- Common TSO-DSO AS market model
- Integrated flexibility market model

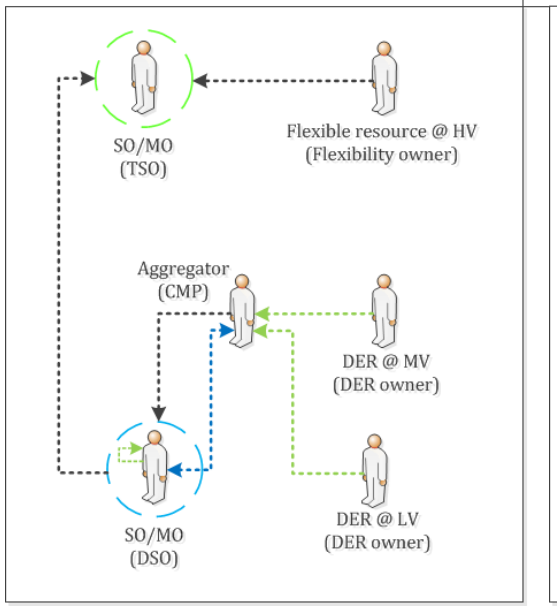
Centralized AS market model



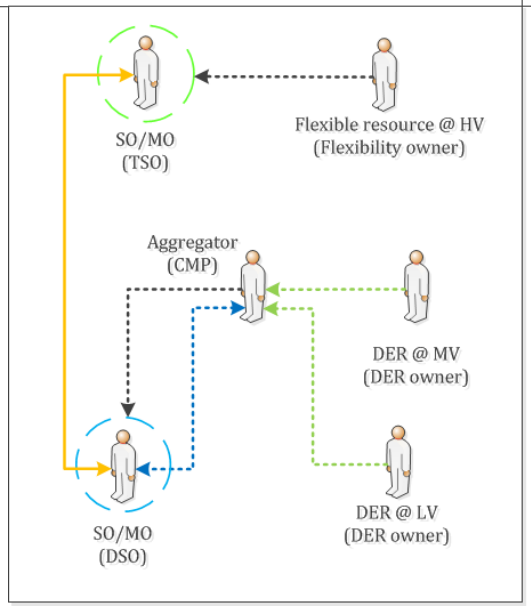
Integrated flexibility market model



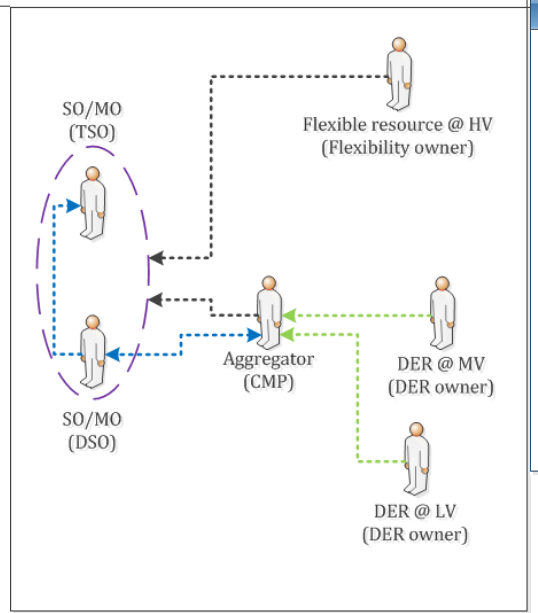
Local AS market model

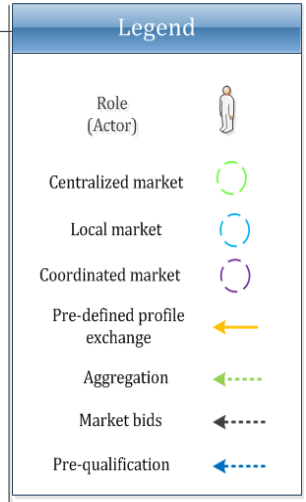


Shared balancing responsibility model



Common TSO-DSO AS market model





Objectives of proposed Market Design

Defining a new ancillary service (AS) market for TSO-DSO coordination schemes

What is required?

- Ensure a safe AS **activation** at the **lowest cost** for system operators
- Extract flexibility of **distributed energy resources** (DERs) in an efficient way
- Allow a **level playing field** for competition between different sources of flexibility
- Valorize flexibility at its **real value** for the power system

What has to be avoided?

- Discouraging participation of DERs by not taking into account their **constraints**
- Creating **congestion** and/or **voltage problem** by activation at a wrong location
- Making **myopic** real-time decisions that compromise an efficient balancing management for future time steps
- Doing **unnecessary activations** that increase cost and/or risk for system operators

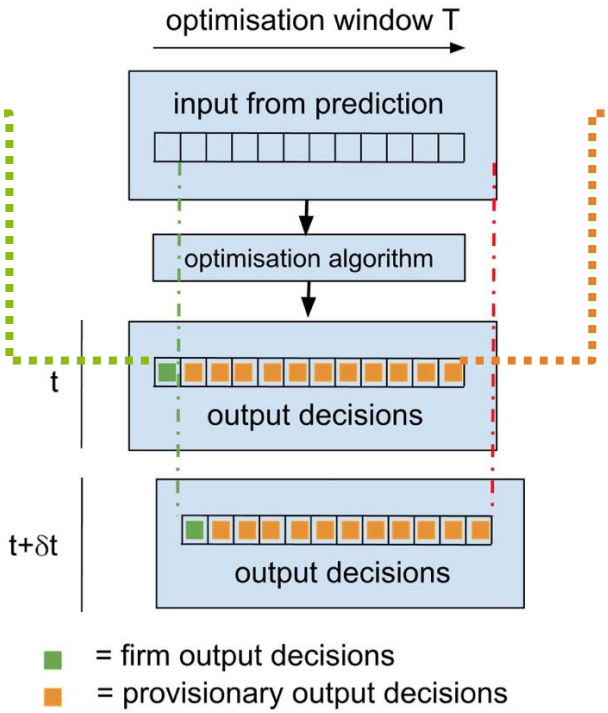
Timing Dimension

What are the the market clearing frequency, time step and horizon?

The market is a **closed-gate auction**. The clearing frequency is chosen close to real-time (e.g. **5 minutes**).

The market uses a **rolling optimization**. The optimization window (or horizon) contains several time steps (e.g. **1 hour**)

Output of the first time step is a firm decision. It contains the actual activation of flexible assets and has to be followed by the aggregators/owners.

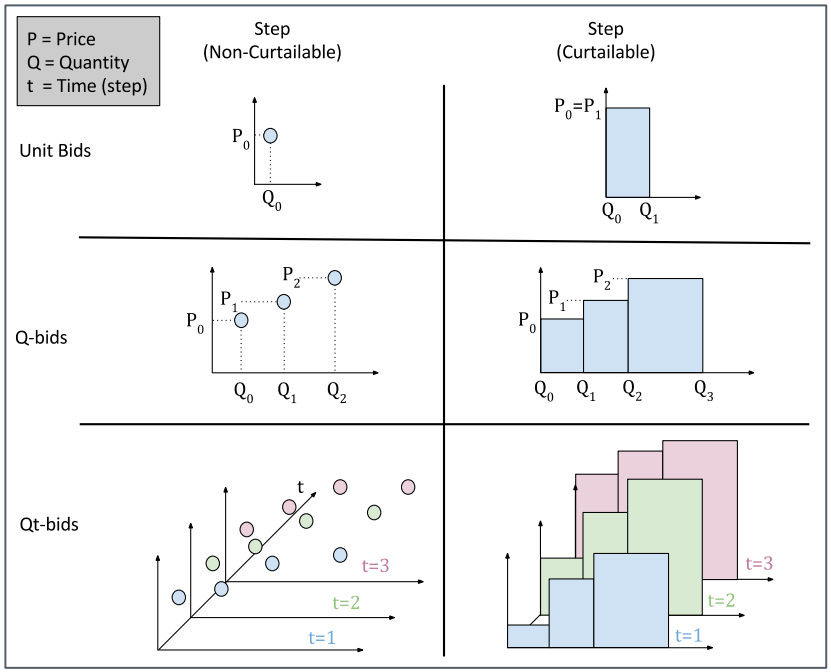


Output of the next time steps are advisory decisions. They will assist the aggregators and the TSO to anticipate the availability of flexibility in the upcoming time steps.

Bidding Dimension

How market actors can bid?
What market products are proposed?

Market allows various bid format, accompanied by temporal and logical constraints:



Temporal constraints (Intra-bid)

- **Accept-All-Time-Steps-or-None**: → Profile tracking
- **Ramping**: → Turbines
- **Max. number of activations**: → Avoiding wear & tear
- **Max. duration of activation**: → Air conditioning
- **Min. duration of activation**: → Plant efficiency
- **Min. delay between activations**: → Avoiding wear & tear; cool-down and warm-up
- **Integral**: → Electric storage

Logical constraints (Inter-bid)

- **Implication**: → Series factory lines
- **Exclusive Choice**: → Parallel factory lines
- **Deferability**: → Wet appliances

Network Dimension

How network constraints are taken in the market clearing?

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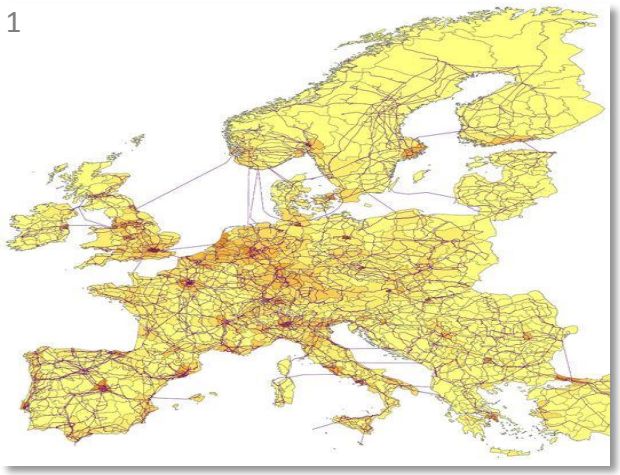
Transmission grid



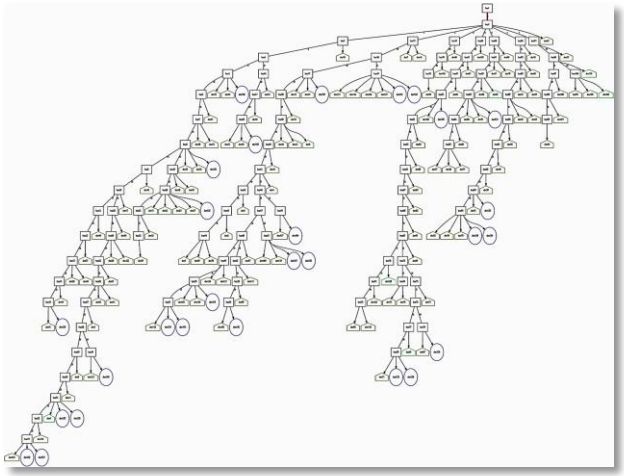
+ Accuracy

+ Numerical Complexity

Copper plate — LP — AC (NLP)

+

MV distribution grid



+ Accuracy

+ Numerical Complexity

Copper plate — LP — SOCP — AC (NLP)

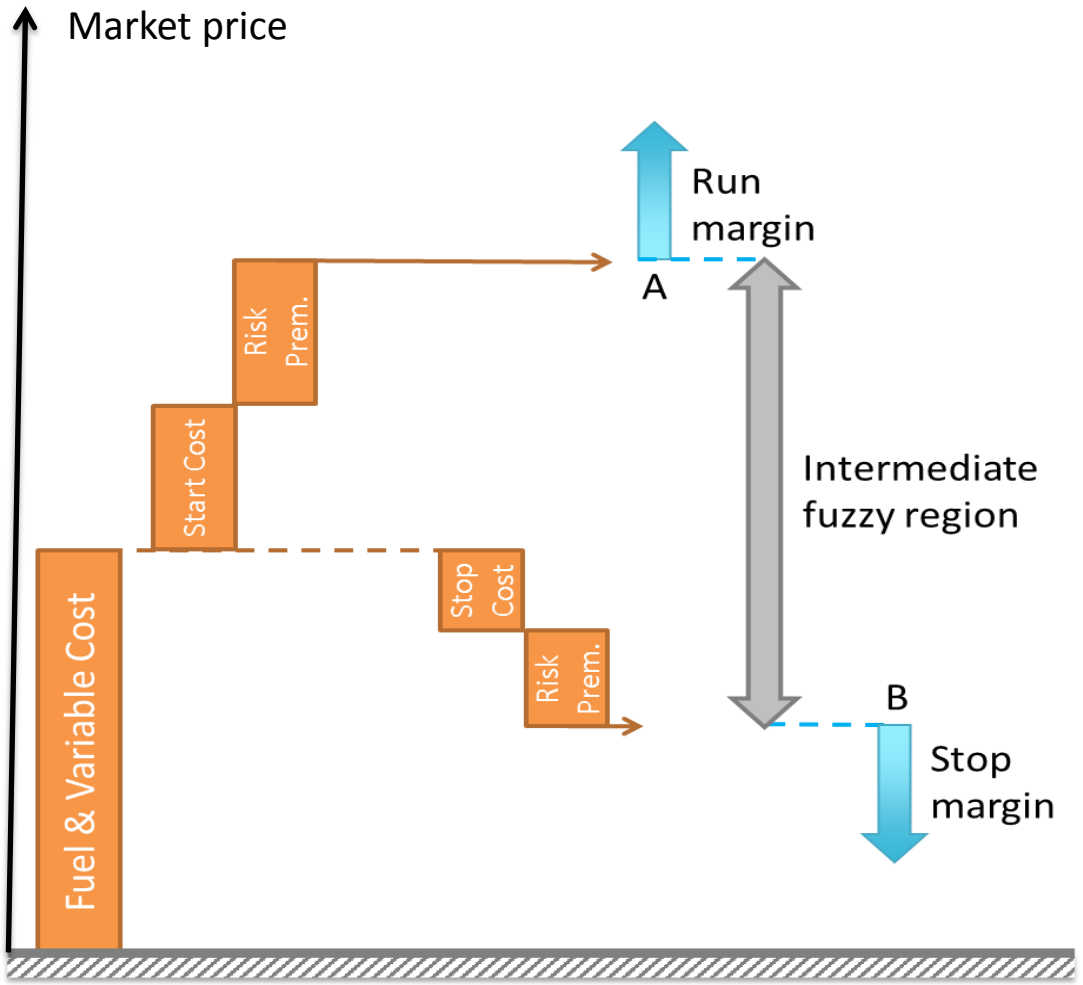
SOCP Problem (Convex)

[1] Photo source: Technical University of Munich (*http://ens.ei.tum.de*)

Further dimensions...

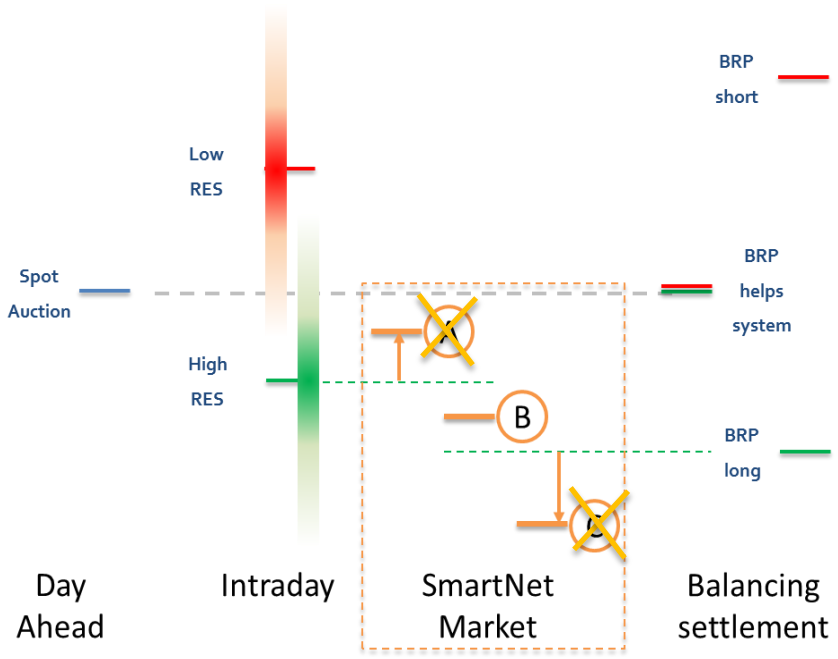
Clearing Dimension	What are the objectives of the market clearing? Minimum cost VS maximum SW
Pricing Dimension	What price is assigned to the activated bids? Pay-as-bid VS pay-as-clear
Bidding Dimension	How are bidding strategies implemented? (see next slides)

Bidding “zones”



$$RiskPremium = f(next\ market, current\ market\ price, etc)$$

Arbitraging between markets



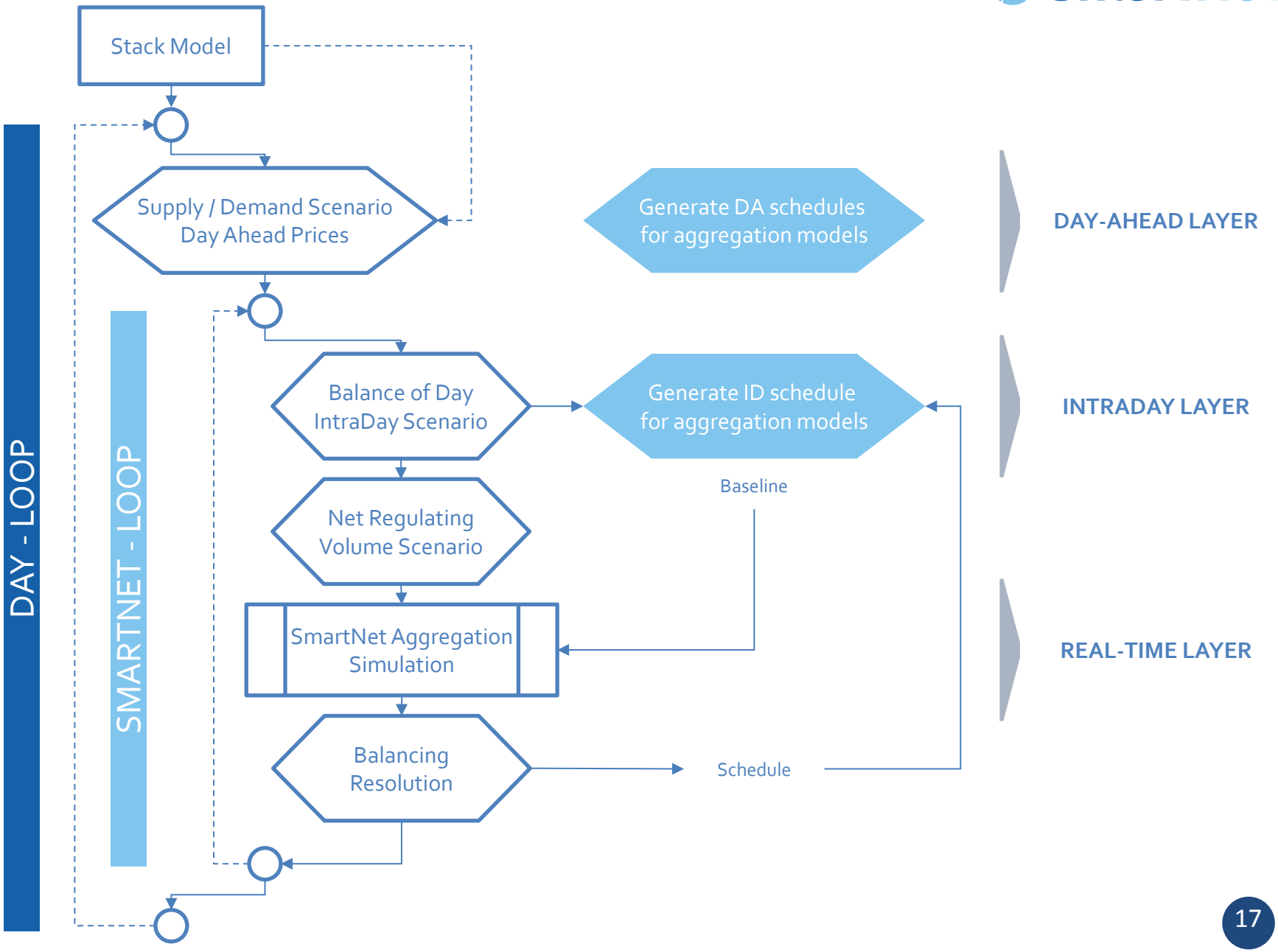
A – The aggregator will be better off pricing his flexibility in wholesale intraday market and not wait for SmartNet Market . He will buy back his production on intraday, and will be meant to not produce in real-time. However, he can always bid for up-regulation.

B - **The aggregator can profit from lower cost buying back his production from SmartNet Market compared to intraday. This is the most likely situation**

C - The Aggregator can buy energy from SmartNet market at down regulation price but do nothing, hence settling the excess energy at a higher balancing settlement price, for which he can make a risk-less arbitrage. Such kind of offers are likely to be out-of-merit order and, in any case, market mechanism and grid codes should rule them out.

Markets tend to converge to balancing settlement prices

The bidding algorithm



The aggregation algorithms

The aggregator acts on behalf of the service providers on the electricity market:

- determining the price and the quantity of individual bids (per node),
- performing aggregation (before bidding on the market)
- Performing disaggregation (after getting market clearing results)

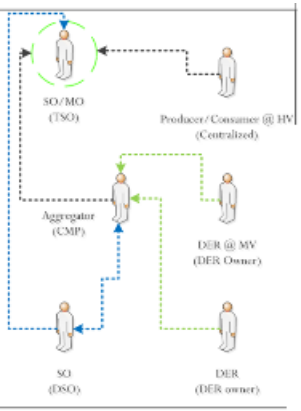
Models	Aggregation approach
Atomic Loads	• Traces
CHP	• Physical
TCL	• Physical • Hybrid
Storage	• Physical
Curtailable generation and sheddable loads	• Physical

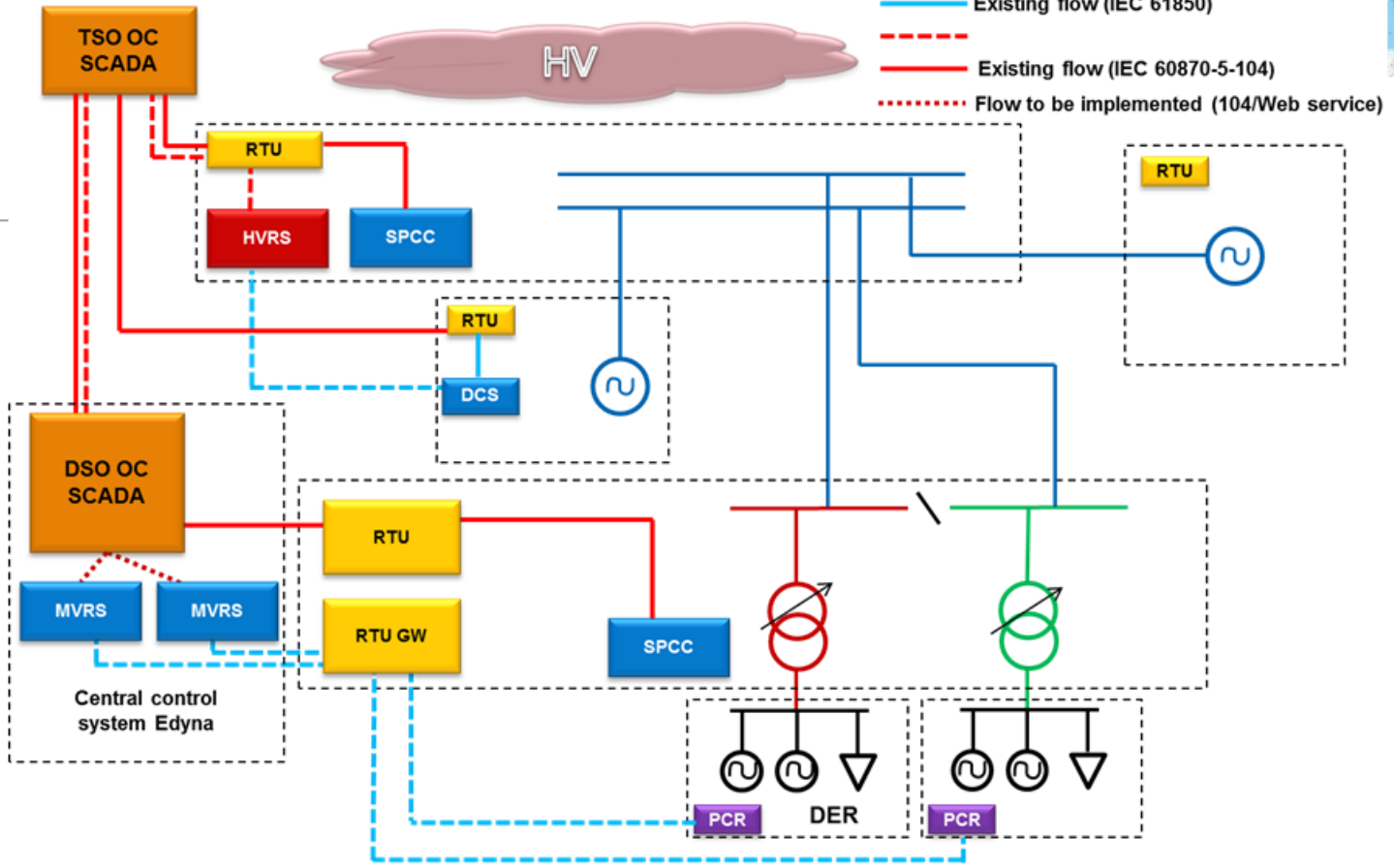
TRACES: the aggregation is represented by all the possible combinations of feasible profiles of all the devices.

PHYSICAL (bottom-up): horizontal summation of power for the individual devices: the aggregator knows all of the parameters of each individual device and also its real time status. It becomes difficult to implement when many heterogeneous energy resources are included

HYBRID: uses a single, or a limited number of virtual devices in order to represent the entire population of aggregated devices. Such practice reduces the number of individual devices and avoids exhaustive bid parametrization. Should the number of clusters equal the number of individual devices, the hybrid approach becomes the physical, bottom-up, approach.

Pilot A: Distribution monitoring and control



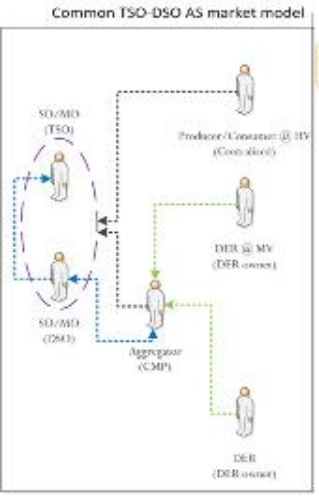


Aggregation of information
in RT at TSO-DSO interconnection (HV/MV transformer)

Voltage regulation
by generators connected at HV and MV levels

Power-frequency regulation / balancing
by generators connected at HV and MV levels

Pilot B: Ancillary services from indoor swimming pools



Receive Grid Load

Market Management System

Day-ahead | Intraday | Real-time

MO

Receive bids

Activate bids

Calculate residual capacity

Clear market

Energy Trading

Day-ahead market

Intraday market

Real-time market

CMP

CMP Trading System

EMS-SCADA

Ancillary services

TSO Trading System

Frequency control

Congestion management

Voltage control

EMS-SCADA

TSO

High Voltage Substation

Primary Substation

Secondary Substation

Send price signal incl. forecast

Technical aggregation

DER services

Value-added services

EMS-SCADA

DER aggregator

Ancillary services

DSO Trading System

Local Frequency control

DMS-SCADA

Local Voltage control

Congestion management

DSO

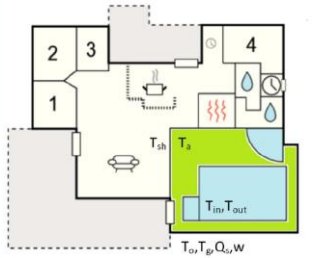
DER gateway

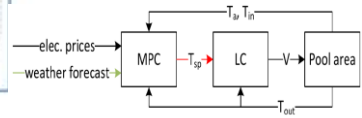
DER trading system

DER

Measurements

Setpoint



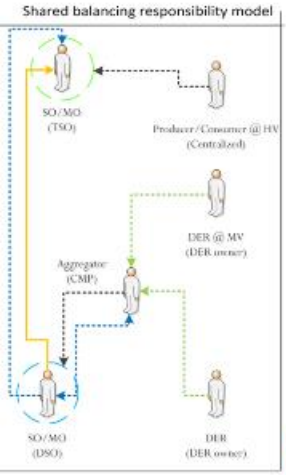


Congestion management
to better integrate PV, EV and HP

Price-based control
of thermal controllers of swimming pools in summer houses

Balancing
of wind power with decreasing contribution of thermal units

Pilot C: Ancillary services from radio-base stations



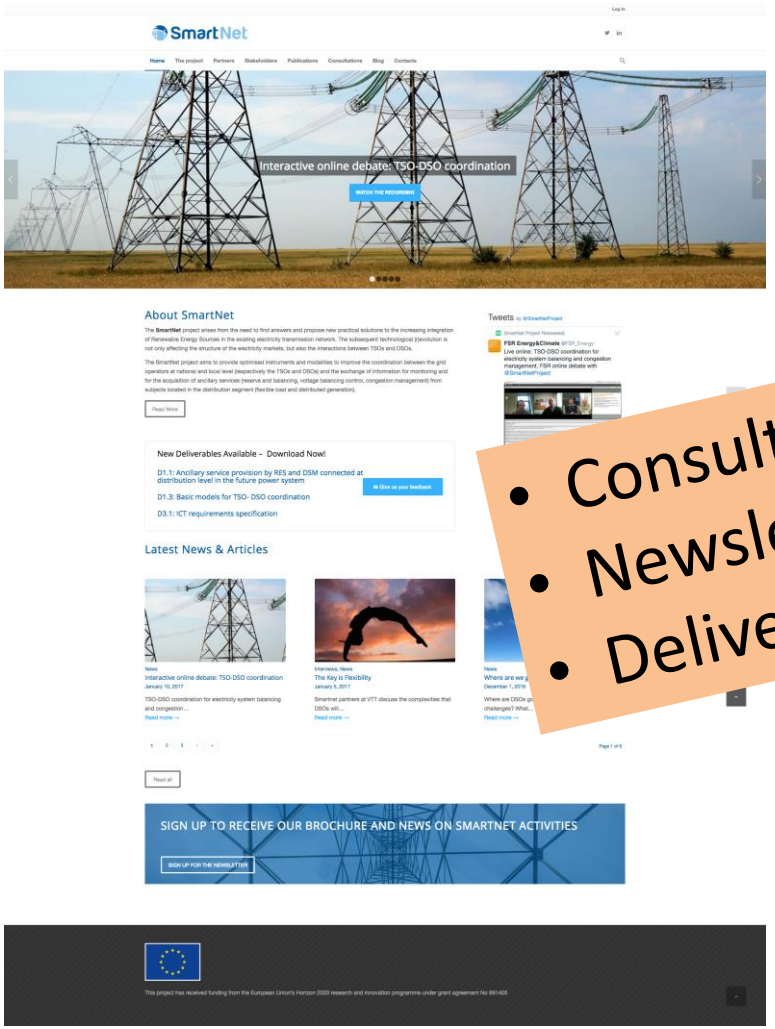
Congestion management at DSO level

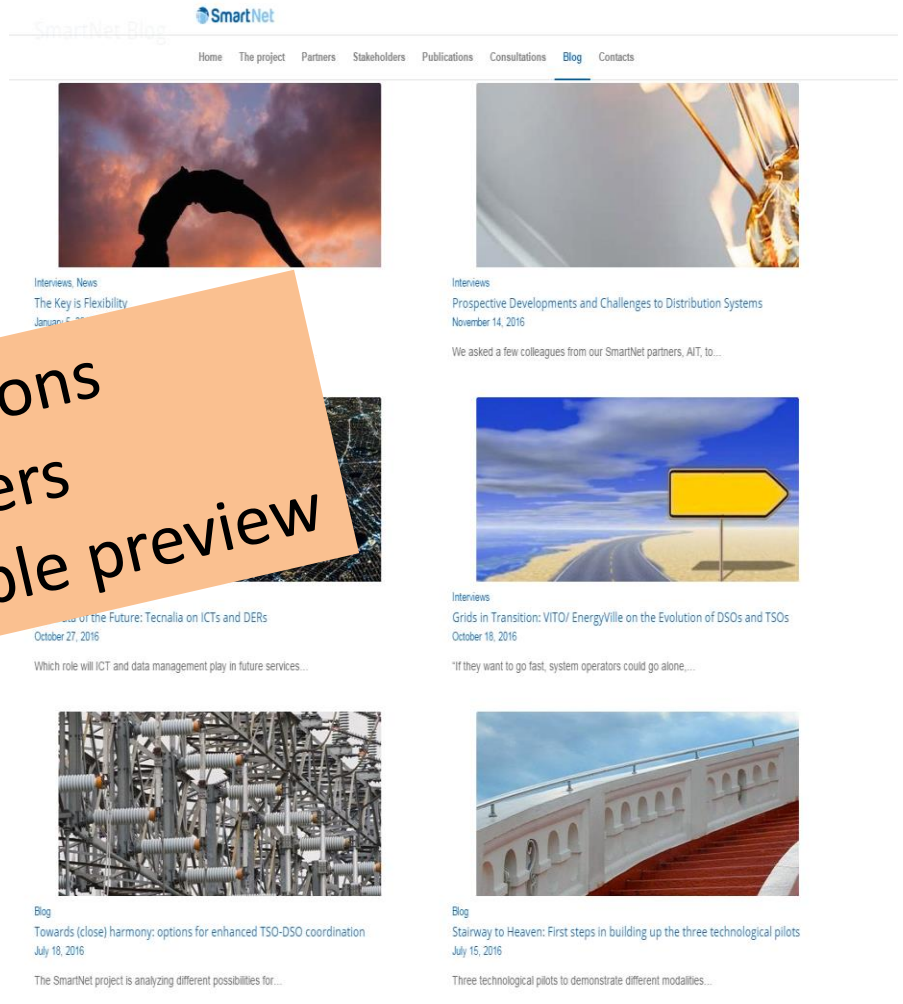
Demand Response Aggregation by using storage flexibility (BS and EV)

Power-frequency regulation / balancing by respecting the exchange program at the TSO-DSO interconnection

Smartnet-project webpage

http://SmartNet-Project.eu





- Consultations
- Newsletters
- Deliverable preview

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Thank You

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