July 2017

Smart grid - II

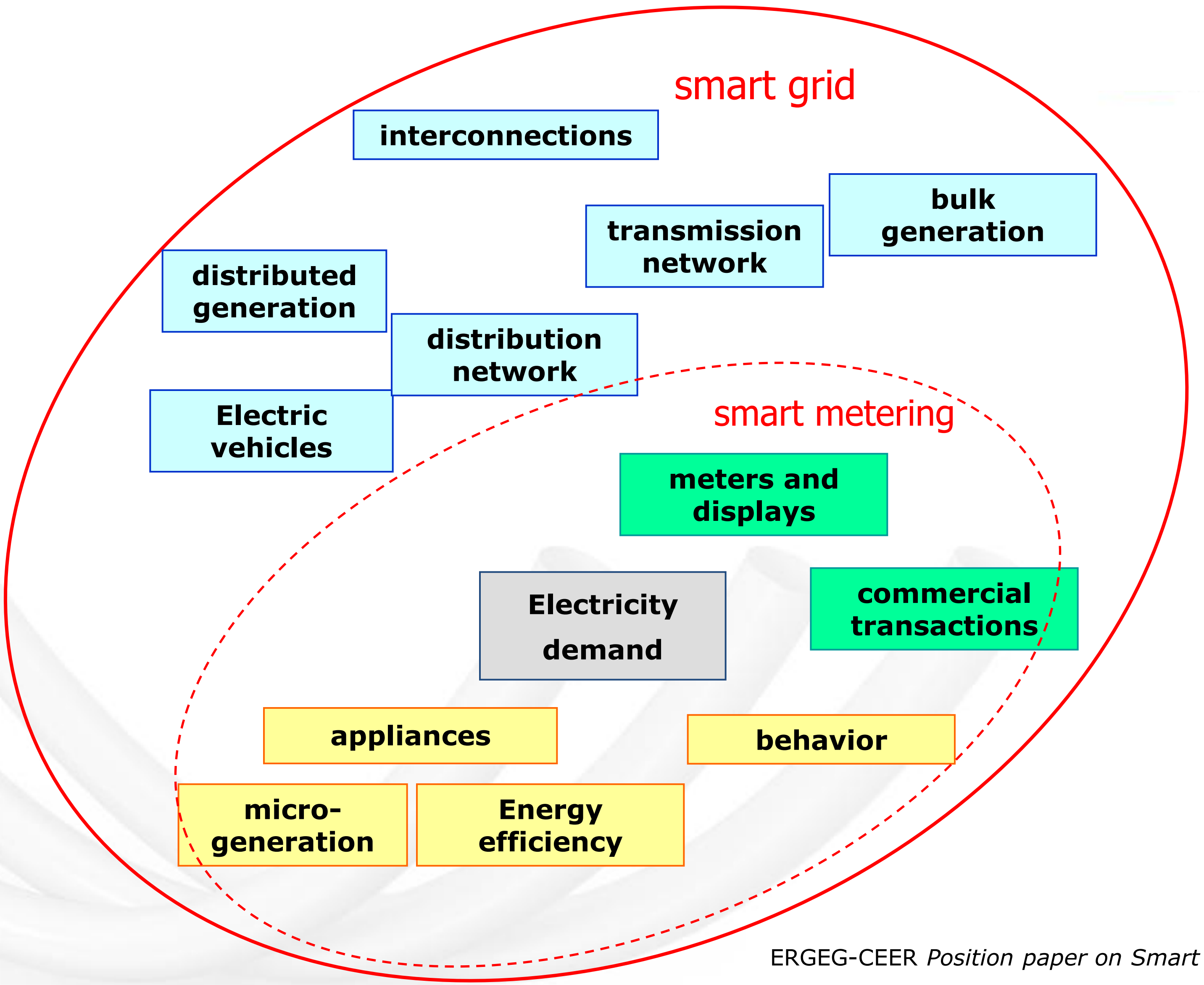
Diana Moneta

agenda

- Role of customers
- Planning & operation of smart grids
- Comparing solution: KPIs
- Research activity

Role of customers

Elements of the system

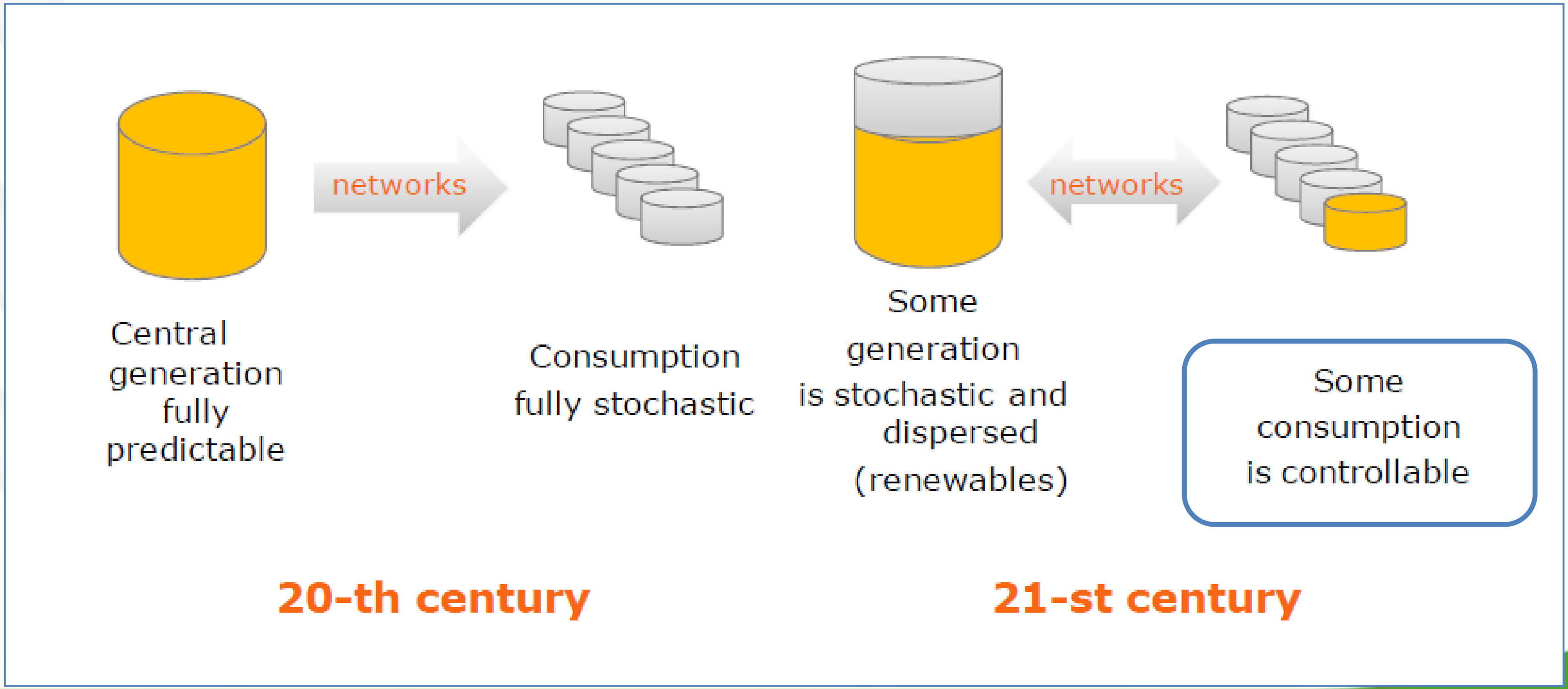


ERGEG-CEER *Position paper on Smart Grids*

Integrating DG – Towards smart grids

The widespread use of diffuse generation requires a gradual evolution of the distribution networks:

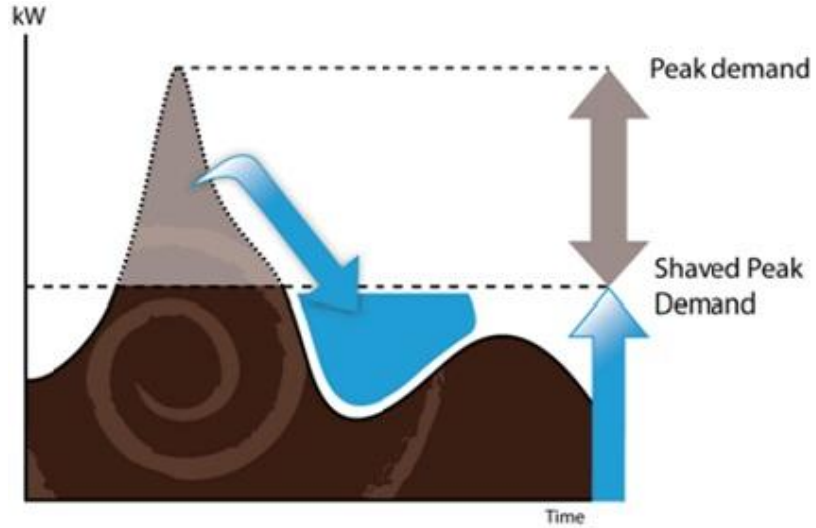
- From a *passive* structure to an *active* one, similar to the current transmission network;
- New control techniques and the management of distributed networks focused on maximization of the GD penetration, which guarantee suitable levels of the service quality to all consumers involved.



Demand Response

***Demand Response**:* customers change their absorption profile, after receiving a *price* signal or a *system* signal (security of the system)

- Curtailment of peaks
- Filling «valleys» (off peak hours)
- Load shifting

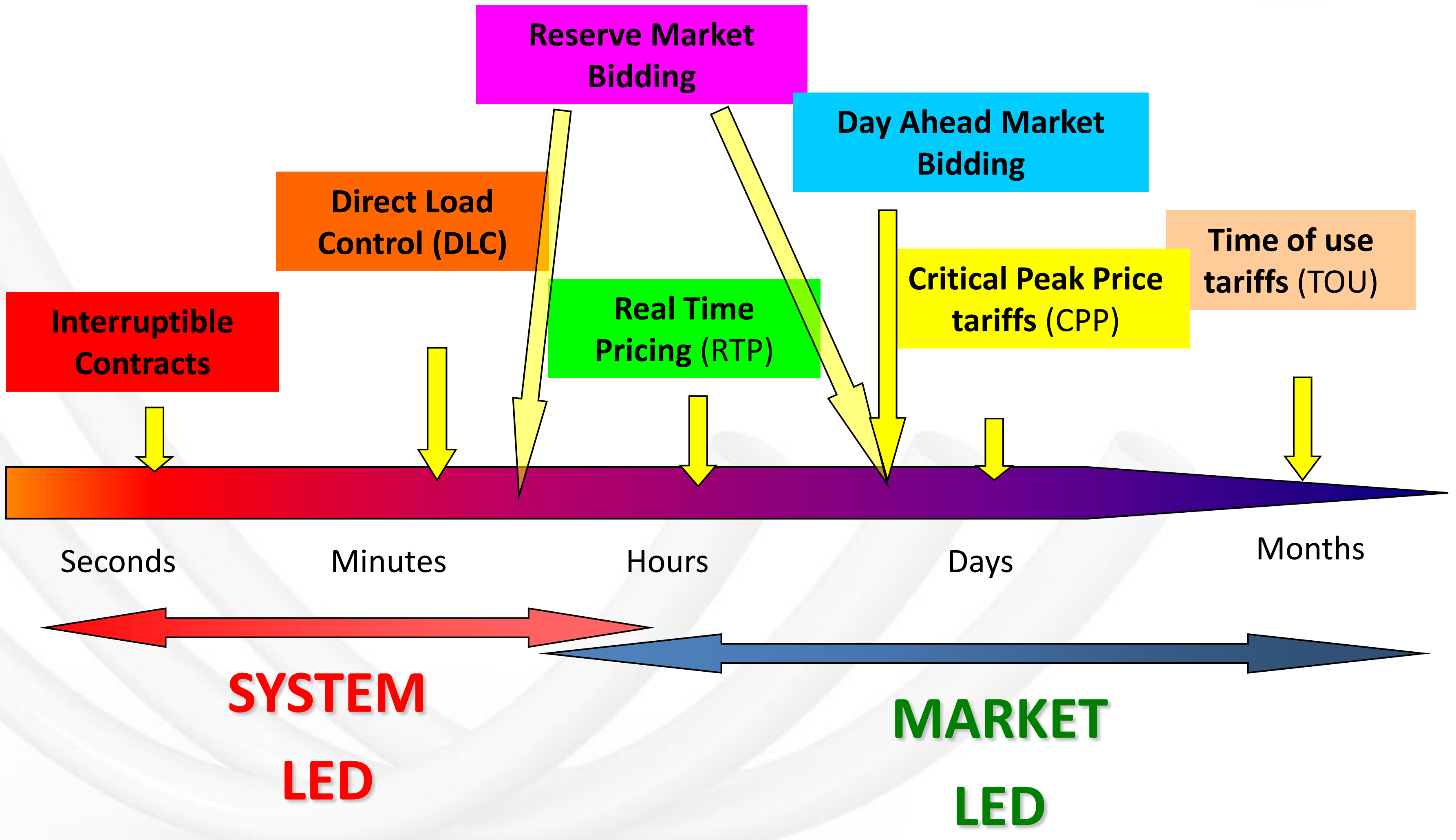


- **Benefits fo the customer**:
  - **Reward** for the participation – it is rewarderd the change of behaviour w.r.t. the usual profile
  - **Social** engagement (improved awareness, active participation)

- **Benifits for the power system**:
  - Avoid over-sizing of generation side
  - Increase the efficiency of the generation
  - Planning of distribution networks on the average load instead of critical peaks

6

Demand participation: Operational time (after notice)



Demand Side Flexibility

CONTROLLING DEMAND

- industrial, commercial, domestic demand have intrinsic levels of flexibility
- especially those including physical energy *storage* (e.g. thermal storage – inertia, potential energy storage – water pumping (municipal) , electric energy storage - EVs

ENERGY EFFICIENCY IS A KEY PRE-REQUISITE

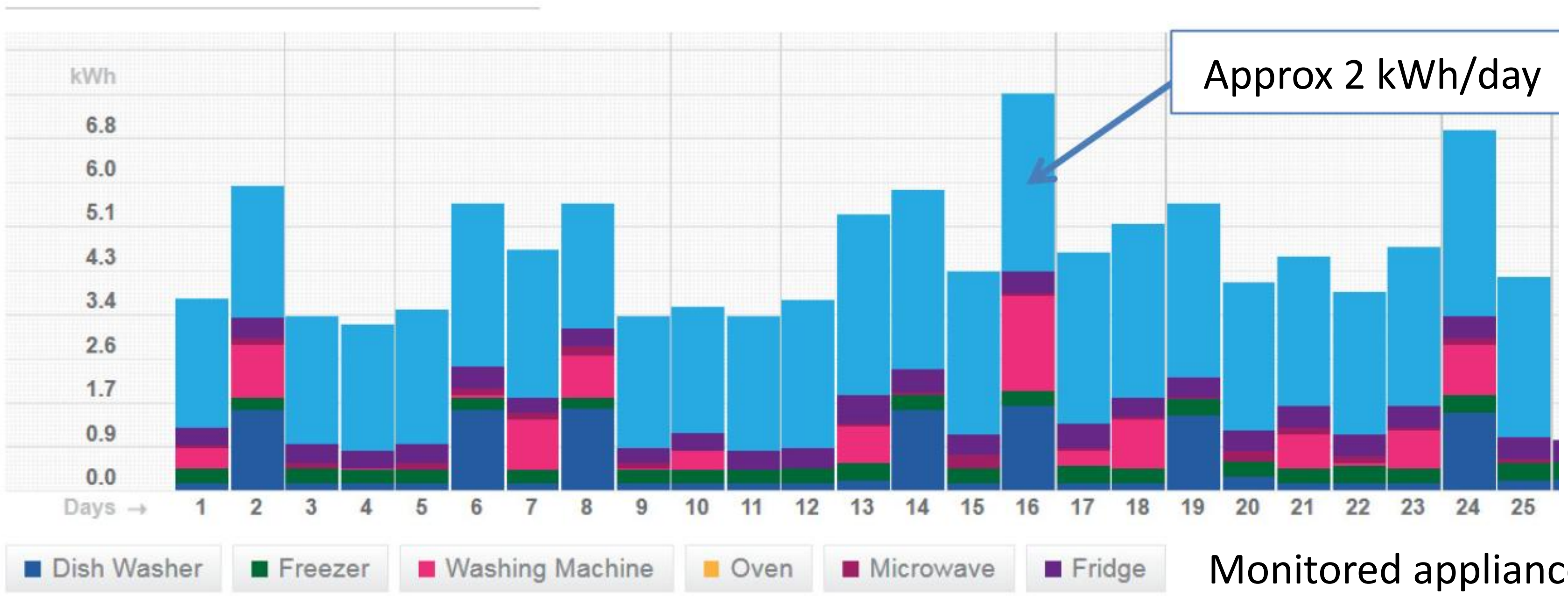
- Increased awareness is the first step for being «active customers»
- it shapes demand to better adapt to available supply

ELECTRIFICATION OF ENERGY USES

- increased electrification of transport and heating/cooling (Heat Pumps)

Increased awareness

Example of real monitoring of a residential customer

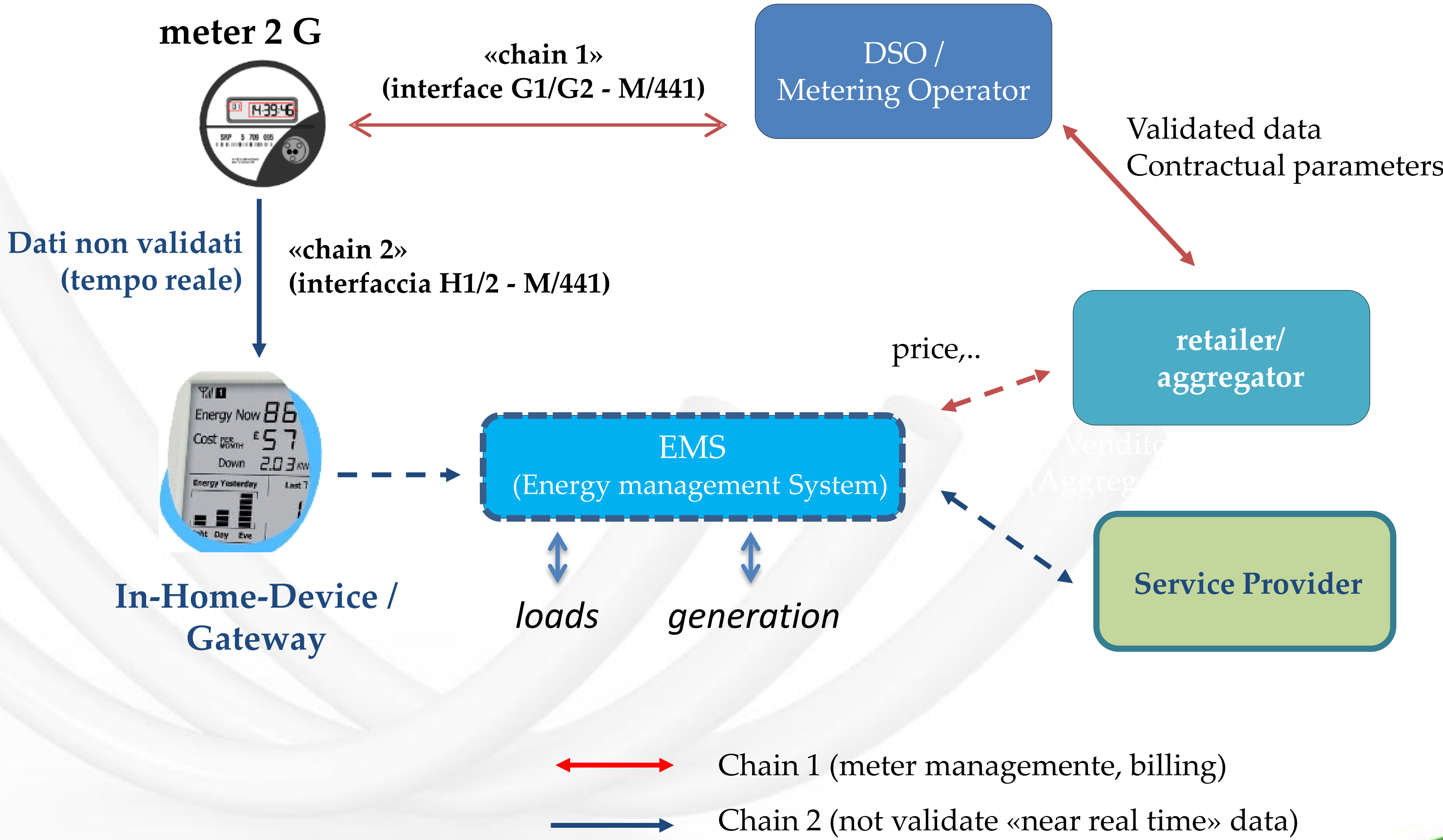


Monitored appliances

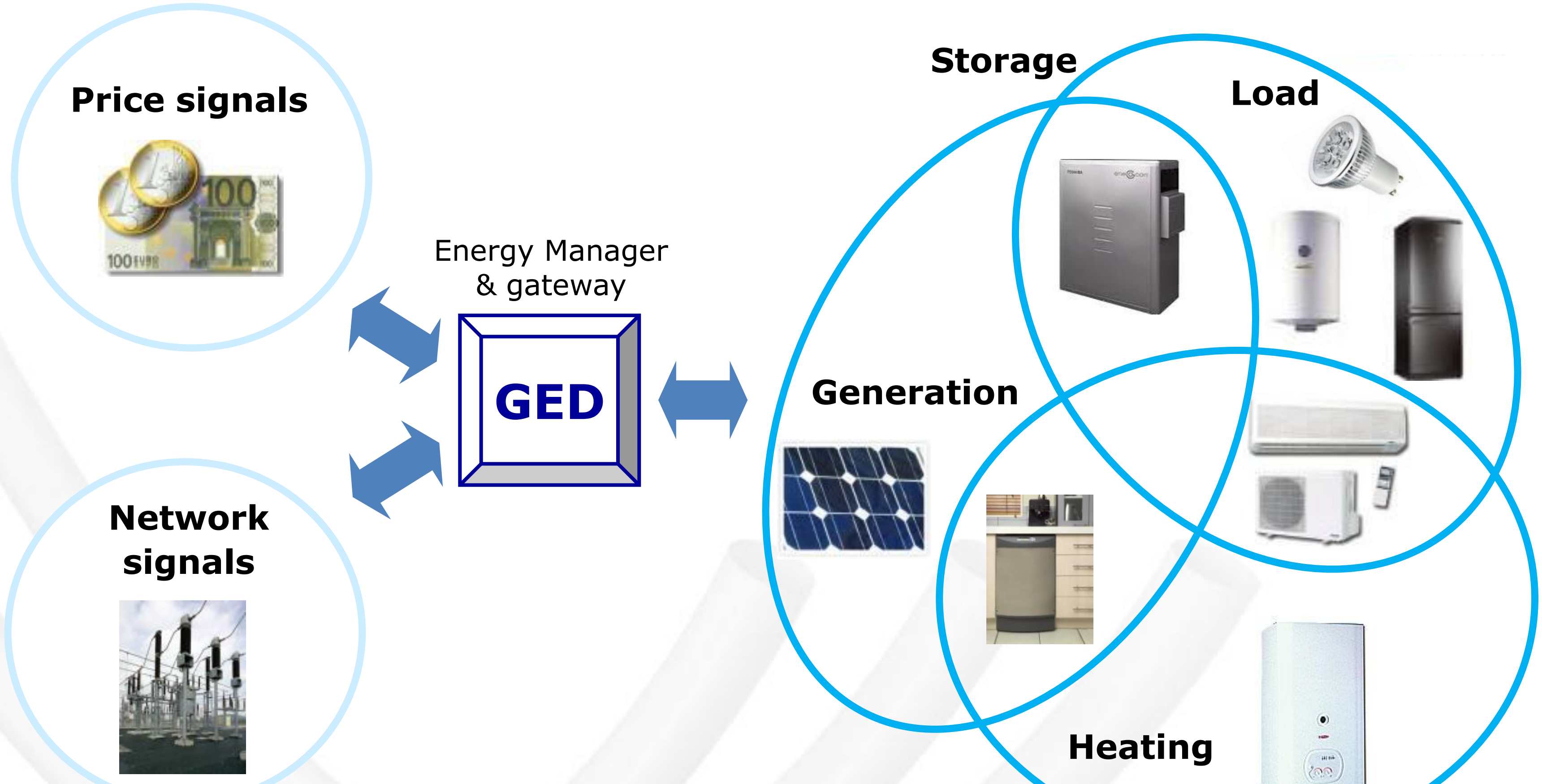
- From literature: In-home-displays can reduce consumption from 3% to 11 %
- In Italy: Smart Info (Enel): 5,000 customers, -4% on the average

Italy- roll out of second generation of electricity smart meter

35 Million meters, 4.3 G€ (2017-2031)



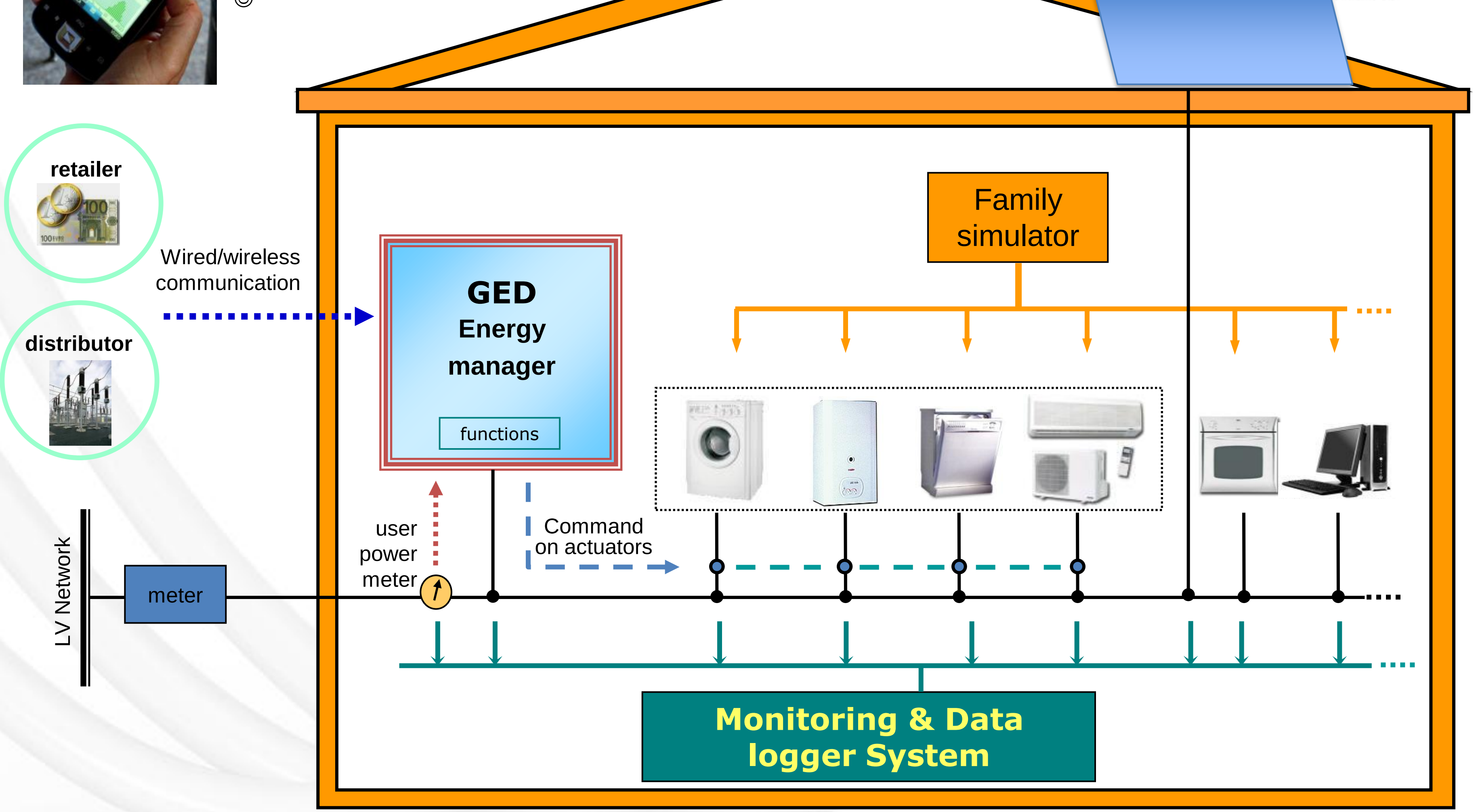
RSE - Home gateway & energy manager



- communication with distributor/retailer,
- interaction with customers,
- management of loads, energy storages and local micro-generators

RSE - Test Facility “domotic house”

2009
☺

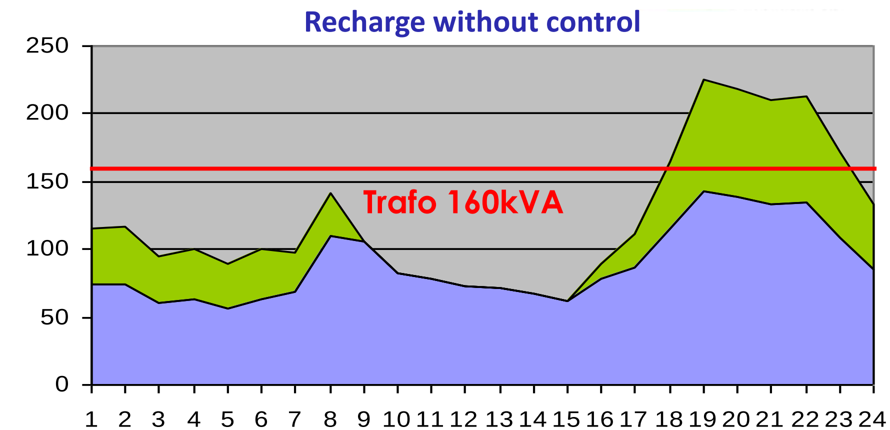


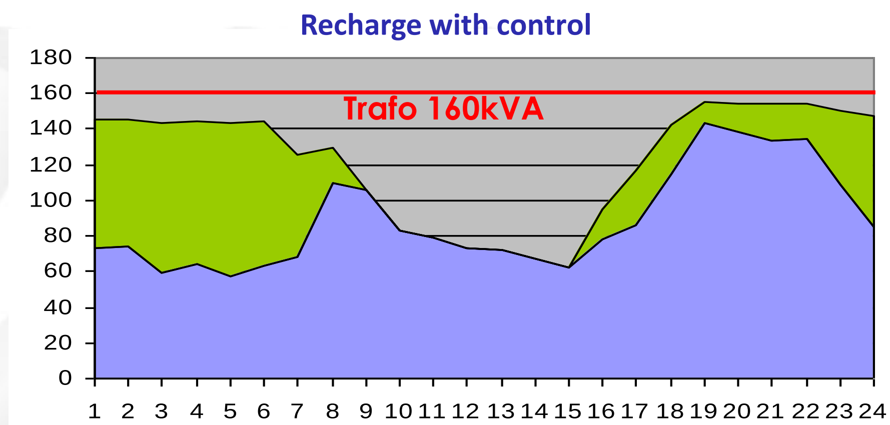
New operators entering in the market

New load: electric vehicle

- In the home: a (particular) load
- On the road: Recharge service (not buying electricity)
- Impacts / benefits on the consumption / distribution network / power system
- Perspectively:
  - AC recharge (one way): flexible load
  - DC recharge (bi-directional, Smart charger): V2H, V2G

Demand Management - Electric Vehicles Charging





Prosumers – perspective role

- opportunities for customers:
  - local ‘dispatching’: increase self consumption (scheduling loads with PV production)
  - perspectively, participation to the services (by aggregation)
- opportunities for DSOs:
  - ‘smart’ DG has less (negative) impacts on distribution networks
  - perspectively, integration of PV plants in network operation
  - possible integration of real time data from inverters in the LV monitoring systems (depends on market scheme also)
- challenges:
  - “lay people” involved
  - simplified & future proof solutions
  - need for a widespread communication infrastructure (CAPEX, OPEX – who pays?)

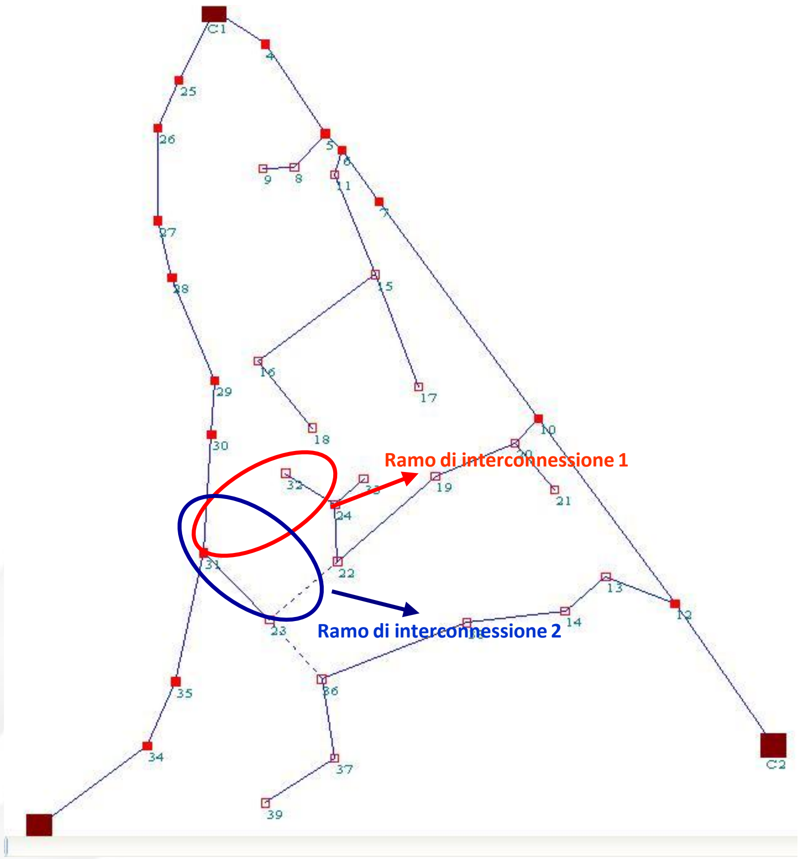
Planning & operation of «smart grids»

RES integration: system planning with DG

SPREAD calculates the best network configuration minimising the overall costs for the distribution operator (CAPEX + OPEX);

Costs categories considered:

- Network investments (upgrade of existing lines, transformers, switchgears and installation of new network equipment);
- Minimise network losses in lines and transformers;
- Minimise non-delivered energy in case of unplanned unavailability;
- Optimise active management (remunerating ancillary services)



Managing «active distribution networks»

Technical Issue	BAU Distribution Network	Active Distribution Network
Voltage rise/drop	• Limits/bands for demand and generation connection/operation • Generation tripping • Capacitor banks	• Coordinated volt-var control • Static var compensators • Coordinated dispatch of DER • On-line reconfiguration
Hosting Capacity	• Network reinforcement (e.g., lines/transformers)	• Coordinated dispatch of DER • On-line reconfiguration
Reactive Power Support	• Dependency on transmission network • Capacitor banks • Limits/bands for demand and generation connection/operation	• Coordinated volt-var control • Static var compensators • Coordinated reactive power dispatch of DER
Protection	• Adjustment of protection settings • New protection elements • Limits for generation connection • Fault ride through specifications for generation	• On-line reconfiguration • Dynamic protection settings
Ageing	• Strict network designs specifications based on technical and economic analyses	• Asset condition monitoring

Advanced control approach

Objective:

Develop advanced control strategies in order to maximise DG diffusion (hosting capacity) and to assure adequate power quality levels

Two different approaches:

- diffuse control (local),
- centralised control

'slow' actions

→ *develop and verify control functions*

Example - Optimization algorithm ('DISCoVER')

- Spatial perimeter: MV network under a Primary Substation (in a fixed configuration)

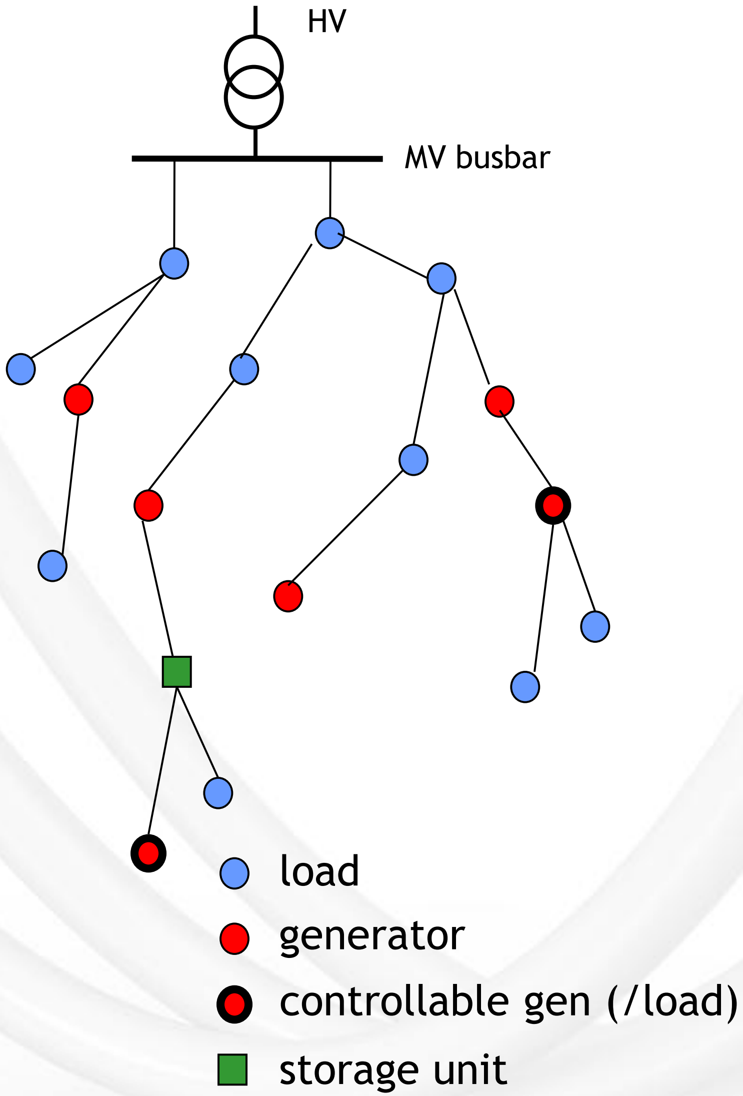
- Temporal horizon: current network status (from State Estimation) and following 24 h

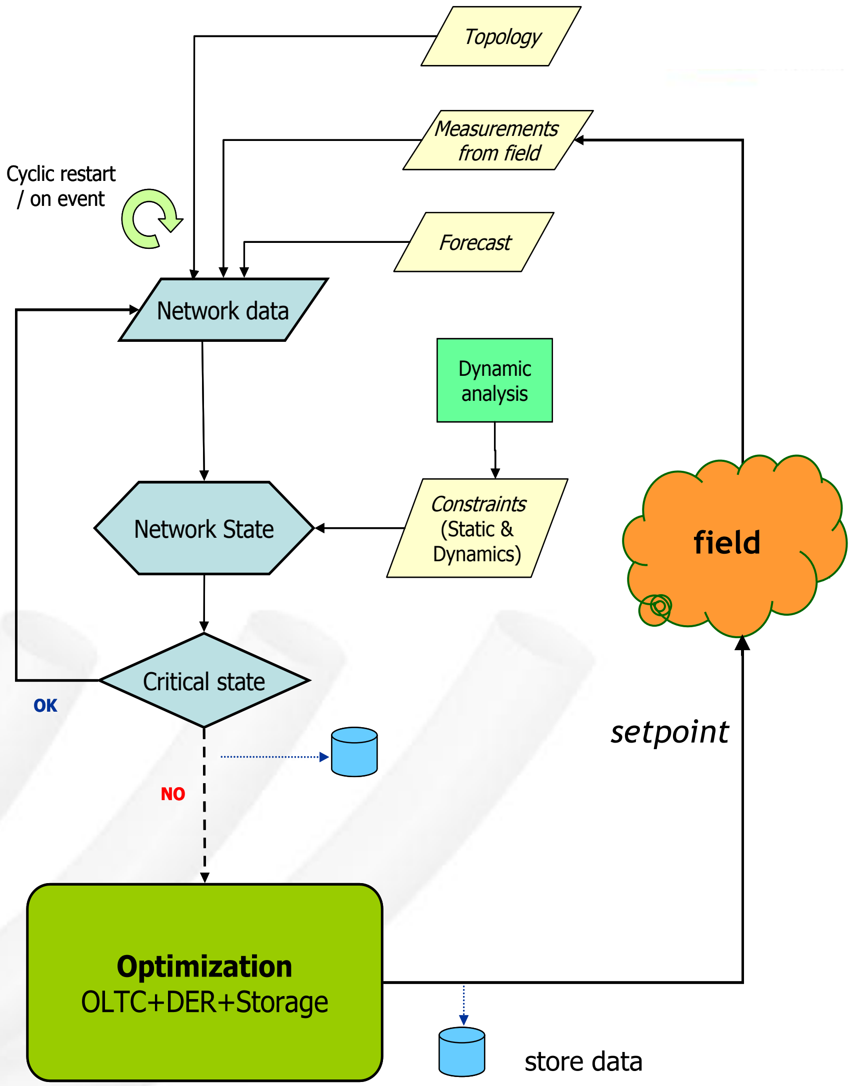
- Load and generation *forecast*

- O*ptimization* procedure to minimize costs of control actions needed to satisfy technical constraint

- Several *resources*

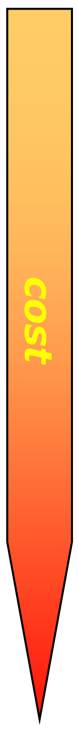
DISCoVER (2)


HV
MV busbar
load
generator
controllable gen (/load)
storage unit


Topology
Measurements from field
Forecast
Cyclic restart / on event
Network data
Dynamic analysis
Network State
Constraints (Static & Dynamics)
field
Critical state
OK
NO
setpoint
Optimization
OLTC+DER+Storage
store data

Regulation resources

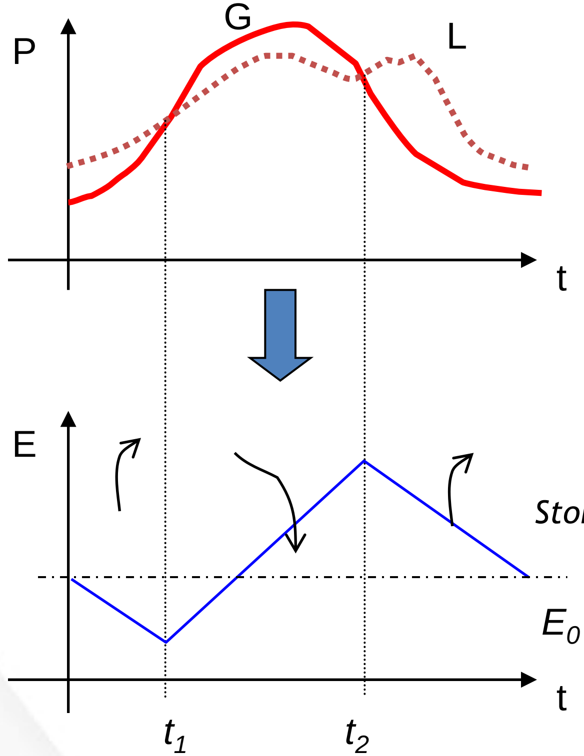
- *On Load Tap Changer (OLTC):*
  - operated by DSO
- *Capacitor bank*
  - operated by DSO
- *Reactive* power injection/absorption by ‘controllable’ generators (subset of DERs)
- *Active* power modulation of “controllable” generators (subset of DERs)
- *Storage:*
  - operated by DSO (*integral* constraint on 24 h period)



capability curves of controllable resources
costs of resources operated by the DSO
rewards of Ancillary Services

Reference scenarios

1



Power flow inversion only in some periods

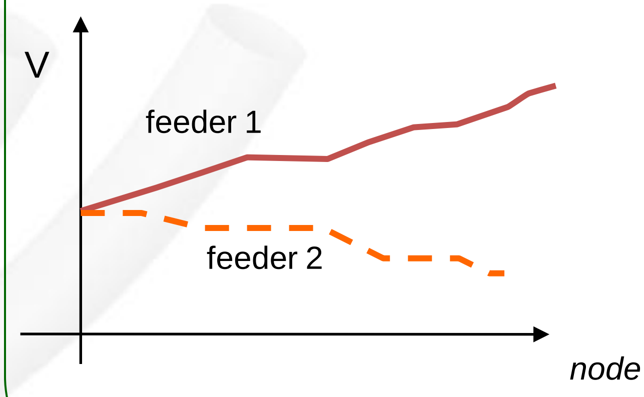
Storage charge-discharge

"47"

It is necessary to define an adequate 'business model' for costs (relative values)

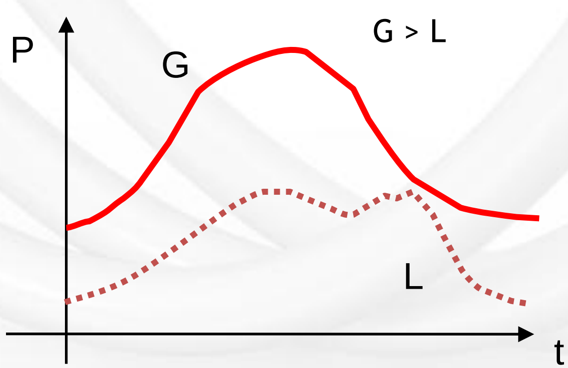
Unbalanced network

3



"49"

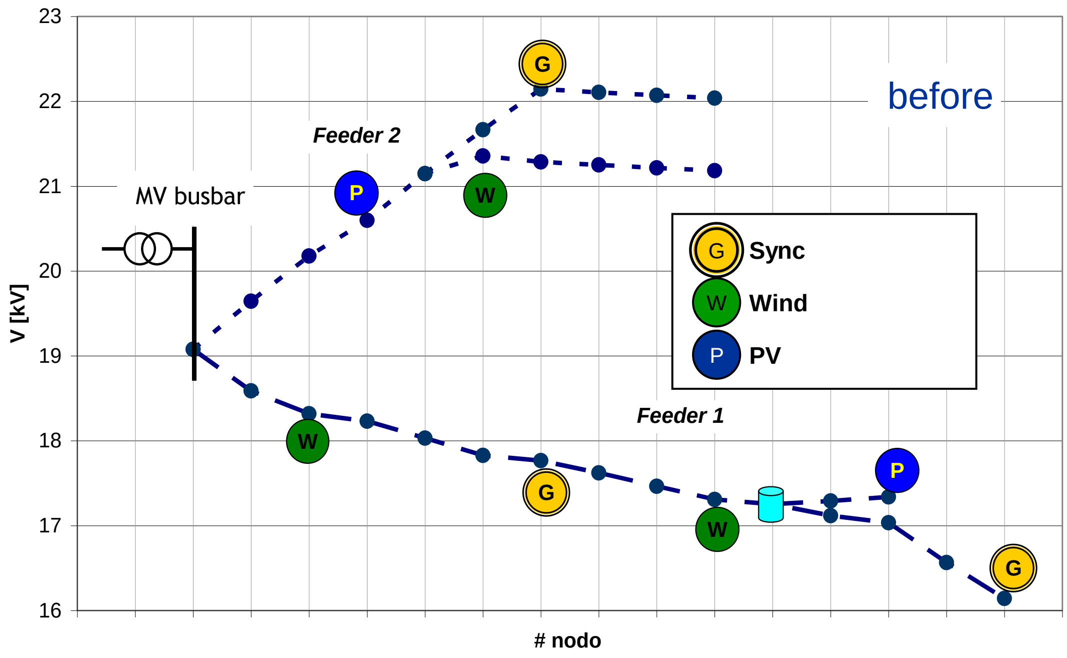
2



Totally 'active' network

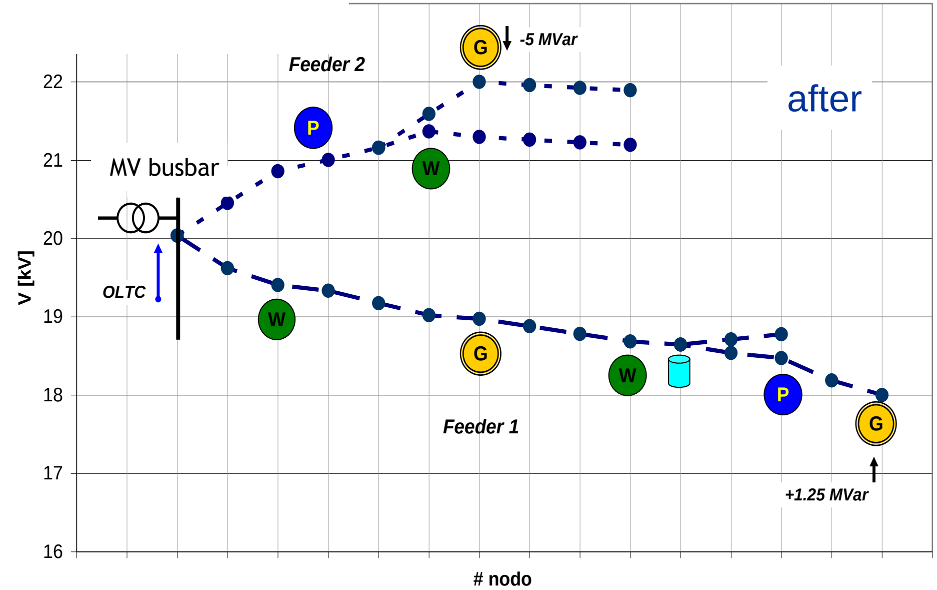
"43"

Case 3

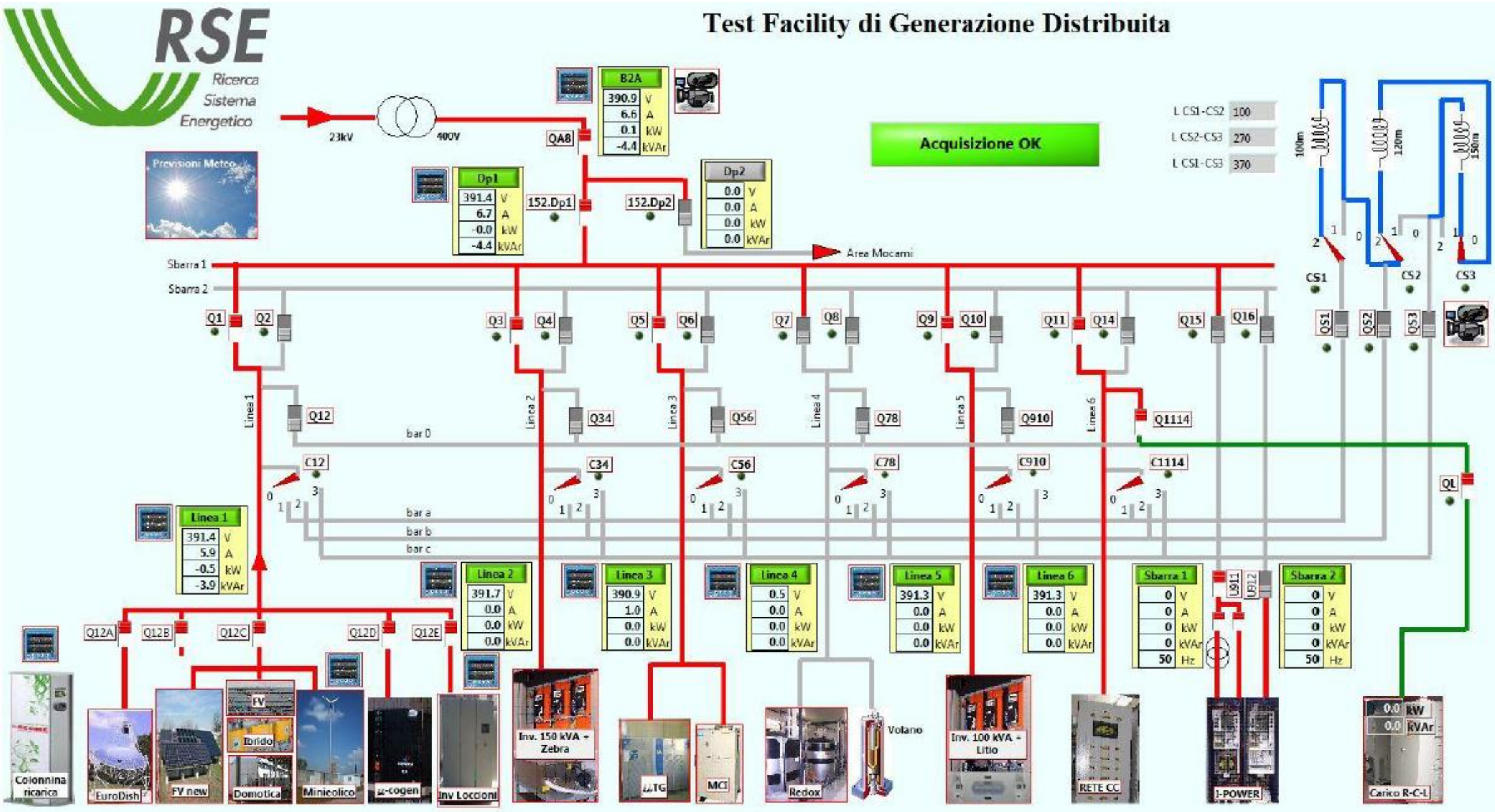


Unbalanced feeders: OLTC cannot operate properly

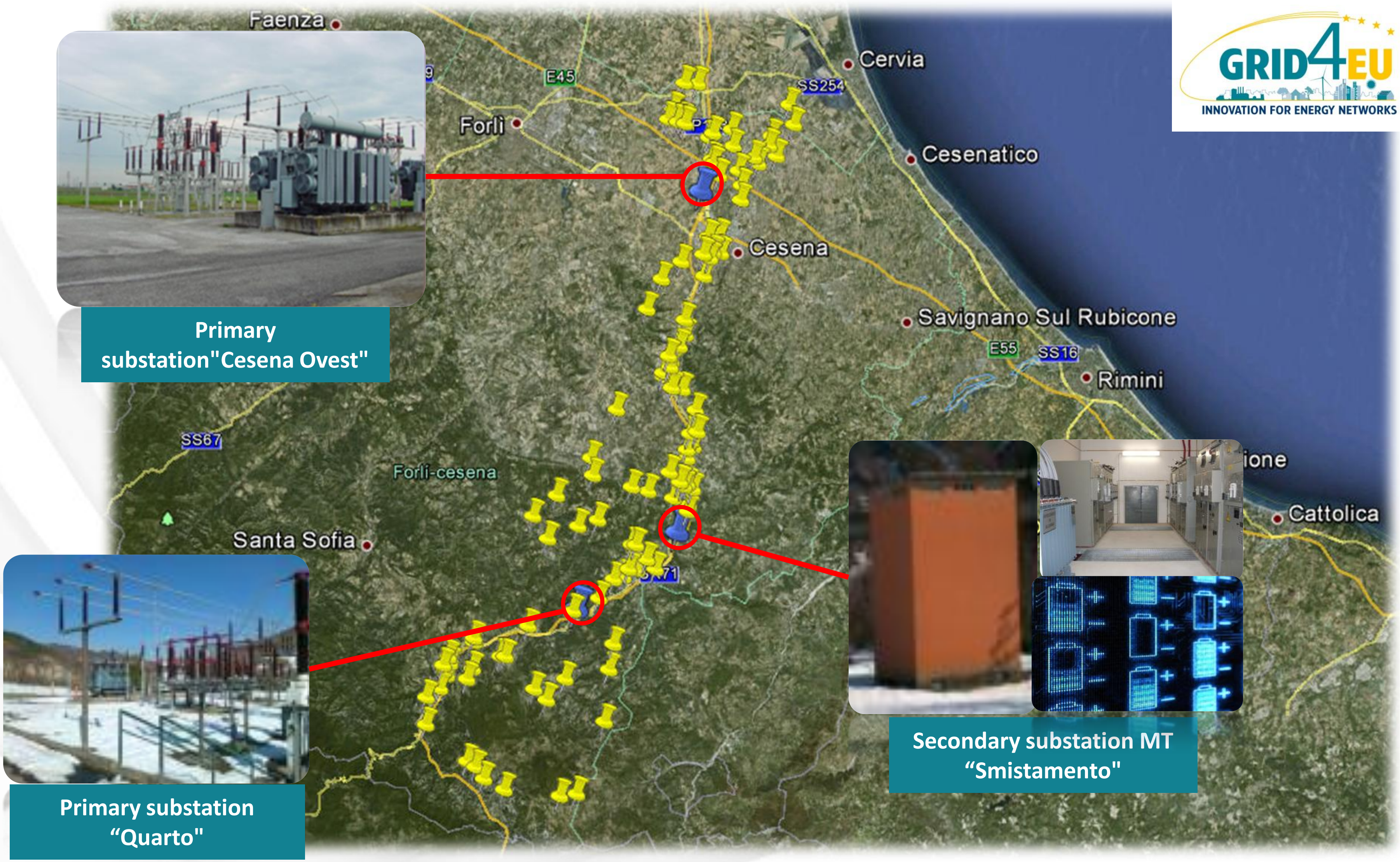
reactive power modulation (to reduce the 'fork') + OLTC



Example – RSE test facility



Real application: Italian demonstrator of EU project Grid4EU



Grid4EU - demonstrators

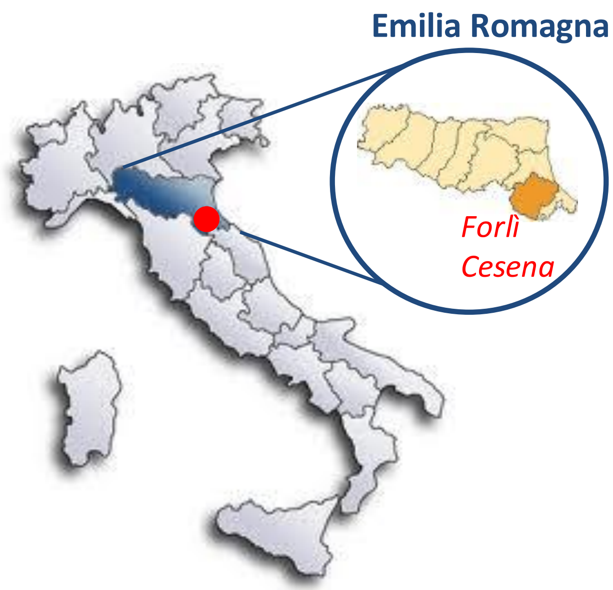
	RWE	VATTENFALL	IBERDROLA	Enel	CEZ GROUP	ERDF
Innovative Power Management at MV level	●		●	●	●	
Innovative Power Management at LV level		●	●		●	●
Distributed Energy Resources (DER)	●			●	●	●
Storage				●		●
Active Demand			●			●
Micro-grid (Islanding)					●	●
Climate	**Moderate** *Continental*	**Cold & Stormy** *Continental/ Oceanic*	**Mild** *Mediterranean*	**Dry** *Mediterranean*	**Cold** *Continental*	**Warm & stormy** *Mediterranean*
Population Density	Semi-urban	Urban	Urban	Rural	Semi-urban	Semi-urban / urban

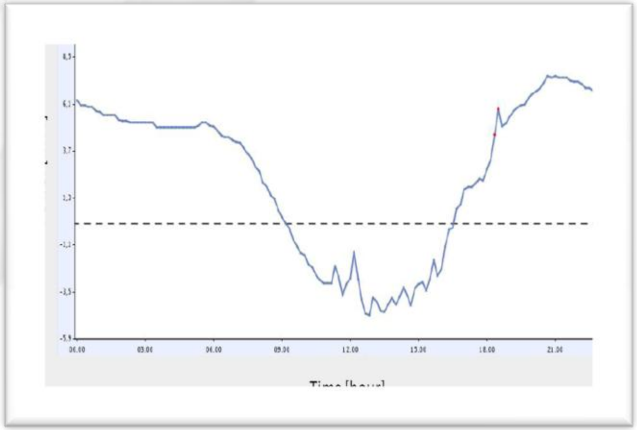
- Nov 2011- Jan 2016
- Carried by 6 DSOs (cover more than 50% of the metered electricity customers in Europe)
- 27 partners (Utilities, Energy Suppliers, Manufacturers, Research Institutes)

Demo4 – Grid4EU

GRID4EU INNOVATION FOR ENERGY NETWORKS

- 2 primary substations
- 20 MV lines, approx 110 secondary substations
- High RES penetration (105 MWp) with rather low consumption
- Reverse flow





Enel L'ENERGIA CHE TI ASCOLTA. RSE Ricerca Sistema Energetico SIEMENS SELTA CISCO

Example – SmartNet

Distributed energy resources (DER) participate to the Ancillary Service market

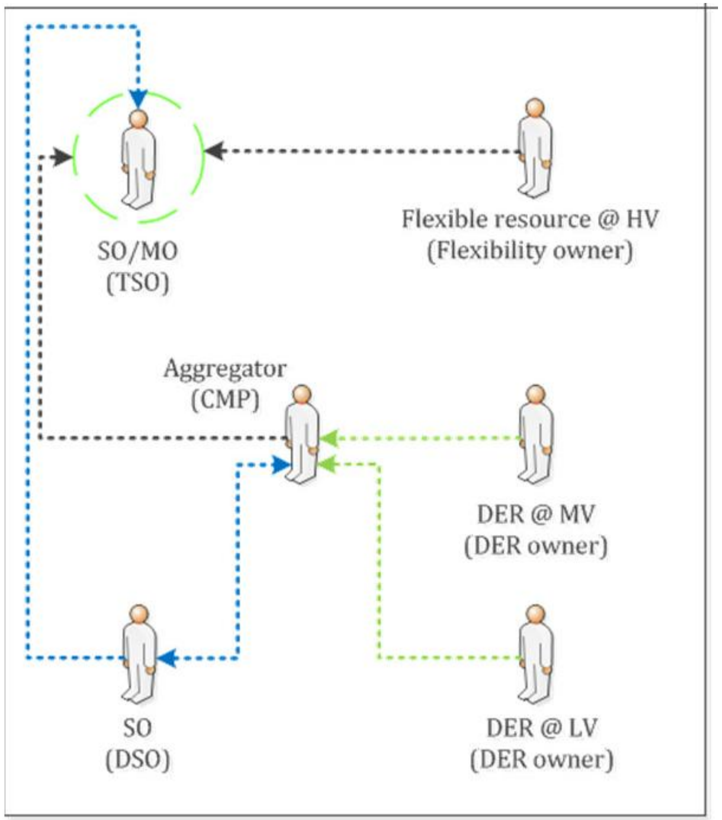
→ Interaction TSO-DSO-DER

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

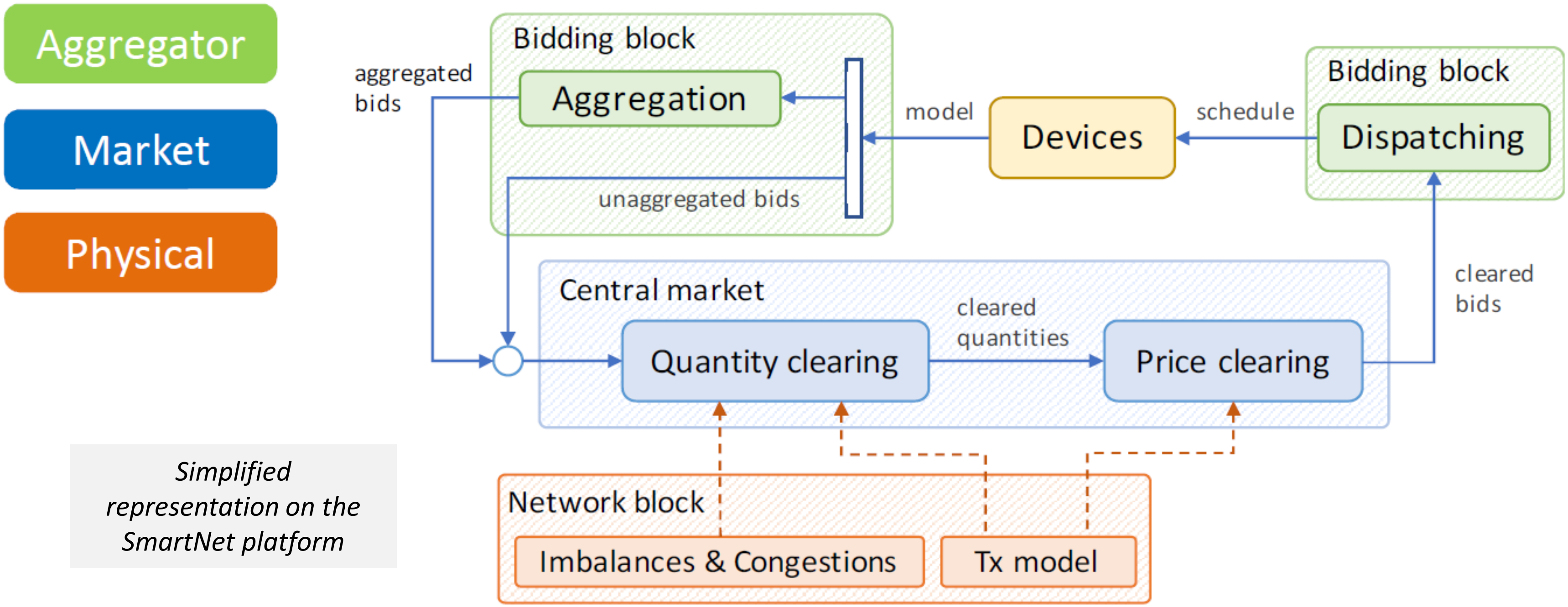
3 pilots:

- Italy (hydro plants)
- Denmark (pools)
- Spain (radiobase stations)



Centralized AS market model

Distribution networks & ancillary services



Simplified representation on the SmartNet platform

- the *extended centralised market model* is simple*, but* DSO grid constraints are not included
- DSOs do not benefit from possible advantages of DER flexibilities
- Other *schemes* involve complex architecture, which can result in higher costs, numerical unfeasibility, and risk of non liquid markets

Evaluate and compare «smart grid» solutions

Comparing solution

- Several technical solutions are available

→ Which is the «best»?

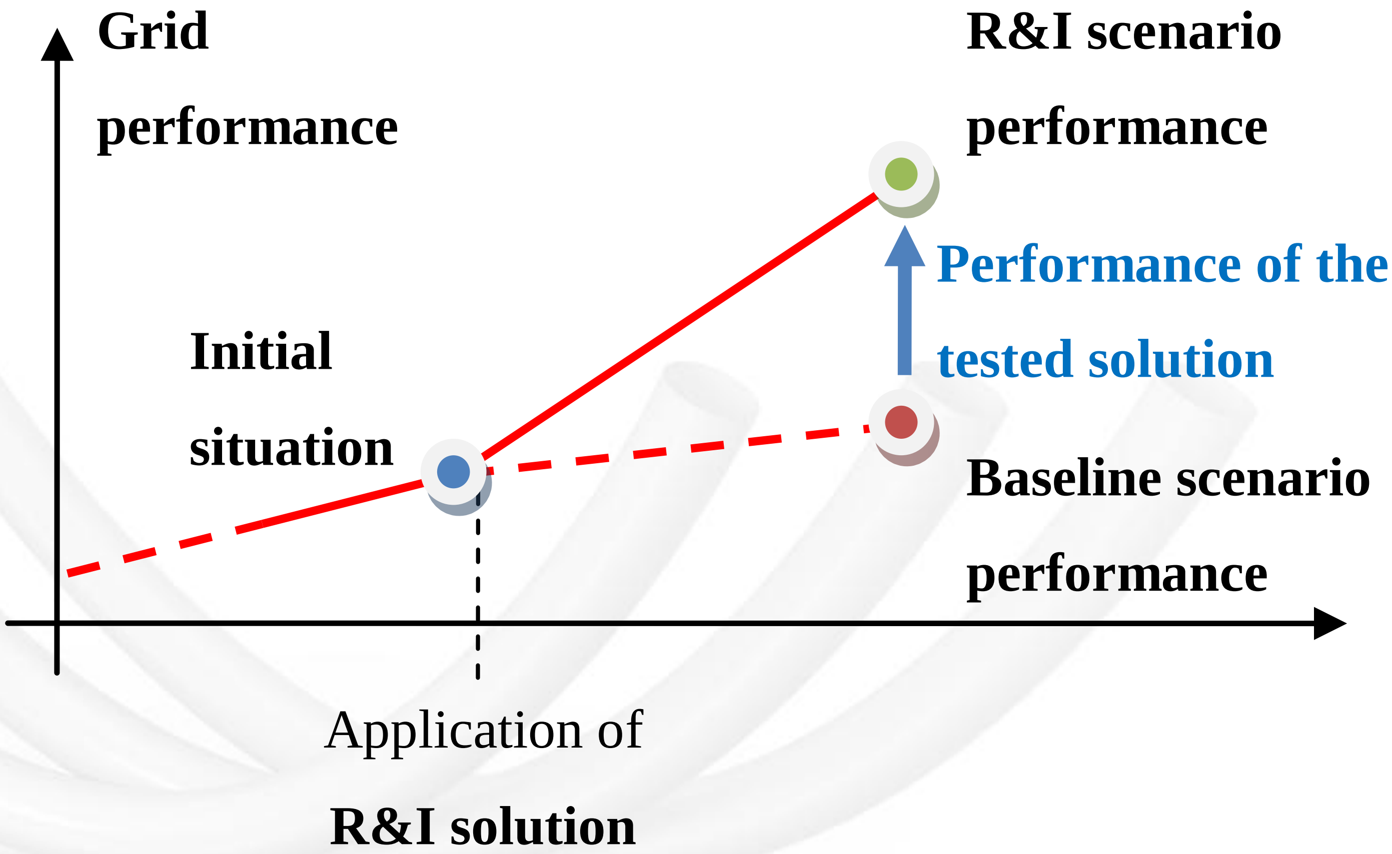
- National regulatory authority: *output based regulation*; increased reward for advanced solutions, only demonstrating the benefits by means of *indicators*

- *Cost-benefit analysis;* e.g. smart metering

  → *Needs to identify* indicators and procedures

Improvement of the network performances

Research and Innovation (R&I) **technologies** are designed in order to increase the **performance** of a network under test (benefit).



KPI Grid4EU demos - compare different solutions

One of the objective of the project was to compare the control solutions

→ For this reason the same KPIs were evaluated in the different demos.

DEMO	RWE	Vattenfall	Iberdrola	ENEL	CEZ	ERDF
Energy Losses	V		V	V	V	V
Fault Awareness, localization and Isolation Time	V	V	V		V	
Network Hosting Capacity	V			V		V
Line voltage profiles				V	V	V
Islanding Metric					V	V
Use of Standards	V		V	V		V
Recruitment			V	V		V
Active Participation			V	V		V

KPI Grid4EU - comparison

DEMO	1	2	3	4	5	6
Energy Losses KPI [%]	26-30		±5	2.2-9.3	47.5	28-37 (storage losses)
Fault Awareness, Localization and Isolation Time KPI [%]	21.5	78.8	-12.8		85-90	
Network Hosting Capacity KPI [%]	17.4			10-63		-
Line voltage profiles KPI [%]				0.8-3.4	0	-
Islanding Metric					1.7-6	0.25-0.63
Use of Standards KPI [%]	100		88	80		-
Recruitment KPI [%]			37	31		15-50
Active Participation KPI [%]			5-28	100		>0

The comparison between different network /solution is quite difficult due to the variation between the demos of:

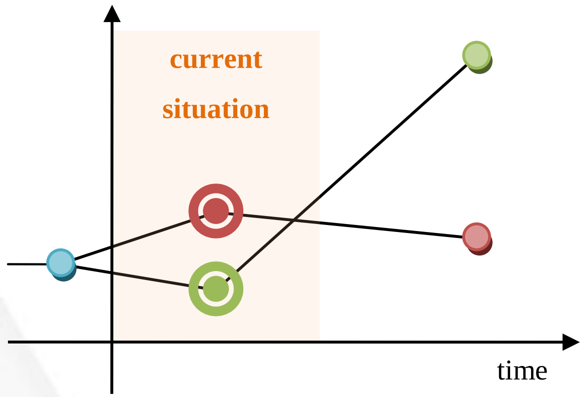
- KPI definitions
- Calculation methodology
- Availablle data (combination of measured and calculated data)
- Baseline condition
- Network characteristic

Beside the KPI sshow:

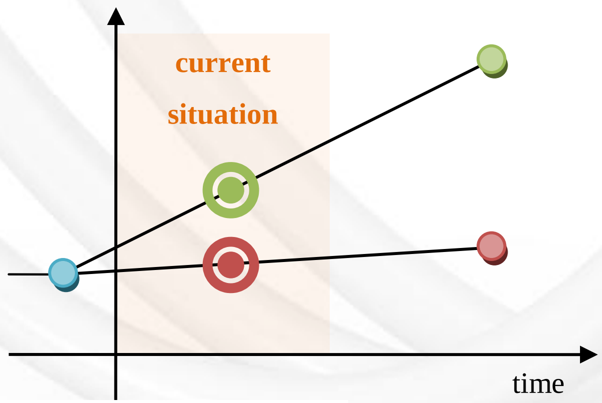
- High interdependence;
- High variability;
- Real field issues (the *a priori* calculation can be different to the real field).

KPI – advanced calculation procedure

Network performance evolution from economic/environmental point of view



Network performance evolution from technical point of view



In some cases, the currently measured smart-grid impact does not represent in an effective way the expected performance of the adopted solutions.
Thus, the impact has to be opportunely scaled in order consider a selected future scenarios.

This scaling procedure is normally necessary when **economic** and/or **environmental** aspects are considered:

•**Cost Benefit Analysis** Output based regulation
(performance from the economic point of view)

•**Life Cycle Assessment**
(performance from the environment point of view)

When the performance of the adopted solutions has to be evaluated from the **technical point of view**, the current scenario often can be reasonably considered comparable with the future one.

Definition of the Baseline scenario

Baseline (BL)

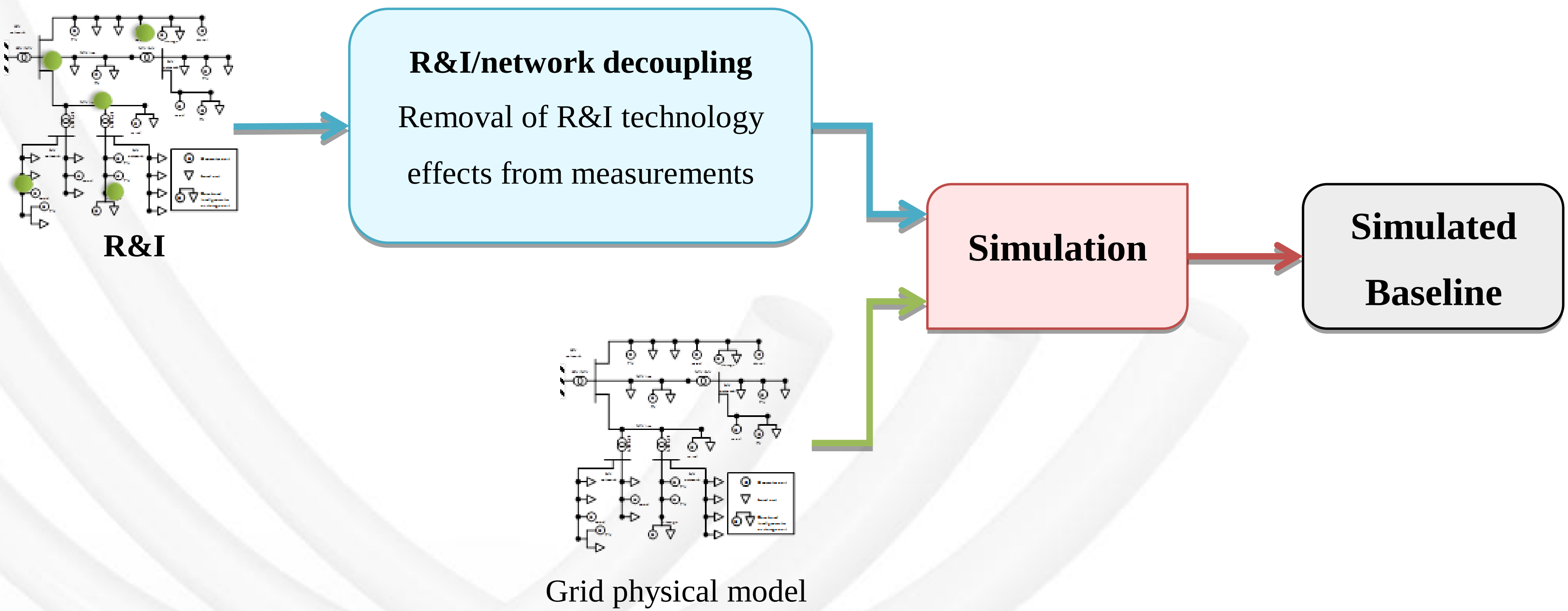
For a given R&I scenario, the baseline corresponds to the network situation, if it exists, in which:

a) the R&I technology is <u>not operative</u>
b) customers have a consumption/generation profile which <u>would have had</u> if the R&I technology has not been operative
c) network assets/devices shows the same behaviour which <u>would have had</u> if the R&I technology has not been operative

Assumption: even with no operative R&I technology, the behaviour of the network would be technically acceptable

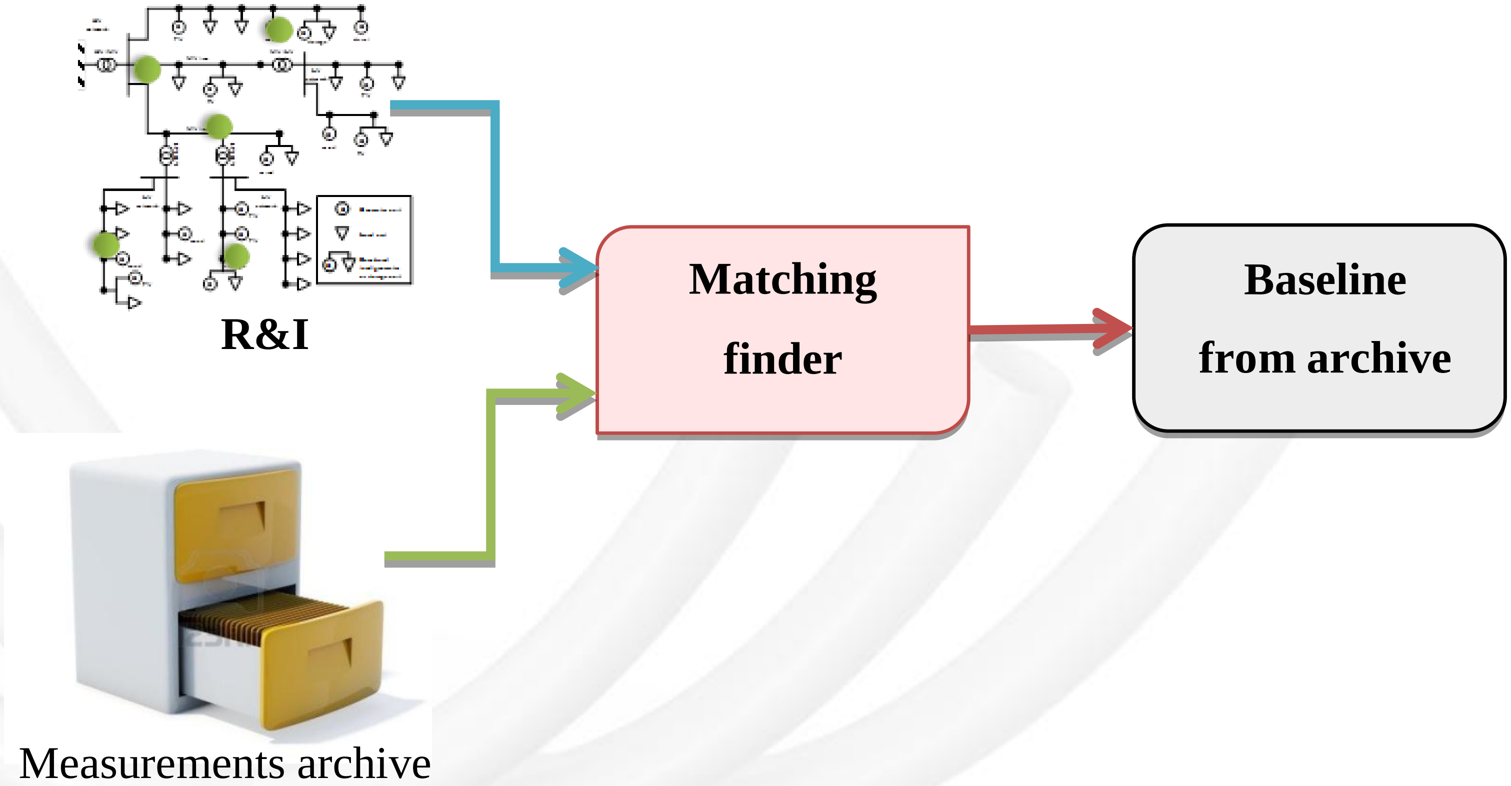
Definition of the Baseline scenario (2)

Baseline from simulation



Definition of the Baseline scenario (2)

Baseline from historical data

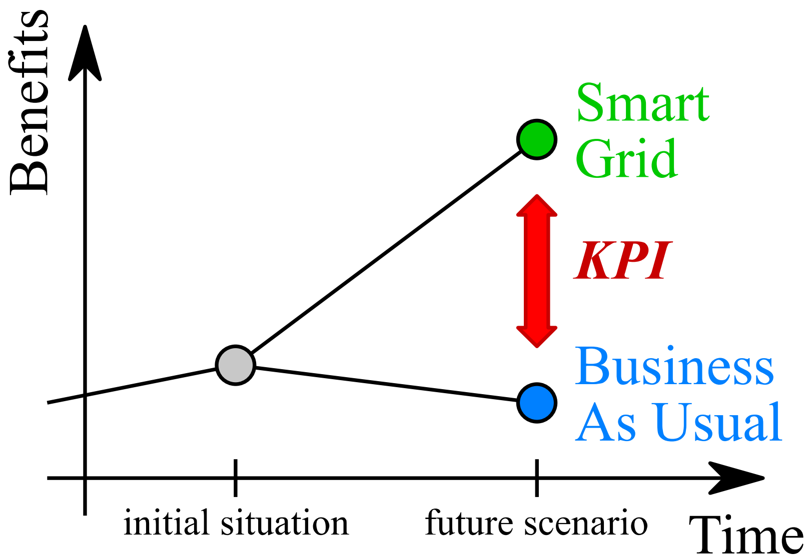


EEGI and IGREENGrid calculation schemes

EEGI
EUROPEAN ELECTRICITY GRID INITIATIVE

Hypothetical **future scenario** and comparison between:

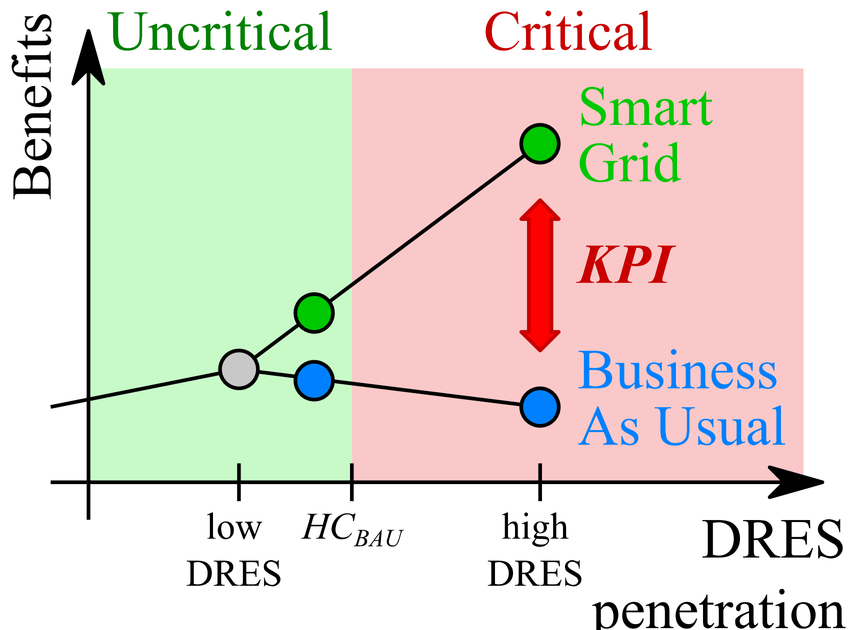
- Network operated as usual
- Smart Grid



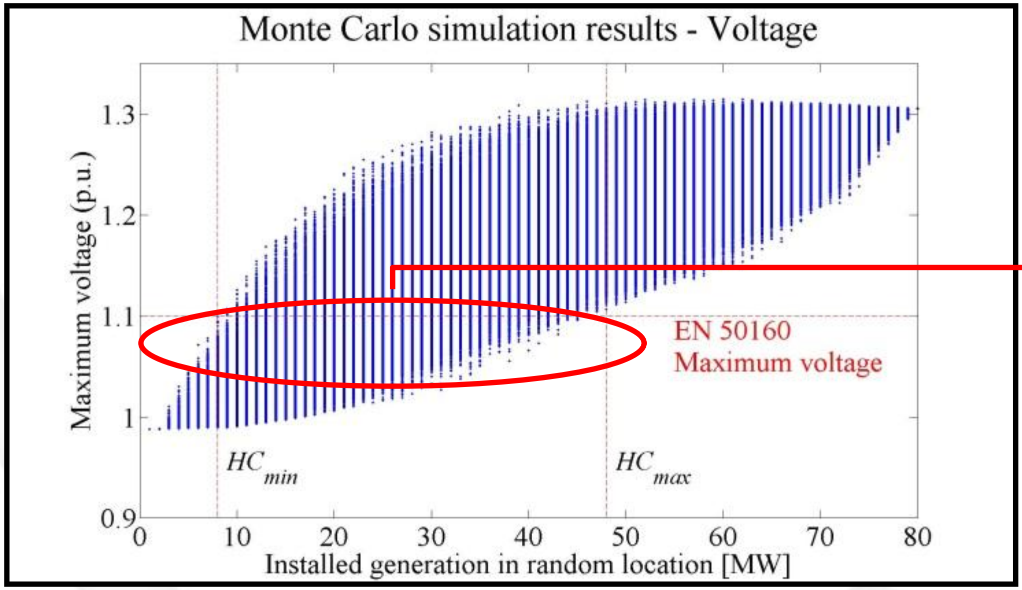
IGREENGrid

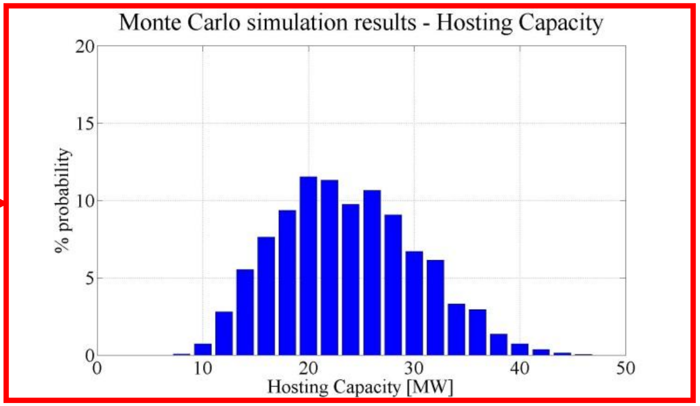
Hypothetical **large DRES integration scenario** and comparison between:

- Network operated as usual
- Smart Grid



Selection of the reference scenario





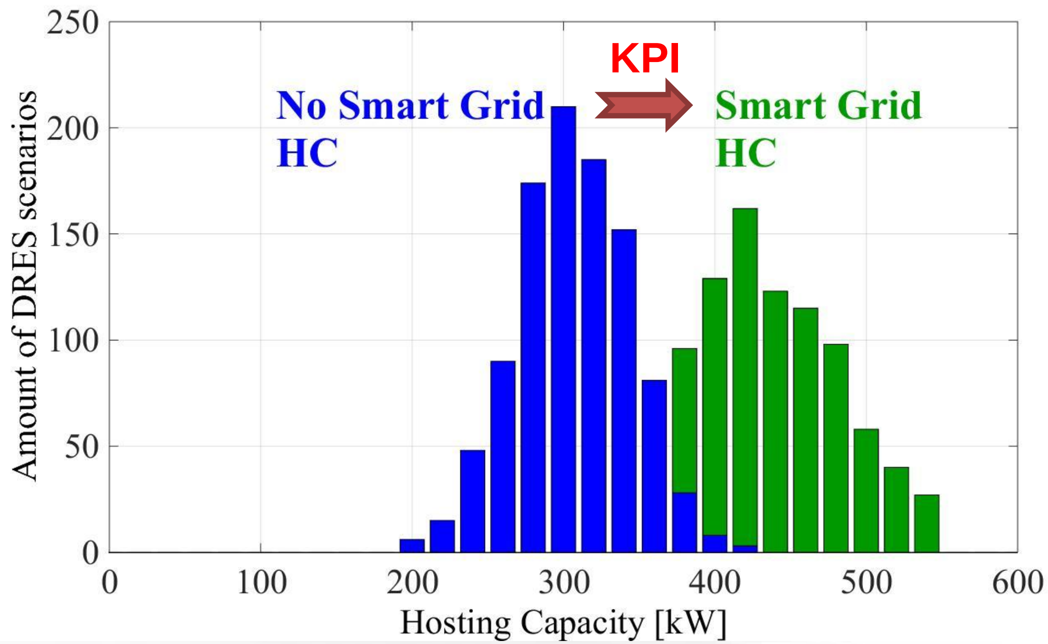
Network Hosting Capacity for different allocations of DRES units

Simulation of scenarios with high penetration of DRES in distribution grids

- **Selection of situations in which the solution has a significant impact on network operations**
- **Uncertainty related to the future scenario to be simulated (*size and location of DRES units*)**

KPI example – Increase of DRES Hosting Capacity

- KPI measures the ability of a **Smart Grid solution** to **maximize DRES generation** that can be hosted by a distribution network

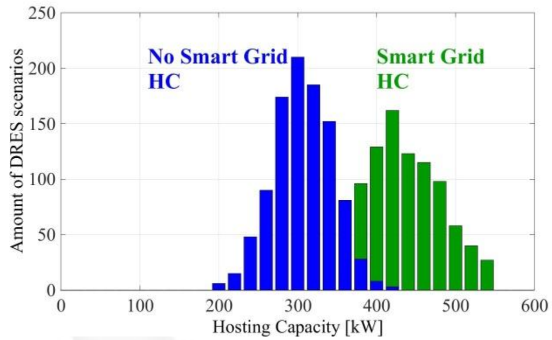


Simulation results calculated for an exemplificative Smart Grid solution applied on a distribution network.

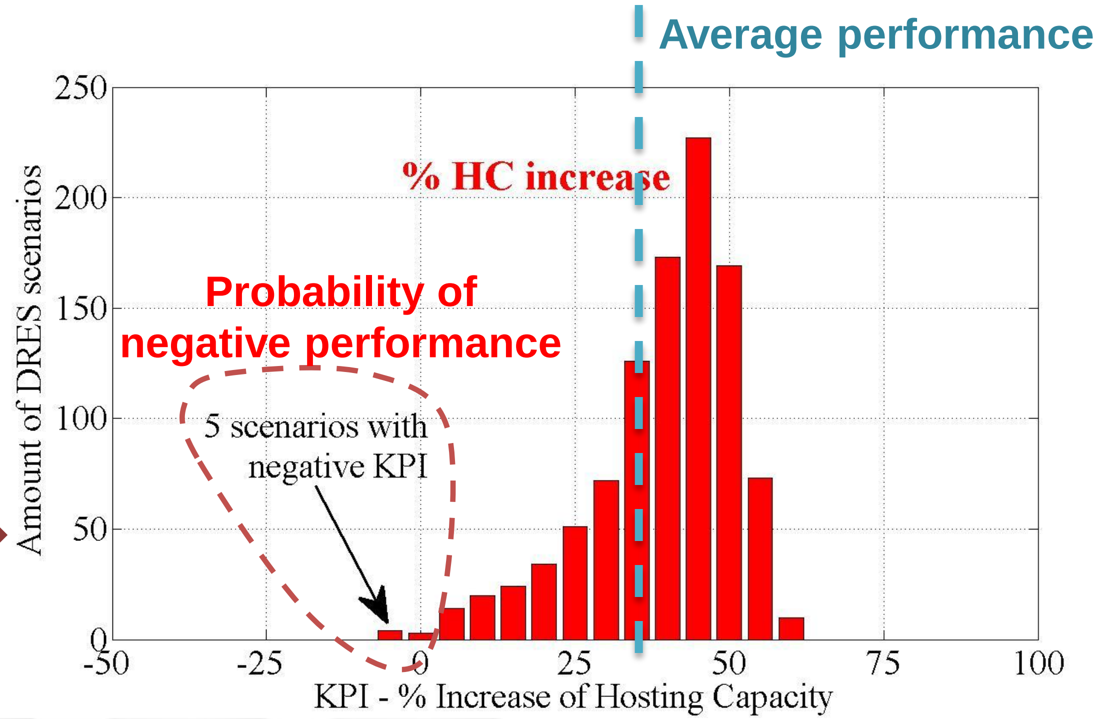
- **DEMO network** simulated
- **1000** random allocations of DRES
- **Time profiles** of DRES and loads of the DEMO area

KPI – Increase of DRES Hosting Capacity (2)

The adopted simulation strategy returns results that can be processed for the **extraction of numerous information** for the evaluation of the performance of a solution



$$KPI_1 = \frac{HC_{R\&I} - HC_{BAU}}{HC_{BAU}} \cdot 100\%$$



Performance sensitivity to DRES allocation

KPI IGreenGRID –Hosting Capacity

Centralized/Supervised solutions *(ICT-based)*

DEMO	Solution	Average Value [%]	Variability	Negative KPI prob.
GERMANY	MV centralized voltage control with field measurements - OLTC	67.00	0.57	0.00
SPAIN	MV centralized voltage control - OLTC + STATCOM control	64.53	0.67	0.00
AUSTRIA	MV supervised voltage control with field measurements - OLTC + DG reactive power control	62.99	1.38	0.00
AUSTRIA	MV supervised voltage control with field measurements - OLTC control	53.36	1.27	0.00
SPAIN	MV centralized voltage control - STATCOM control	20.02	0.19	0.00

Distributed solutions *(local controller-based)*

DEMO	Solution	Average Value [%]	Variability	Negative KPI prob.
GERMANY	MV distributed voltage control with AVR	37.75	2.87	0.00
FRANCE	MV distributed voltage control - DG reactive power control (droop Q-V control)	37.13	1.62	0.00
FRANCE	MV distributed voltage control - DG reactive power control (fixed tan(phi))	34.81	3.10	3.00
ITALY	MV distributed voltage control - OLTC + DG reactive power control	29.72	3.53	27.50
GREECE	MV distributed voltage control - DG curtailment + DG reactive power control	13.89	2.25	3.00
GREECE	MV distributed voltage control - DG curtailment	10.83	0.39	0.00

Enel progetto AEEGSI 39/10 «Carpinone» (Isernia)

KPI IGreenGRID– Increase of Energy Efficiency (losses)

Centralized/Supervised solutions *(ICT-based)*

DEMO	Solution	Uncritical situation [%]	Critical situation [%]
GERMANY	MV centralized voltage control with field measurements - OLTC	-0.09	-0.13
SPAIN	MV centralized voltage control - OLTC + STATCOM control	0.08	0.04
AUSTRIA	MV supervised voltage control with field measurements - OLTC + DG reactive power control	-0.09	-0.13
AUSTRIA	MV supervised voltage control with field measurements - OLTC control	0.00	-0.02
SPAIN	MV centralized voltage control - STATCOM control	0.06	-0.02

Distributed solutions *(local controller-based)*

DEMO	Solution	Uncritical situation [%]	Critical situation [%]
GERMANY	MV distributed voltage control with AVR	-3.49	-2.95
FRANCE	MV distributed voltage control - DG reactive power control (droop Q-V control)	-0.02	-0.03
FRANCE	MV distributed voltage control - DG reactive power control (fixed tan(phi))	-0.27	-0.33
ITALY	MV distributed voltage control - OLTC + DG reactive power control	-0.11	-0.19
GREECE	MV distributed voltage control - DG curtailment + DG reactive power control	-0.02	-0.04
GREECE	MV distributed voltage control - DG curtailment	0.00	0.31

Conclusion on the use of KPIs

- The use of simulations allows the evaluation of Smart Grid solutions performance on demonstrators
  - simulation of several scenarios in order to extract more information about the performance (sensitivities, high/low penetration of DG, etc…)

- The evaluation of multiple KPIs (in addition to HC increase) allows the extraction of relevant information
  - effectiveness in case of voltage congestion
  - impact of the solutions on different aspects of the network operation

…however…

The assumed hypotheses for an harmonized KPI calculation procedure are not accurate representations of the real operation practices

- voltage limits / maximum loading of lines
- safety reserves for robust network management

Resulting KPIs are strongly dependent on the network nature (rural/urban/etc.) and it is not possible to perform comparison of solutions on the basis of their results

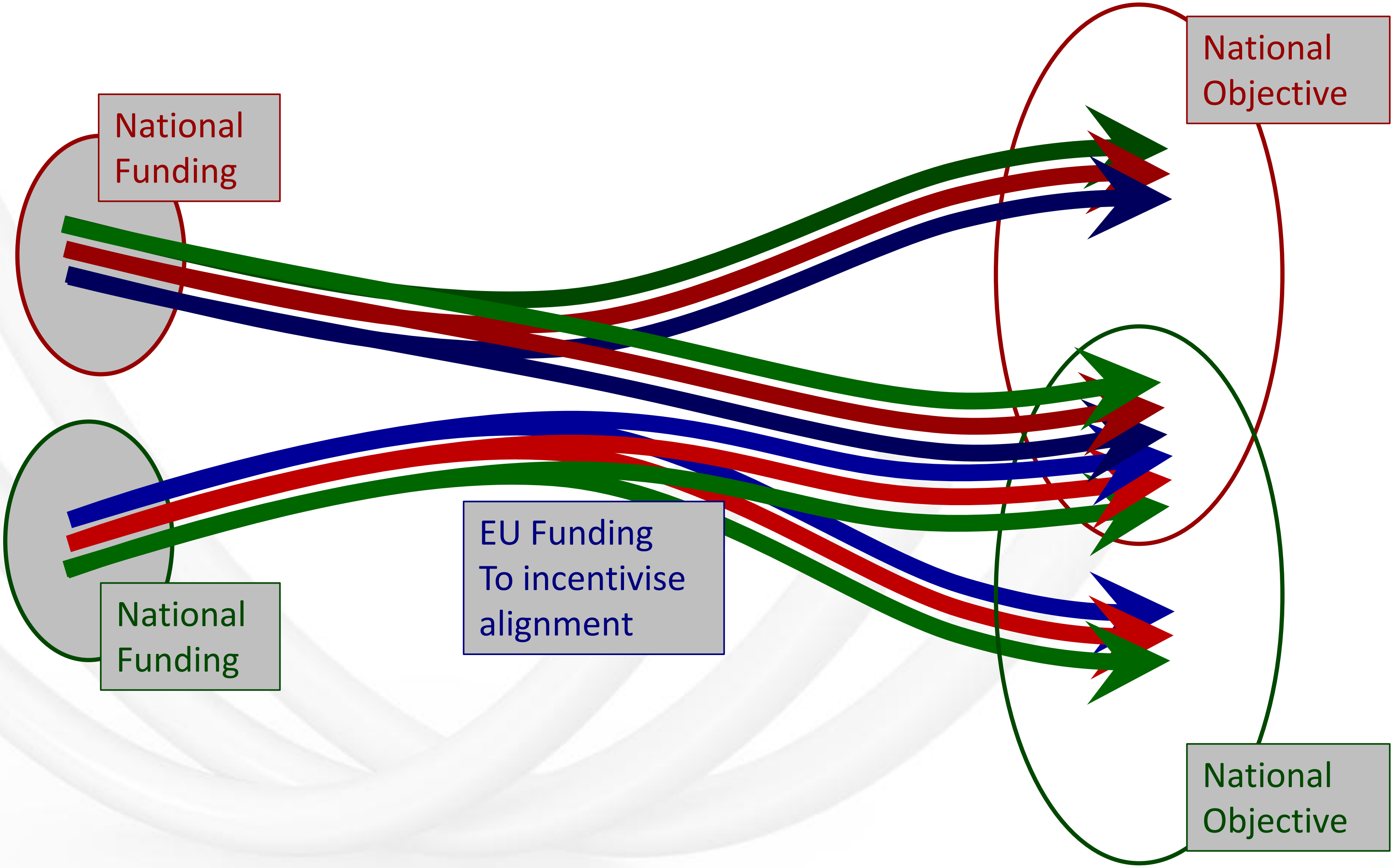
- demonstrators networks have different characteristics
- KPIs should be investigated on clustered networks

Conclusion and future activity

- «Smart grid» is the .. *label* for the ongoing update process of distribution networks
- Smart grids are 'technical enablers', so it is not always possible to get simultaneously *all* the goals (eg. increase hosting capacity *and* decrease losses)
- Composing opposite needs
- Impacts of new market rules; increased complexity of information exchange between several *actors*
- Some difficulties to understand the potential scalability/replicability of the solution
- Role of customers

R&D activities on «smart grids»

- Methods and techniques for voltage control
- Cyber Security.
- Load forecasting (meteo).
- Storage technologies, applications and CBA.
- Distributed generation forecasting.
- Energy management Systems.
- Inverter protections and automation.
- ISLANDING tests.
- ICT Technologies.


National
Funding
National
Funding
EU Funding
To incentivise
alignment
National
Objective
National
Objective

SmartNet

Duration (month/year-month/year)	January 2016 – December 2018
Total budget and amount from EU/national funding scheme (specify type – eg. FP7/H2020 country and the organisations)	12.6 M€ (H2020 – Call: LCE6-2015)
Coordinator and partners (acronyms)	Project Coordinator: **RSE** (IT) Other partners: AIT, Danske Commodities, DTU, ENDESA, Energinet.dk, Eurisco, European University Institute, NOVASOL, N-SIDE, NYFORS , SELNET, SELTA/Edyna, SIEMENS Italia, SINTEF ENERGI, STIFTELSEN SINTEF, TECNALIA, TERNA, University of Strathclyde, VITO, VTT, VODAFONE. Linked third party: KULeuven

TSO-DSO interaction to support RES integration in the power system

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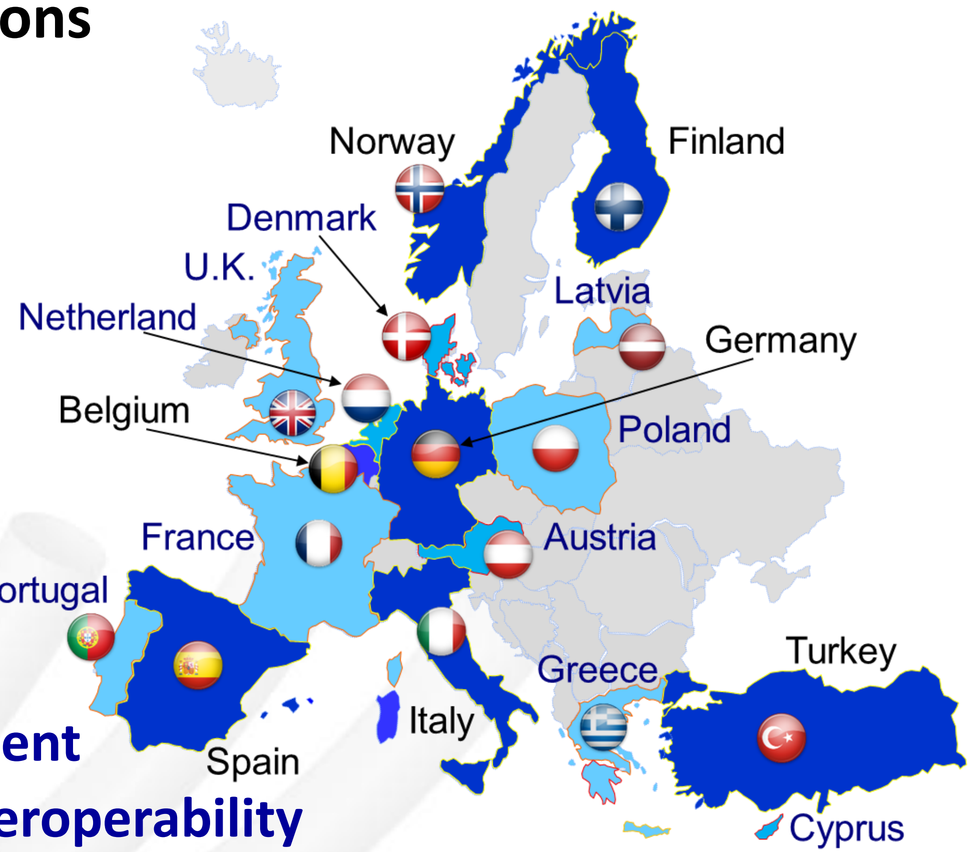
EERA JP Smart Grids

European Energy Research Alliance
Smart Grids Joint Programme

20+21 Research Organizations (106 + 44 py/y)

17+1 European Countries



JP sub-programmes:

SP1 Network Operation
SP2 Power System Management
SP3 ICT & Control System Interoperability
SP4 Electrical Storage Integration
SP5 Transmission Networks

Int. Smart Grid Action Network

- **ISGAN** is the short name for the **International Energy Agency (IEA)** Implementing Agreement for a Co-operative Programme on Smart Grids.
- ISGAN was launched at the 1st **Clean Energy Ministerial (CEM),** a meeting of energy and environment ministers from 23 countries and the EU.
- The Ministerial was an outgrowth of the the **Major Economies Forum** on Energy and Climate (MEF) in L'Aquila, July 2009, where countries agreed to collaborate on advancing clean energy technologies.
- ISGAN aims at accelerating progress on key aspects of smart grid policy, technology, and related standards through voluntary participation by governments in specific projects and programs.
- ISGAN will facilitate dynamic knowledge sharing, technical assistance, peer review and, where appropriate, project coordination among participants.

Questions?

contacts

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