
Italian Transmission System Challenges up to 2030

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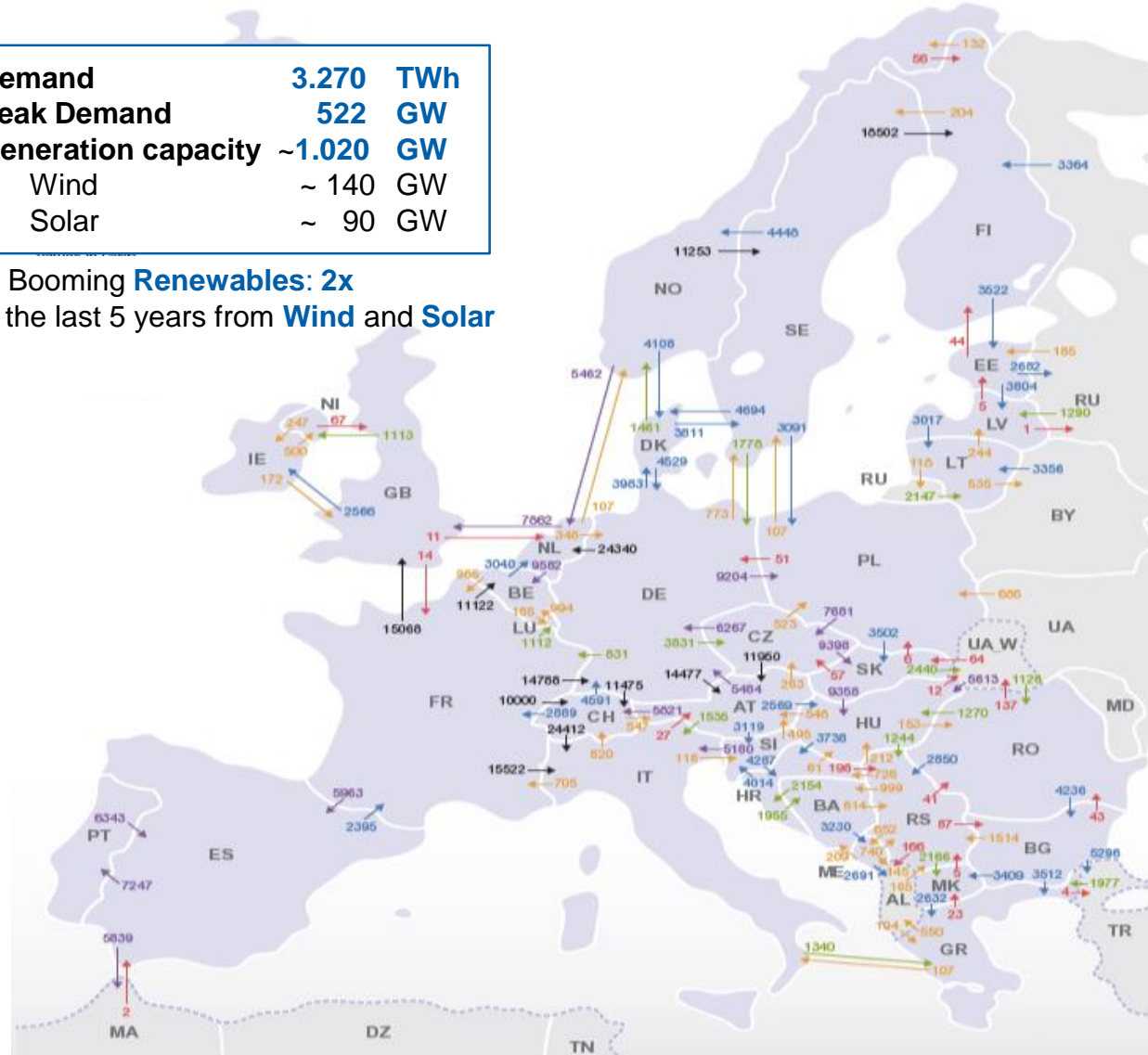
Terna Rete Italia SpA

HEAD OF TECHNOLOGIES DEVELOPMENTS

European electrical system

Demand	3.270	TWh
Peak Demand	522	GW
Generation capacity	~1.020	GW
Wind	~ 140	GW
Solar	~ 90	GW

➤ Booming **Renewables: 2x**
in the last 5 years from **Wind** and **Solar**



A **strong** interconnected system, affected by a big **paradigm shift**

- Booming **renewables**
- Weak post-crisis **demand** but high peak in extreme weather conditions

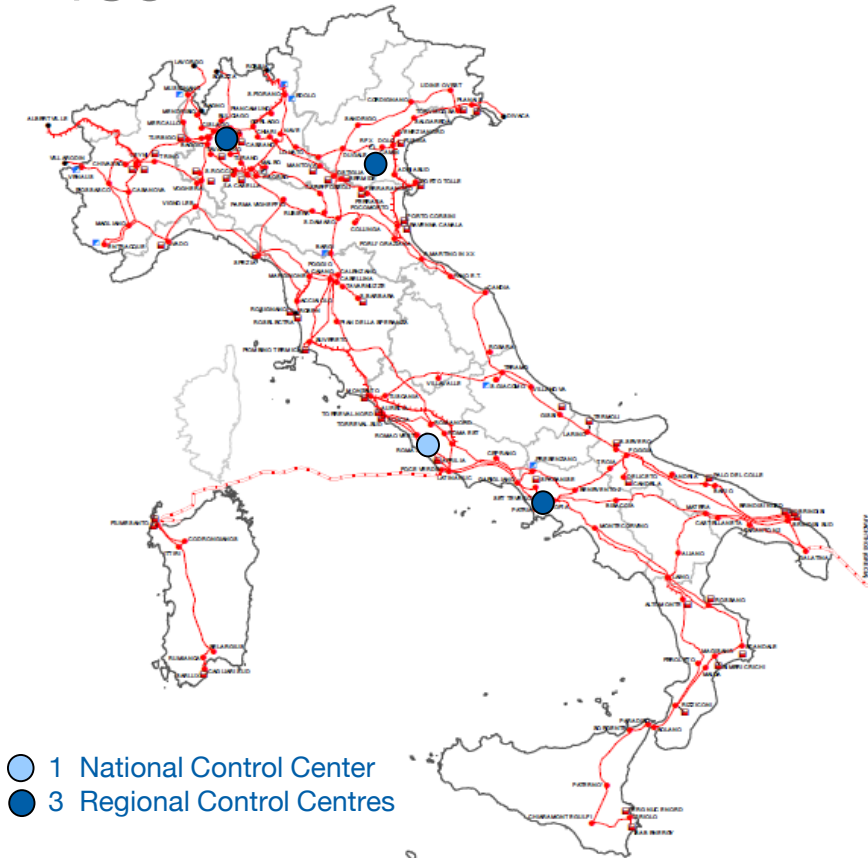
... volatility in energy flows

... increasing needs in

- **joint development**
- **coordination**

Italian electrical system

TSO



- 1 National Control Center
- 3 Regional Control Centres

Demand	315	TWh
Peak Demand	59	GW
Generation capacity	~ 120	GW
Wind	9	GW
Solar	19	GW

Terna is the largest independent **Transmission System Operator (TSO)** in Europe

- the **owner** of the National High Voltage Transmission Grid
- responsible for the **transmission and dispatching** of the electricity all over the Country

- > **Transmission Grid** {
 - ~ 72,300_{Km} of three-phase conductors
 - ~ 840 substations
 - 25 interconnections (o/w 21)
- > **Grid users** {
 - 3.500 interconnection with DSOs
 - 1.000 production plants directly connected
 - 600.000 "dispersed generation" plants

Italian electrical system

Main changes in the last years

Up to 2000

Centralized planning of the system

- Generation and Grids
(Transmission & Distribution)

Lack of generation

- Big import from abroad
- National generation mainly from fossil fuels (oil)

Stable growth of the Demand

From 2000 to nowadays

Liberalization of generation

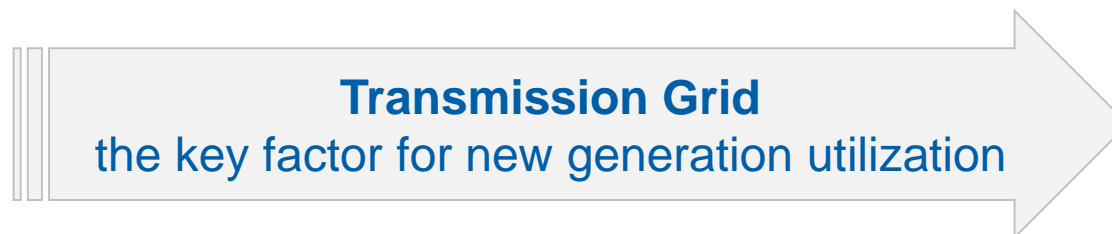
- **CCGT** thermal plants: **22 GW**

RES growth

- Booming **wind** and **solar**: **28 GW**

Demand crisis

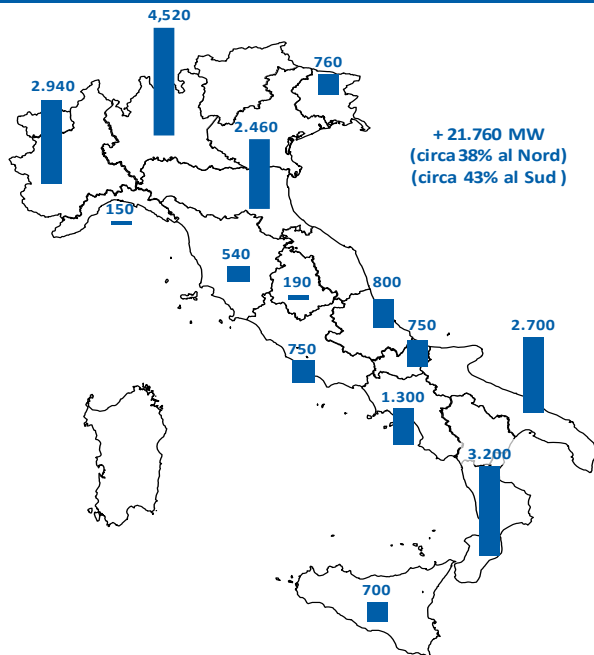
- Financial crisis in 2008
- New reduction in 2012



Italian electrical system

Main changes in the last years

CCGT POWER PLANT



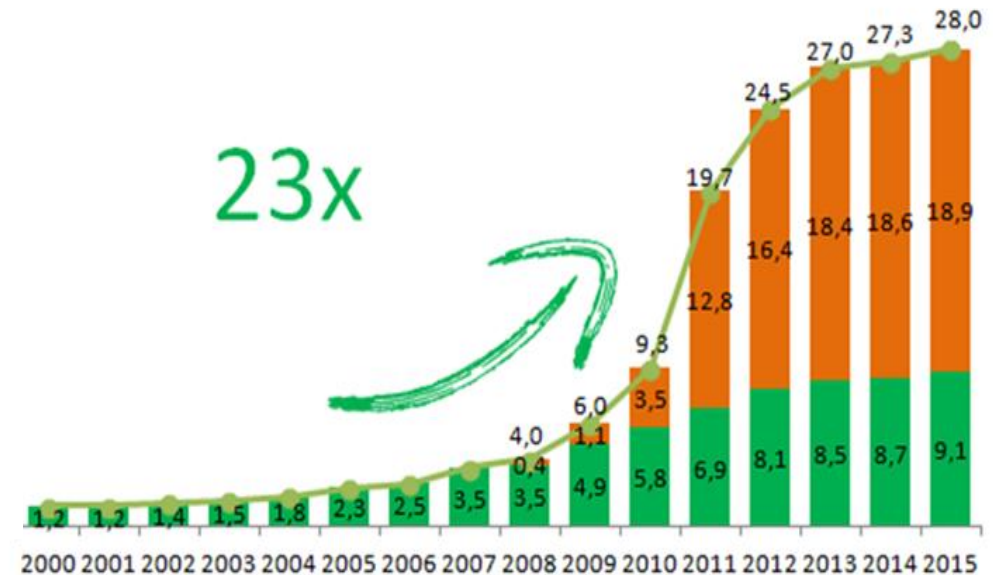
After the **black-out** in 2003 and with the start of the **Electricity Market** in 2004, a new law for the authorization procedure of new power plants was issued, thus boosting investments in generation

- **CCGT** thermal plants: **22 GW**

Investments mainly in the **South** (far from consumption area) ...

RES GROWTH

GW



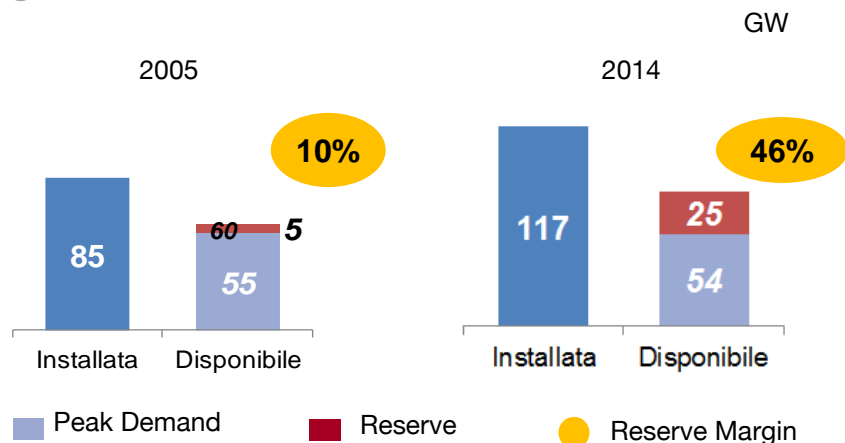
Favourable incentivisation scheme defined by Italian Government boosted investments in RES generation

- **Wind: 9 GW**
- **Solar: 19 GW**

Italian electrical system

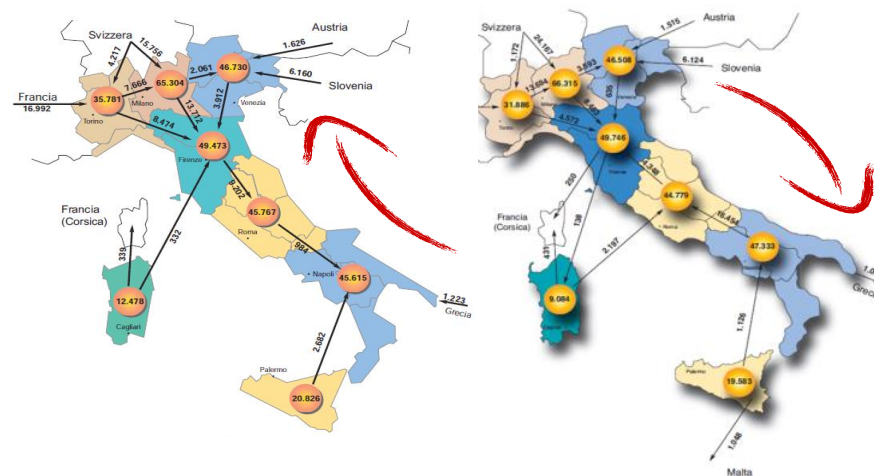
Main changes in the last years

From under- to over- capacity



Peak Demand satisfied with adequate reserve

Energy flow change verse

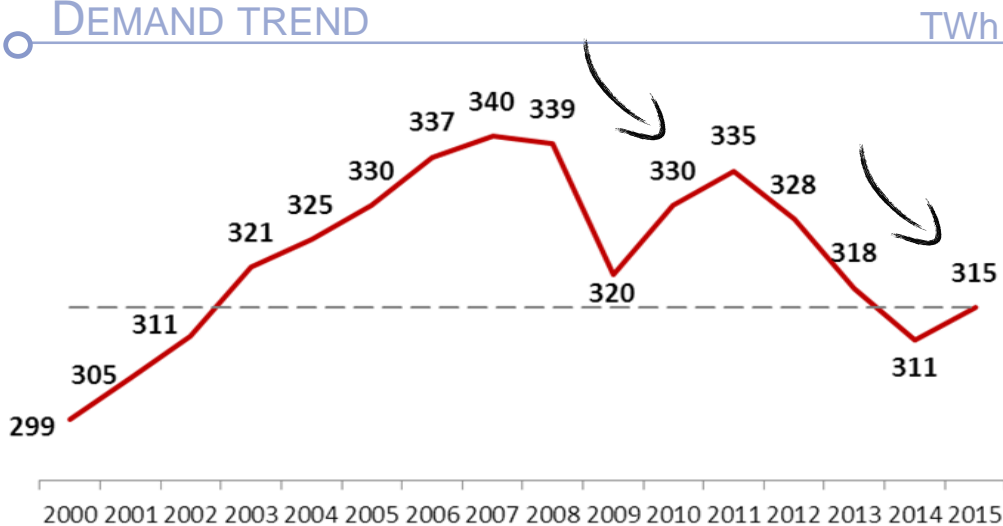


New energy flows from the South to the North

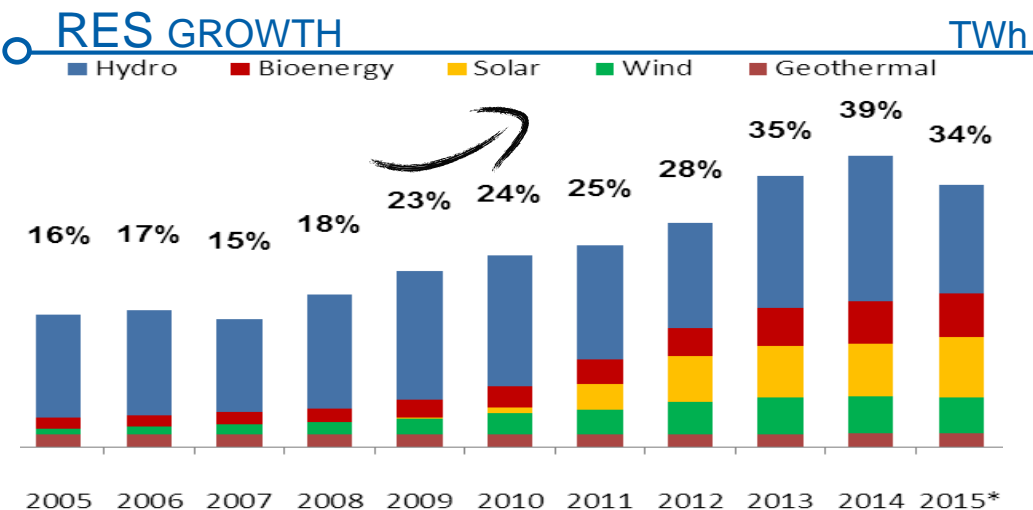
Italian electrical system

Main changes in the last years

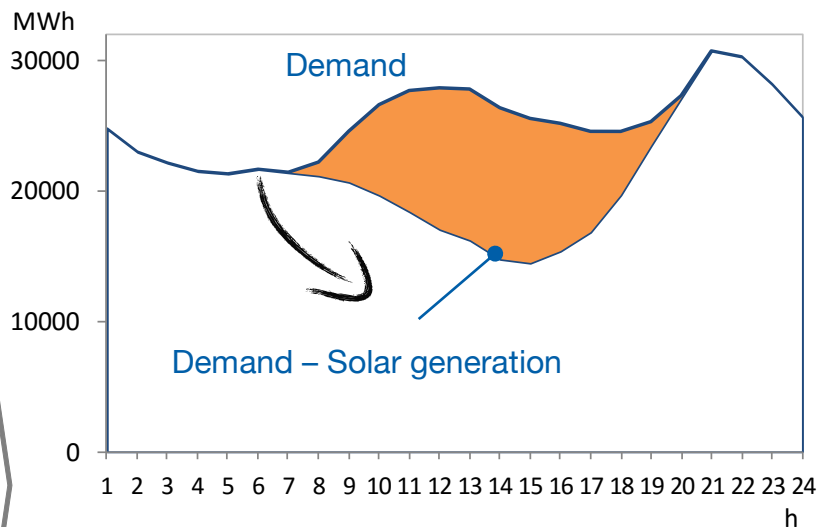
DEMAND TREND



RES GROWTH



High volatility of Demand

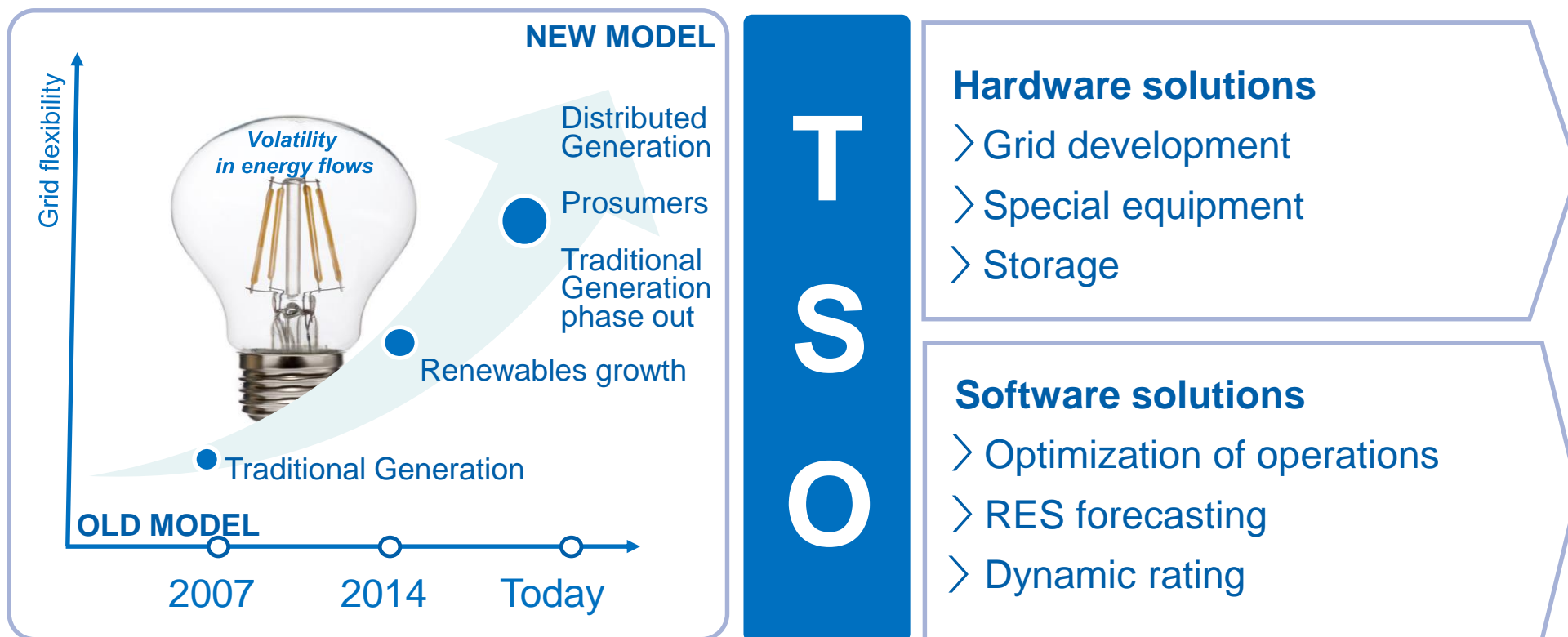


Weak Demand together with booming RES causes **balancing issue**

- to control low Demand in solar hours
- to cover higher peak in the evening

... More flexible resources are needed
 ... Less resources for control are available

New role for TSOs



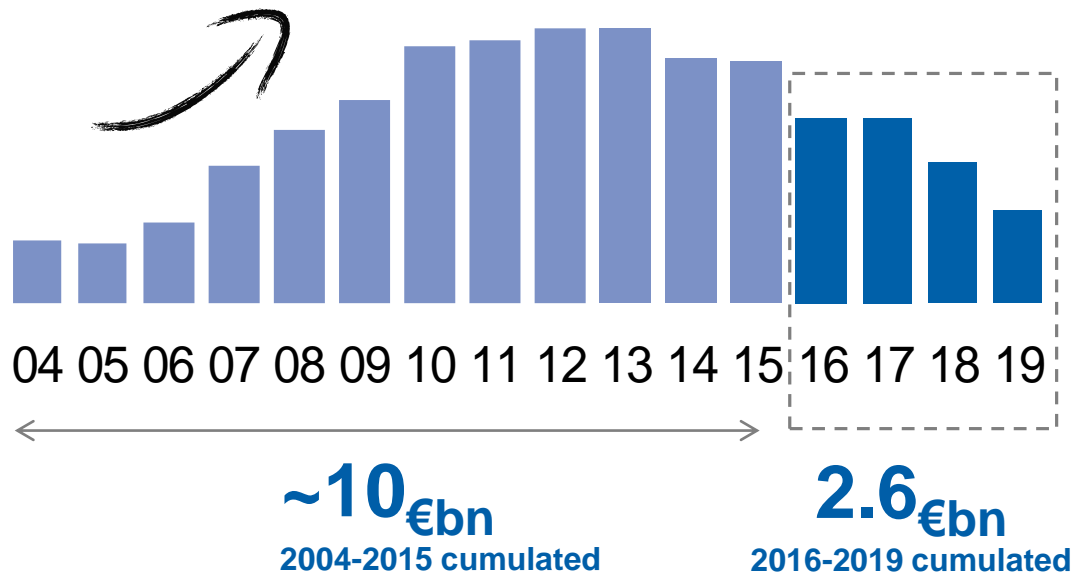
Improved coordination of the European TSOs for security of supply

New role for TSOs

Hardware solutions



INVESTMENTS



- CapEx in 2015: 4x Capex in 2004
- Regulated Asset Base (RAB) more than doubled

Grid development

New links and interconnections for

- solving bottlenecks
- connecting new power plants
- stronger European interconnection

Special equipment

- System stability
- Voltage and power control
- Control of active power exchanges

Storage

- Energy flow control
- Less wind curtailment
- Synthetic inertia

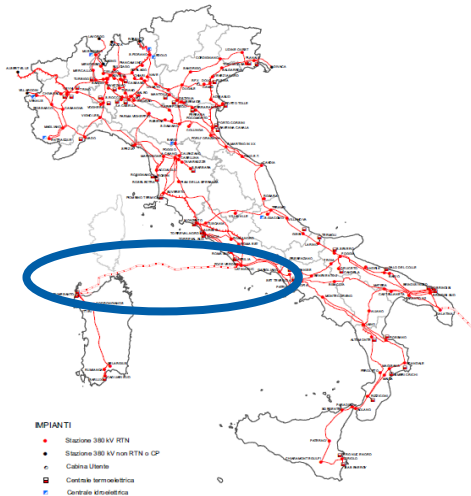
Hardware solutions

Grid development - HVDC link



HVDC LINK SARDINIA-MAINLAND «SAPEI»

Commissioned in 2011



The longest HVDC cable at time of construction (435 km)
The world deepest submarine HVDC cable (1.600 m)

HVDC link that increases **security of supply** and improves **market competitiveness** in Sardinia

- Voltage: ± 500 kV LCC
(Line Commutated Converter)
- Rated power: 1.000 MW

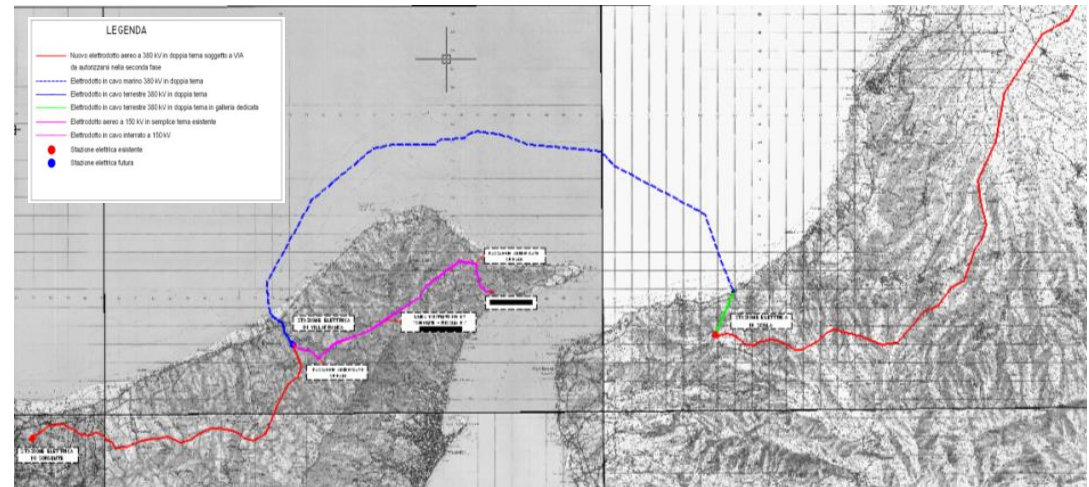
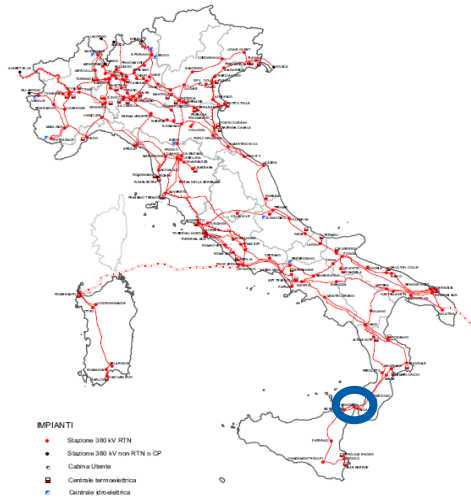
Hardware solutions

Grid development - HVAC link



NEW HVAC LINK SICILY-MAINLAND

Commissioned in May 2016



The world longest AC 420 kV cable (43 km)

HVAC link that will increase **security of supply** and will improve **market competitiveness** in Sicily

- Voltage: 420 kV
- Rated power: 2.000 MW

Hardware solutions

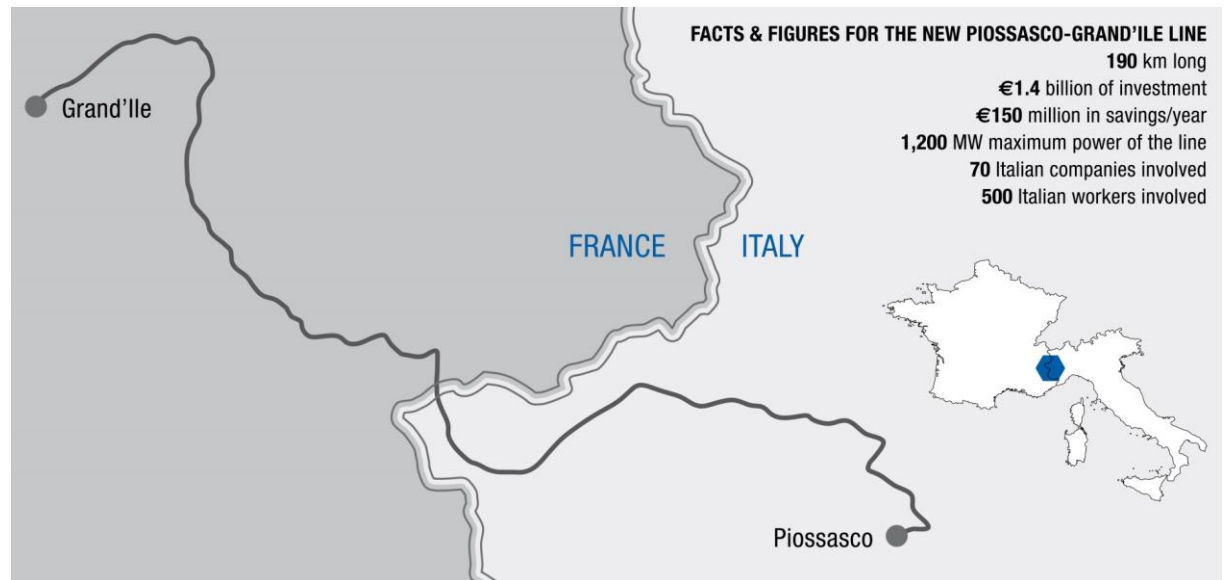
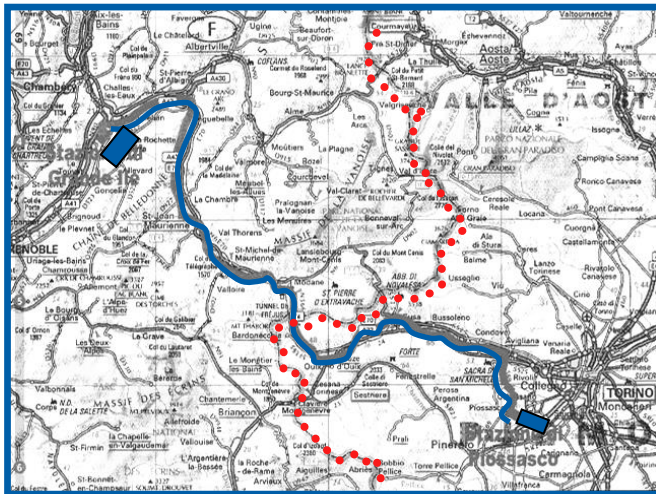
Grid development - HVDC interconnection



NEW INTERCONNECTION FRANCE-ITALY



Under construction



New HVDC interconnection

- Voltage: ± 320 kV VSC (Voltage Sourced Converter)
- Rated power: 1.200 MW

• The world longest HVDC cable connection along an highway route (190 km)



Hardware solutions

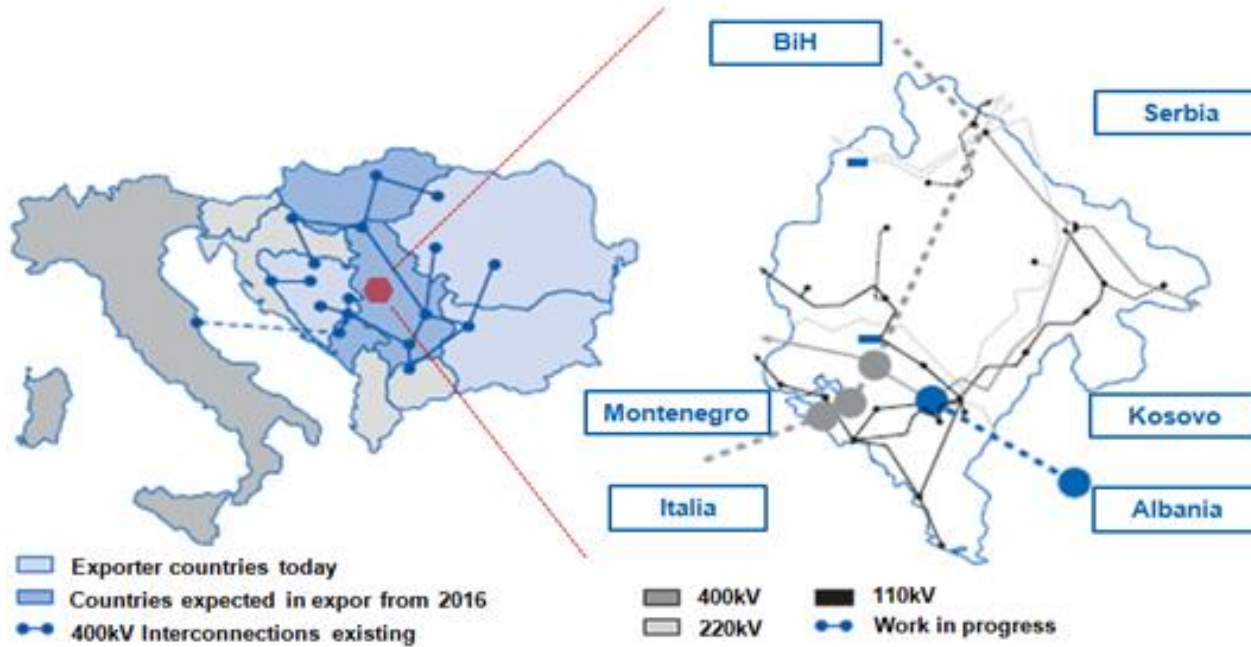
Grid development - HVDC interconnection



NEW INTERCONNECTION ITALY-MONTENEGRO



Under construction



New HVDC interconnection

- Voltage: ± 500 kV LCC
- Rated power: 1.200 MW
- Length 400 km. Depth: 1200 m

First electricity HVDC bridge between Europe and the Balkans

Hardware solutions

Special equipment for Voltage control



SYNCHRONOUS CONDENSER

Improvement in

- **system stability** (bigger network inertia), essential in the major islands with large RES installations
- **voltage control** (better short circuit current)
- **HVDC link control** with reduction of commutation failure risk (in Sardinia)

4 synchronous condensers installed in 2015-2016

- in Sardinia: 2 x 250 MVAR, in Sicily: 2 x 160 MVAR



SHUNT REACTORS AND CAPACITORS

Improvement in **voltage control**

- 36 shunt reactors (258 MVAR)
- 83 capacitor banks (54 MVAR)



Hardware solutions

Special equipment for Energy flow control



PHASE SHIFTING TRANSFORMERS (PST)

Improvement in energy flow control

- PST installed on **tie lines** to control of active power exchanges and avoid loop flows
- PST installed on lines **between South and Centre** to control internal flows and solve congestions (mainly due to large RES and CCGT installations in the South)



Hardware solutions

Special equipment - Storage



STORAGE

Commissioning from 2015

Storage energy intensive

Improvement in

- energy flow control mainly from the South (peak shifting)
- congestion relief mainly on 150 kV sub-transmission grid where windfarms are connected, also to avoid wind curtailment

Recent installations in the South based on Sodium-Sulfur technology (35 MW)



Among the biggest installations in Europe

Storage power intensive

Improvement in frequency control and synthetic inertia

Recent installations in the major islands based on Li-Ion_{Lithium}, Zebra technologies (12 MW)



New role for TSOs

Software solutions



STRONG FOCUS ON SECURITY OF SUPPLY

ICT as the key factor for improving the security of supply

Optimization of operation

- Applications for security analysis, both preventive and on real time (Steady State Analysis, Dynamic Security Assessment, Wide Area Measurement System)

RES forecasting

- Wind, solar and hydro forecasting, to manage volatility in energy flows

Dynamic rating

- Dynamic thermal rating to adapt asset utilization on real time environmental conditions to optimize grid utilization

Software solutions

Optimization of operations

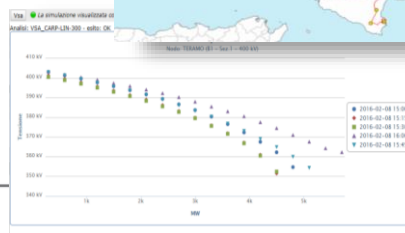
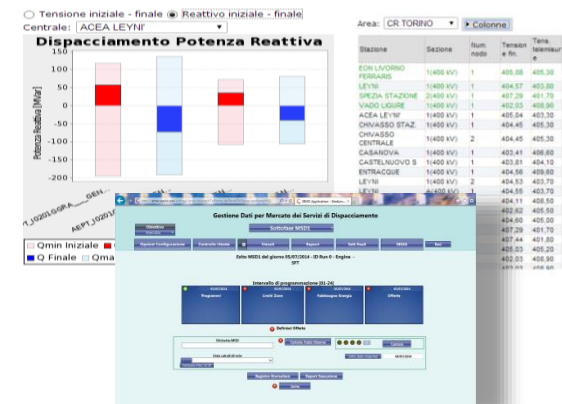
STRONG FOCUS ON SECURITY OF SUPPLY

Steady state analysis

- Optimal Power Flow (OPF) and Optimal Reactive Power Flow (ORPF) applications, for optimization in real time of both active and reactive power flows
- Applications supporting operations both in the planning and in real time phase

Dynamic Security Assessment

- Applications that assess the **security** and **resilience** of the **system** and its **Defense Plan** on the occurrence of severe but possible events (i.e. single or multiple faults of tie lines or generators, cascading events, voltage collapse)
- Application supporting real time operations in the Control room, identifying issues and additional countermeasures



Software solutions

Optimization of operations

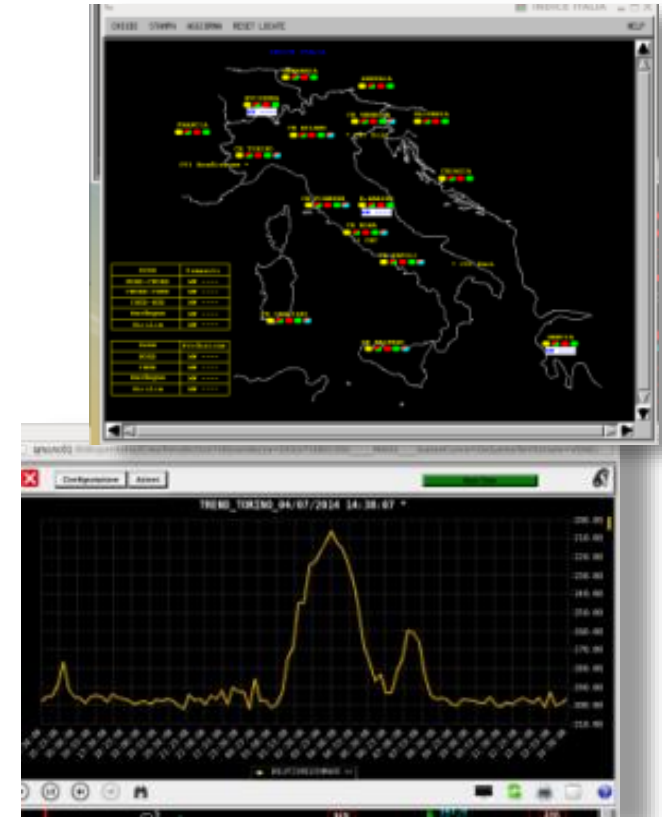
STRONG FOCUS ON SECURITY OF SUPPLY

Wide Area Measurement System (WAMS)

Applications for the monitoring of **system stability**, supporting both real time operations and post-event analysis

WAMS methodology is based on phasor calculations

- a wide installation of Phase Measurement Units (PMU) is required for significant assessment and analysis



Among the widest installations in Europe of PMU (about a hundred)

Software solutions

RES forecasting

FORECASTING TO MANAGE VOLATILITY OF ENERGY FLOWS

RES forecasting is a key activity supporting operation, both in planning and in real time operation

Wind forecasting

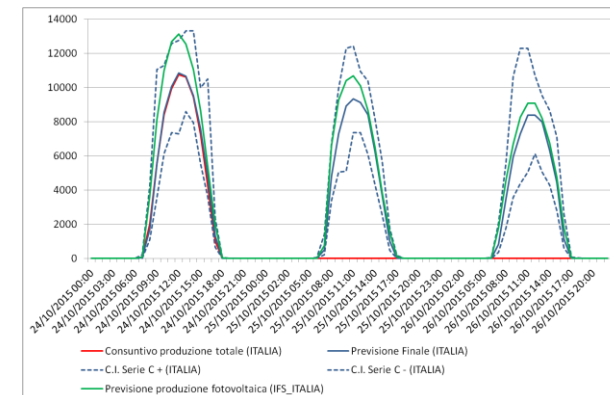
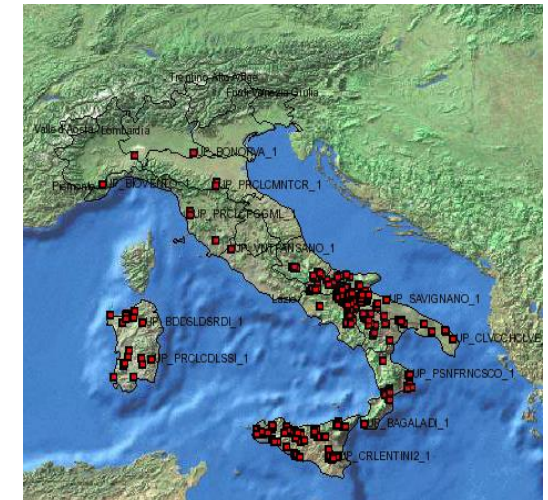
“Trained” neural networks that model wind turbine operations and “translate” wind forecast → wind production forecast (also considering meteorological and orographic variables)

- 284 windfarms in the South and in the major islands

Solar forecasting

Predictive algorithms that model photovoltaic panel operation and “translate” solar radiation forecast → solar production forecast (also considering meteorological variables and localization of the panels)

- dispersed generation throughout the Italian territory



Software solutions

Dynamic rating

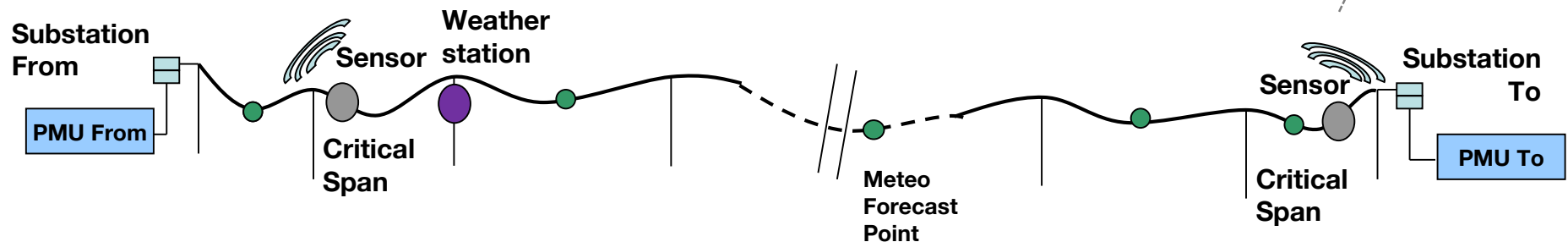


DYNAMIC RATING TO OPTIMIZE GRID UTILIZATION

Dynamic thermal rating applied on overhead lines to determine the effective transportation capacity of lines, exploiting conductor characteristics, according to real time environmental conditions (i.e. temperature of lines, temperature of surrounding environment, wind speed)

Objectives

- Overcome structural congestions
- RES integration and curtailment reduction (installations near to windfarms)



The European vision



EUROPEAN COMMISSION

European Commission

Stated goal of harmonizing rules for the management of European electrical system

- Improving the security of supply
- and the efficient and secure use of interconnections across national borders
- also with the establishment of a pan-European market



ACER the Agency for the Cooperation of Energy Regulators

A European Union Agency, created in 2011 by the Third Energy Package to further progress the completion of the **internal energy market** for electricity and natural gas

- The Agency fosters cooperation among European energy regulators to ensure **market integration and harmonisation** of regulatory frameworks, thus enhancing **security of supply** for EU businesses and consumers

Coordination with TSOs



European Network of Transmission System Operators for Electricity

cooperation across Europe's TSOs established in 2009

- 42 TSOs from 35 countries
- 305.000 km lines
- 532 millions of citizens served

Objectives

- Setting up the **internal energy market** and ensuring its optimal functioning, and ensuring its optimal functioning, supporting the ambitious European energy and climate agenda
- Integration of a high degree of **Renewables** in Europe's energy system through improvement in flexibility, and a **customer** centric approach
- Development of the most suitable responses to the challenge of a changing power system while maintaining **security of supply**

Key factors: innovation, market based approach, customer and stakeholder focus, security of supply, flexibility, regional cooperation

Future challenge

Security of Supply

New scenario → Paradigm Shift

HARDWARE SOLUTIONS

- › Grid development
- › Special equipment
- › Storage

SOFTWARE SOLUTIONS

- › Optimized operation
- › RES forecasting
- › Dynamic rating

COORDINATION WITH TSOs

- › New rules and procedures for joint development and secure management

SMART SYSTEM = SMART GRID + SMART USERS