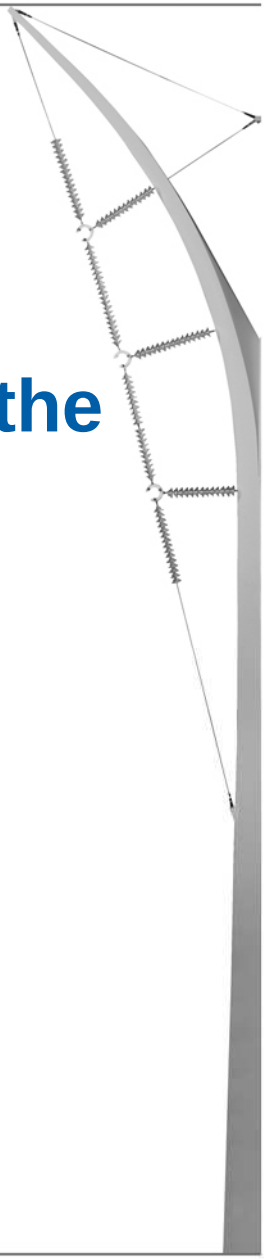
# Needs and Technologies from the past to the future: Terna experiences with the Substation Automation Systems



1st International Forum on

Research and Technologies for Society and Industry

*Organised by the IEEE Italy Section and Politecnico di Torino*

Panel "Smart Energy Systems "

TURIN, September 16th 2015

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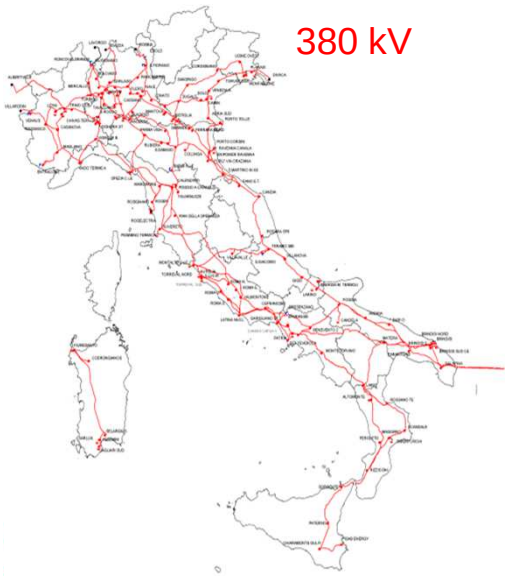
# Terna is the italian Transmission System Operator

## Terna assets

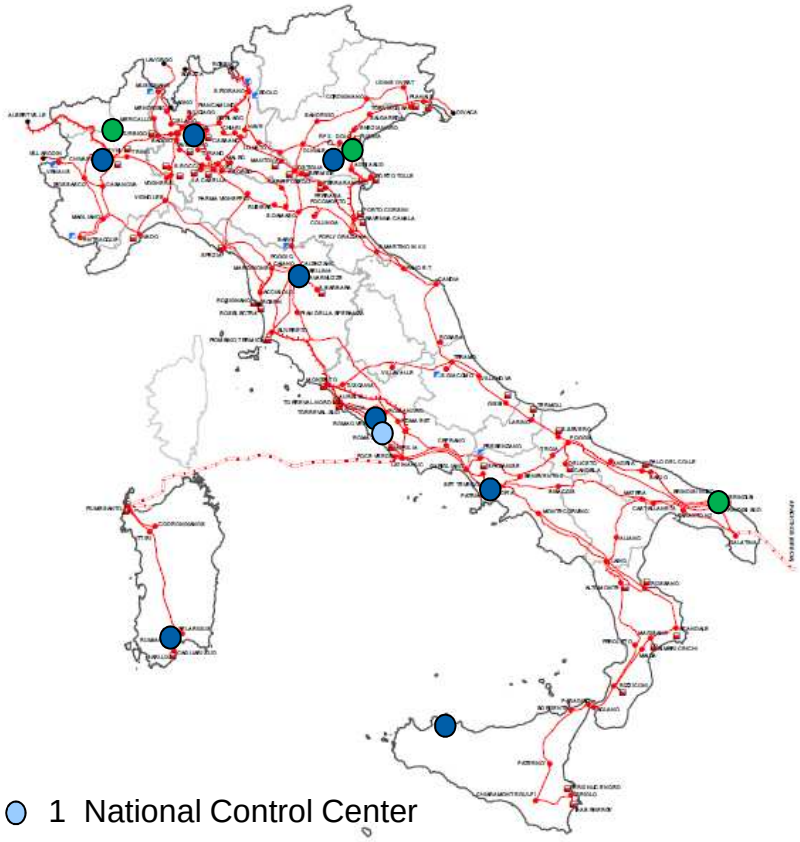





- **63,900 km of high- and extra-high voltage power lines** (132/150 kV, 220 kV, 380 kV)
- **491** transmission **Substations**
- **21 interconnection lines** with neighbouring countries owned by Terna

# Terna

## Transmission Grid and Control System



1 National Control Center

8 Regional Control Centers

3 Operation Centers

### Transmission Grid

Plants connected to the transmission grid:

- **3.500** Distribution Substations interconnecting with Distribution grids
- **1.000** Power Plants directly connected to the transmission grid
- **> 600.000** Power Plants connected to the distribution grid

### Control System

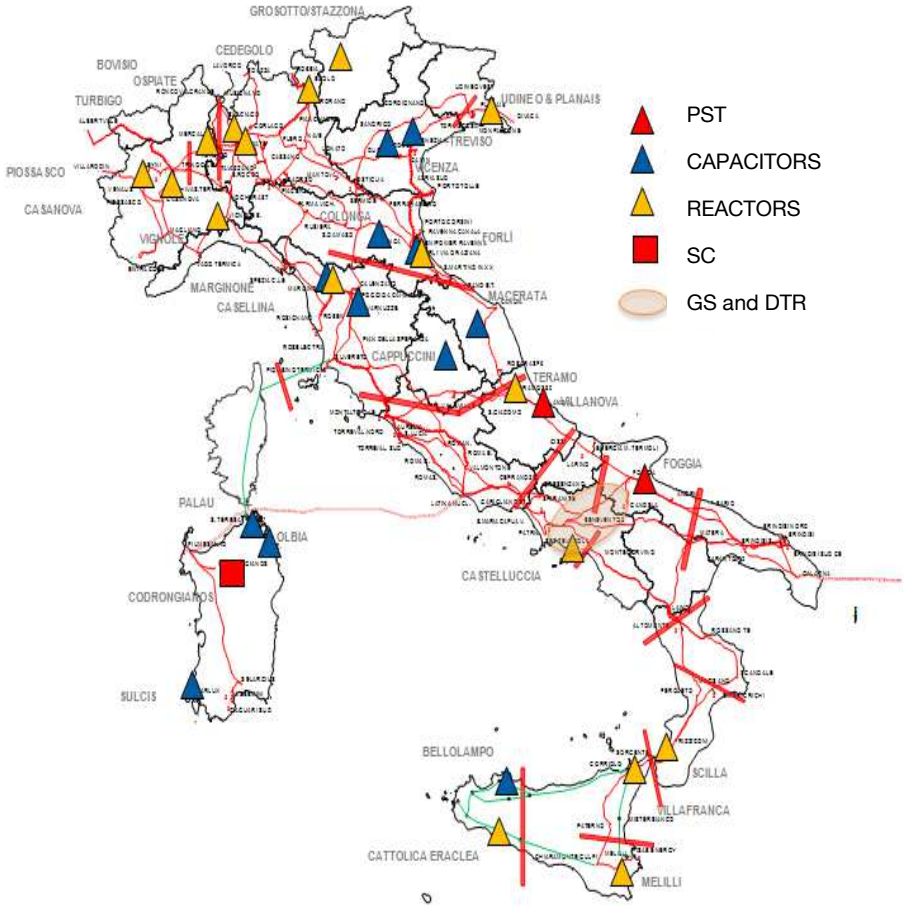
Information managed by the control system:

- **45.000** Monitored measures (scheduled periodically)
- **160.000** Monitored signals (scheduled on event)
- **2.500** Dispatching orders per day by CNC
- **1.000** Operation Commands per day by CTI

# Terna

## Terna's innovation - Smart Transmission Solutions to make the grid more flexible and adaptable to new system scenarios

- **Phase Shifting Transformers (PST)**: *optimization of HVAC grid power flows*
- **Synchronous Compensators (SC):** *increasing of the power system stability and safety*
- **Capacitors and Reactors:** *cost-effective management of reactive power and grid voltage profiles*
- **High Capactiy conductors and Dynamic Thermal Rating (DTR):** *maximizing existing lines capacity depending on weather conditions*
- **Grid Storage (GS):** *maximizing the use of non programmable RES production and contributing to the power system regulation*
- **Smart management:** *improvement of weather forecasting functions and related management of distributed generation*
- **Adoption of international standards:** *187 Digital Substation Automation Systems (SAS), 90 of which based on IEC 61850, operating in EHV/HV substations;*
- **Local dispatching:** *extension of the controlled perimeter from EHV grid to HV and MV grids through the implementation of local dispatching functions in the SASs.*




*I PST di Foggia e Villanova sono entrati in esercizio rispettivamente a luglio e novembre 2012

# PAST AND PRESENT:
# Evolution and Tradition

# Substation Automation Systems

The functions

**A Substation Automation System is a group of devices (relays, wires, computers, routers, switches, fiber optic), located in each High Voltage substation, whose functions are:**

- To operate the substation (from remote) in safety conditions
- To control and monitor the state of the installation (HV equipment and system itself)
- To monitor and protect the grid in case of faults

# Substation Automation Systems

Terna strategy: The “Standard” approach, since the ‘70s

**The Standard approach doesn’t depend on the system technology and consist in applying the following principles to each substation:**

**Prototype:** For the project development and testing before the widespread installation

**System modularity:** Modular design like «*Lego* bricks»

**Architecture uniformity:** Same architecture in all the substations

**Functional uniformity:** Same functions in all the substations

**Operation uniformity:** System technology transparent for the remote control center operator

**Maintenance uniformity:** Same criteria and spare parts for all the plants

**Safety and availability:**

- Redundancy of critical elements
- Interchangeability of the main devices (e.g. protections)
- Possibility of operation from different sites (remote/local)

# Substation Automation Systems

The technology

## 4 macrofamilies:

- Since the ‘60s: electromechanical pre standard
- Since the ‘70s: elechtromechanical standard
- Since the late ‘90s: the first digital (proprietary)
- Since the early ‘00s: the digital standard

## For the digital systems, Standard means:

- Terna Standard (since the ‘70s)
- IEC 61850 Standard, whose goal is interoperability (*) (since 2003!)

(*) Interoperability of devices producted by different manufacturers

# Substation Automation Systems

The electromechanical systems: bay cubicles

50’s-60’s-70’s | 70’s-80’s | 90’s

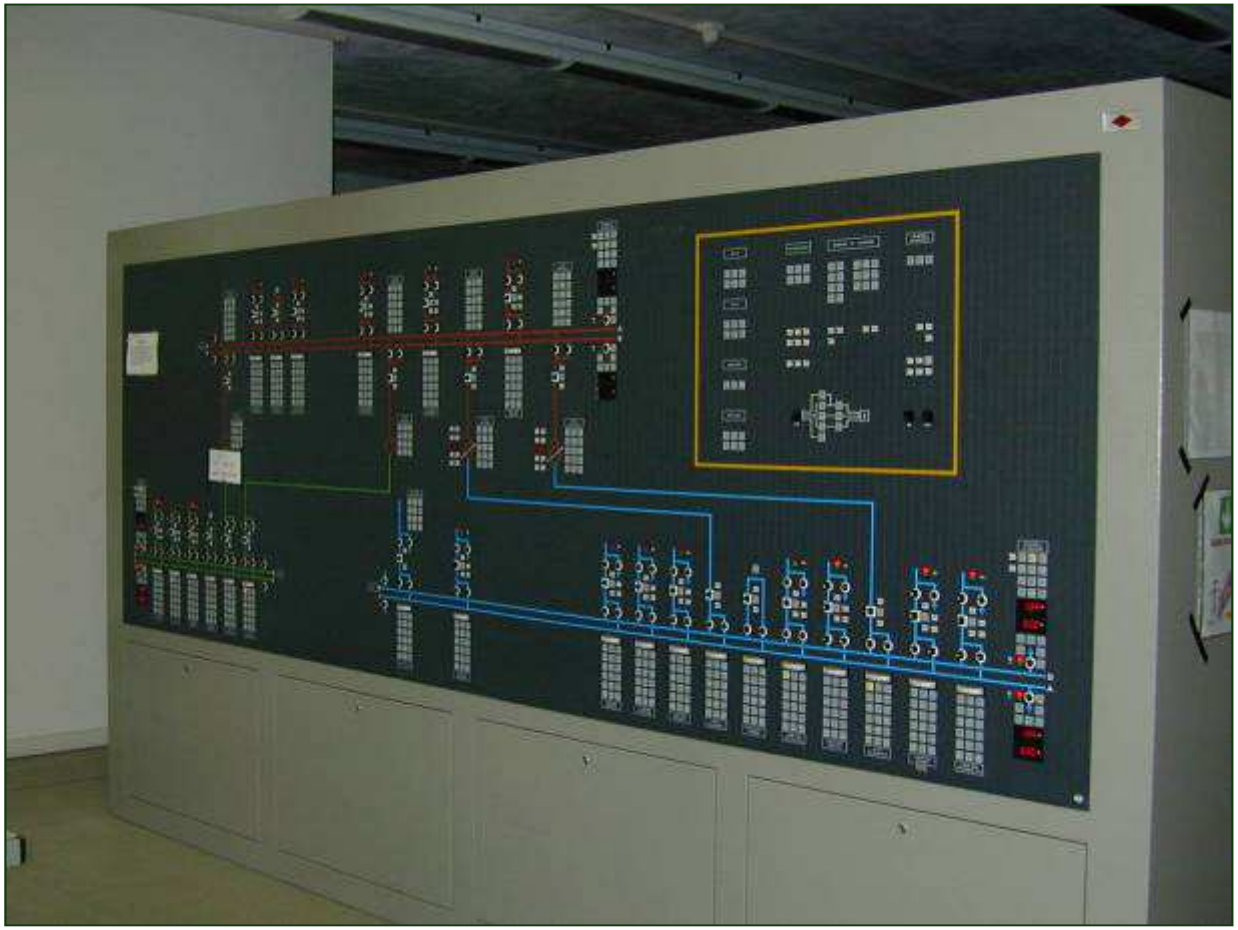
Pre standardisation

First standardisation

Last standardisation

# Substation Automation Systems

The electromechanical systems: substation HMI



# Substation Automation Systems

## The digital systems: bay cubicles

**BPU3**
- Busbar protection

**BPU2**
- Distance protection (Main 2)

**BPU1**
- Distance protection (Main 1)

**The last relays**

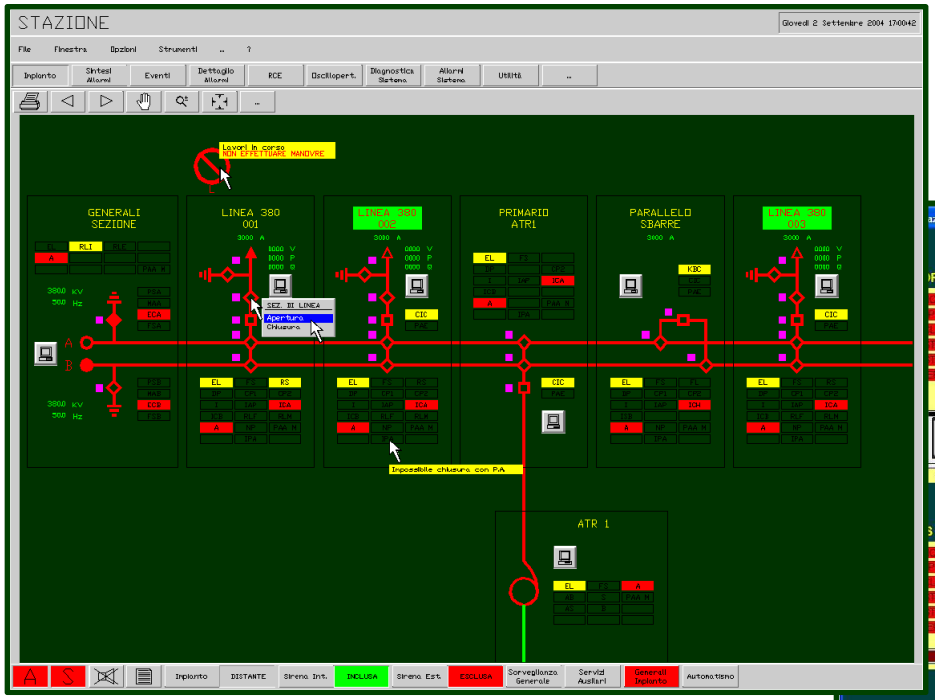
**BMU**
- Monitoring

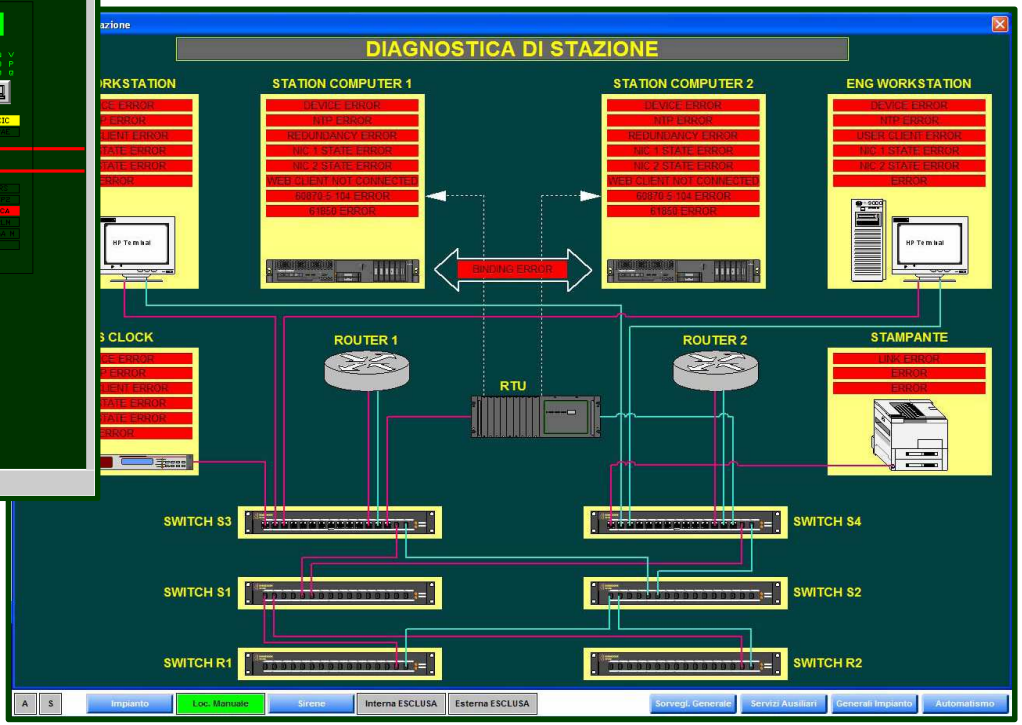
**BCU**
- Control

**Field simulator**
(Only for factory test)

# Substation Automation Systems

## The digital systems: substation HMI



# Substation Automation Systems

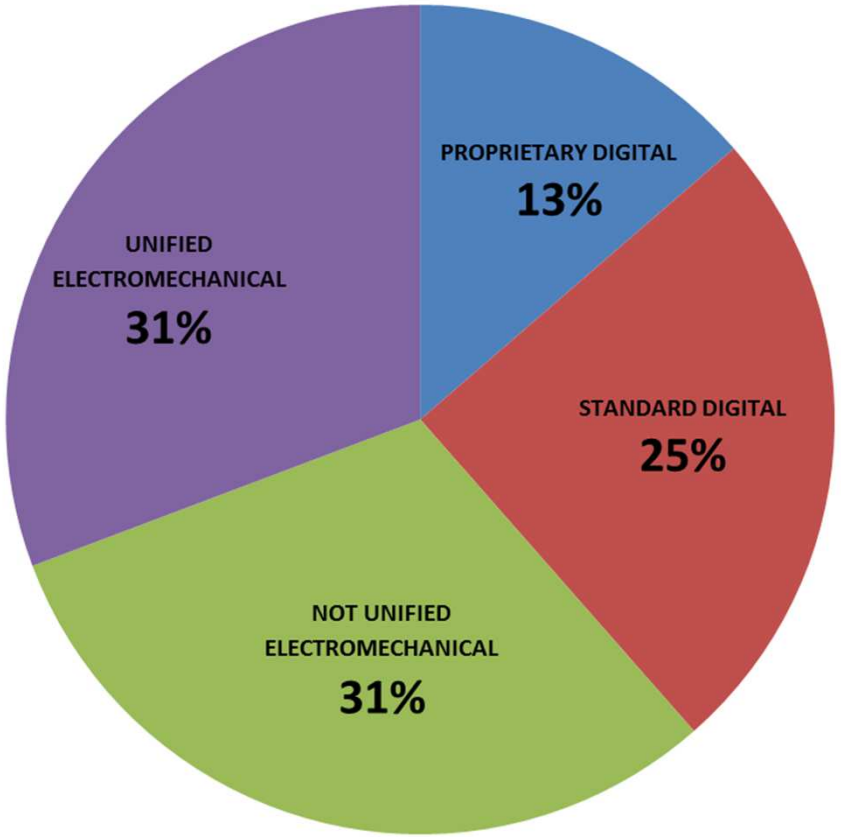
## SAS projects: Overview of the 491 systems installed so far

Non Standardised Electromechanical: 151

Standardised Electromechanical: 153

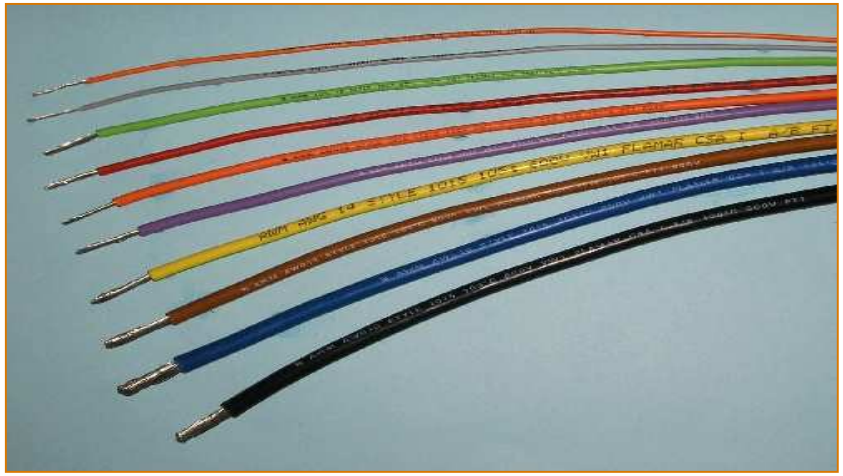
Vendor Proprietary Digital: 63

Standard Digital: 124



# Substation Automation Systems

## Digital vs Electromechanical



**Conventional device:**
**~10** contacts
1 function

**IED**
**Over 1000 processed** data
Multifunction
**Communication**

# Substation Automation Systems

Digital vs Electromechanical

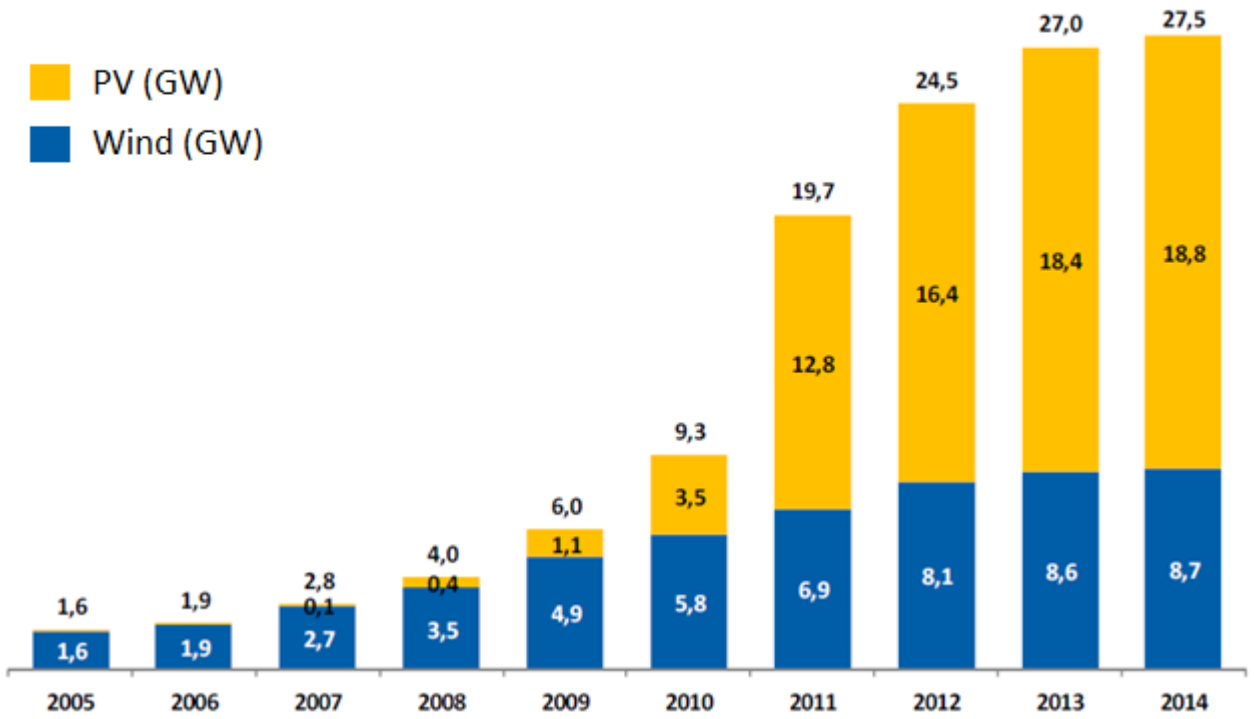
**Digital:**

- Less components and wiring
- Less room
- New functions
- Easy configuration/reconfiguration
- Autodiagnosis
- Remote access for maintenance
- Cost reduction
- Shorter life cycle
- Dependency on manufacturer
- Need for SW testing
- Need for SW updating
- Need for training
- Cyber security issues

# PRESENT AND FUTURE:
# New needs and new functions

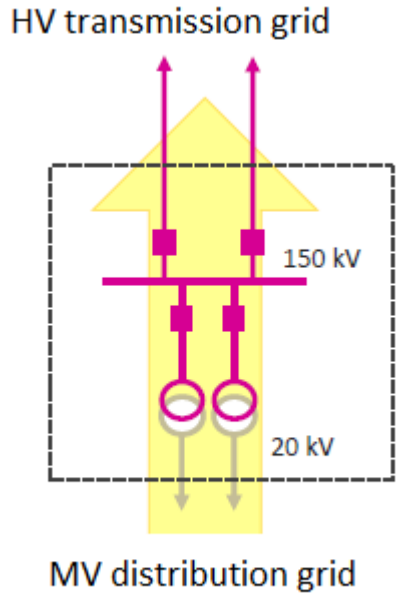
# Generation from renewables

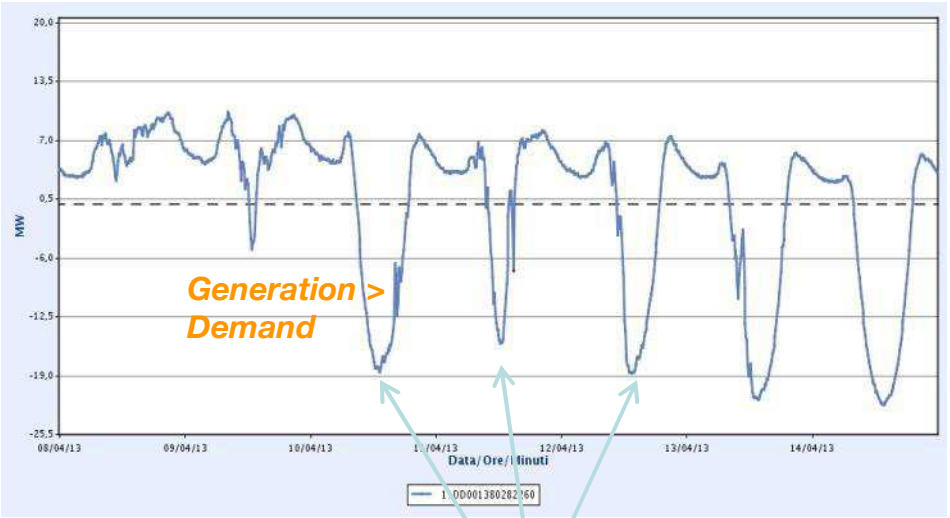
Trend of generation capacity from renewables in the Italian electrical power system



# Generation from renewables

From a passive load distribution grid to an active distribution grid with distributed generation

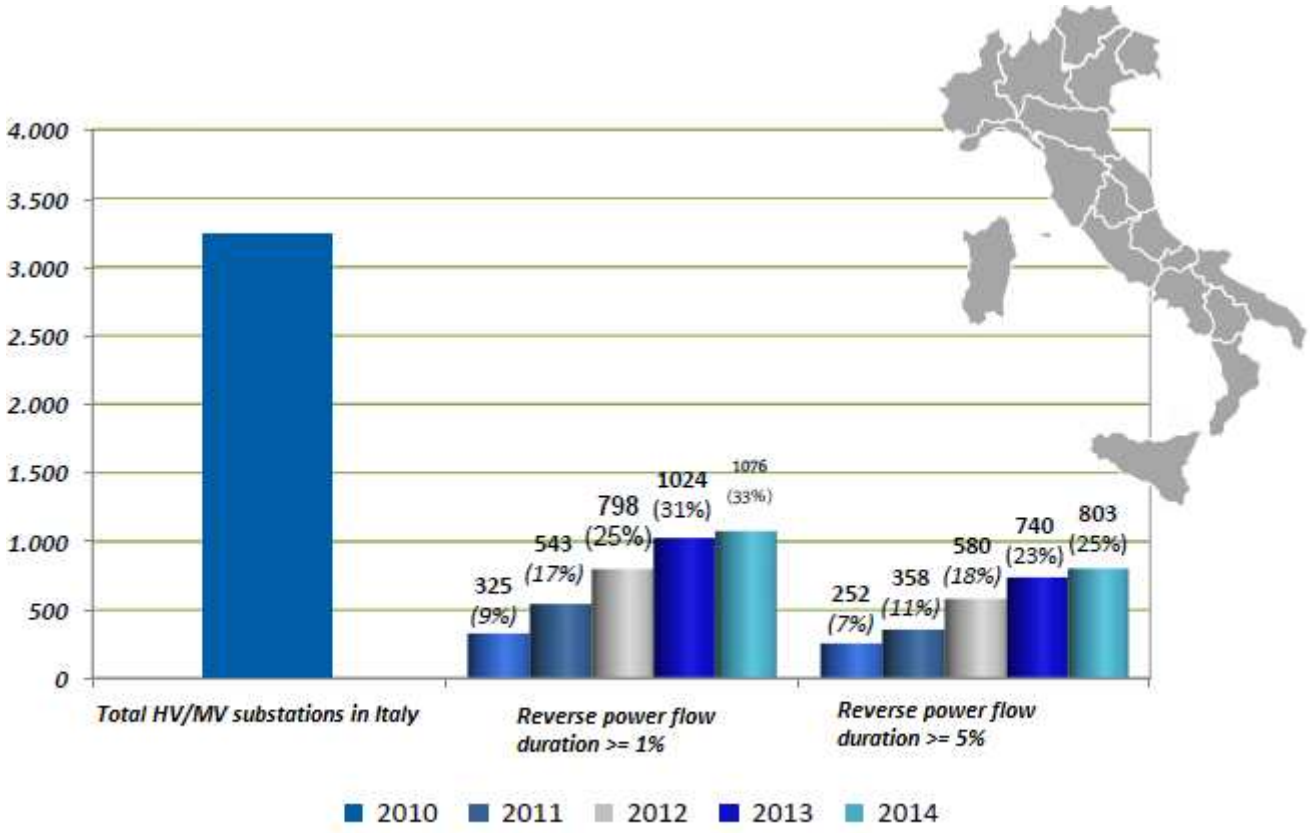



**Significant reverse power flows require adequate technologies and accurate network management**

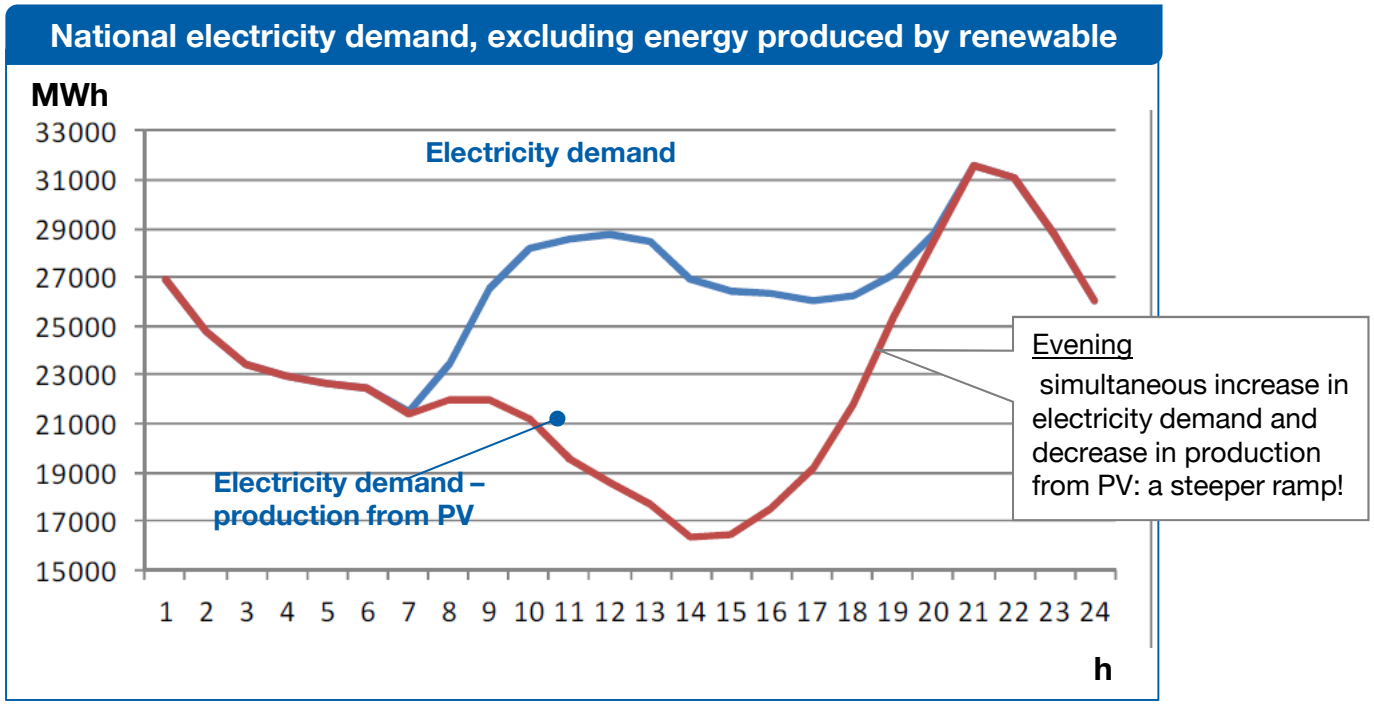
# Generation from renewables

Reverse power flows in the italian electric power system



# Generation from renewables

The impact of renewables on the operation of the electric power system



# DSAS for the integration of generation from renewables

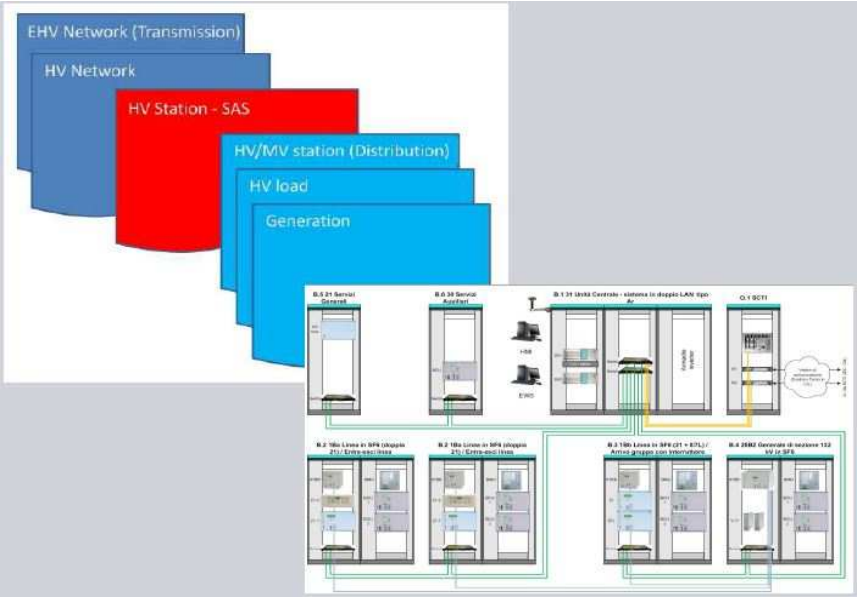
A new role for the Substation Automation Systems

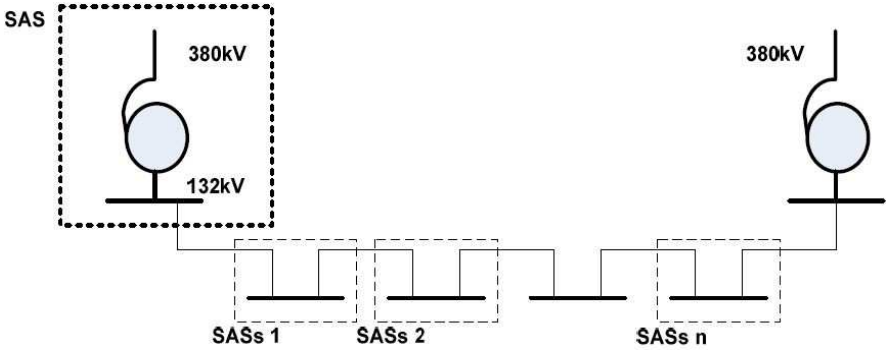
- We think that Substation Automation Systems must have a significant role in this new scenario
- Some functions, typical of the central systems, can be delocalized in the SAS, that means close to where the problems are
- The main problems are voltage regulation and congestion management
- The players are HV substations, distribution substations, power plants directly connected to the transmission grid, dispersed generation

# DSAS for the integration of generation from renewables

## ISOLDE Project: ISOLe Di Energia (Terna, PoliMi, Siemens): objectives

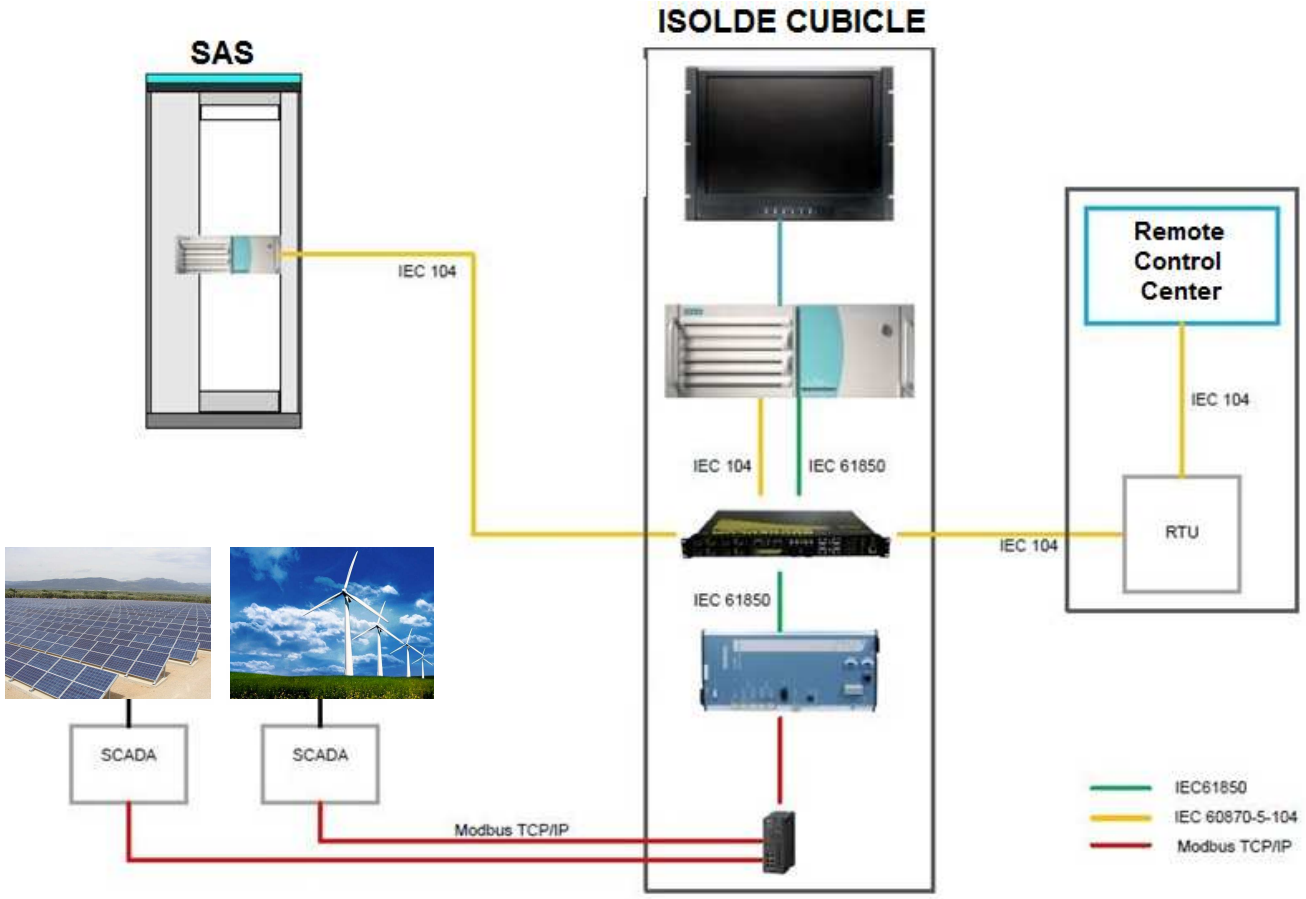
- Development of new control functions integrated in DSAS in order to:
  - Coordinate some dispatching functions exploiting power plants directly connected to the subtransmission power system and the dispersed generation resources in order to:
    - Increase in the integration of generation from renewables in order to:
      - Improve the quality and reliability of supply



# DSAS for the integration of generation from renewables

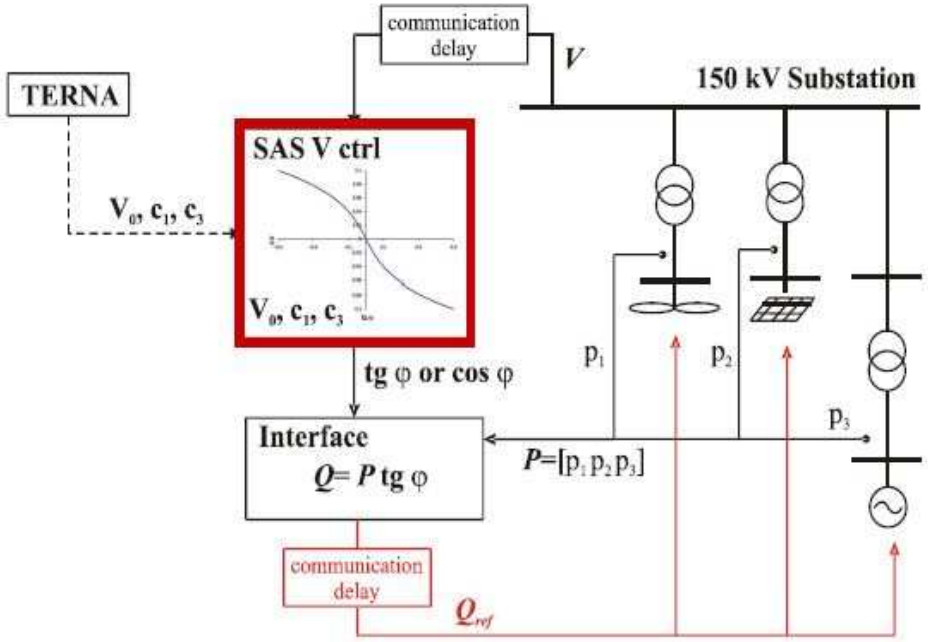
ISOLDE Project: system architecture

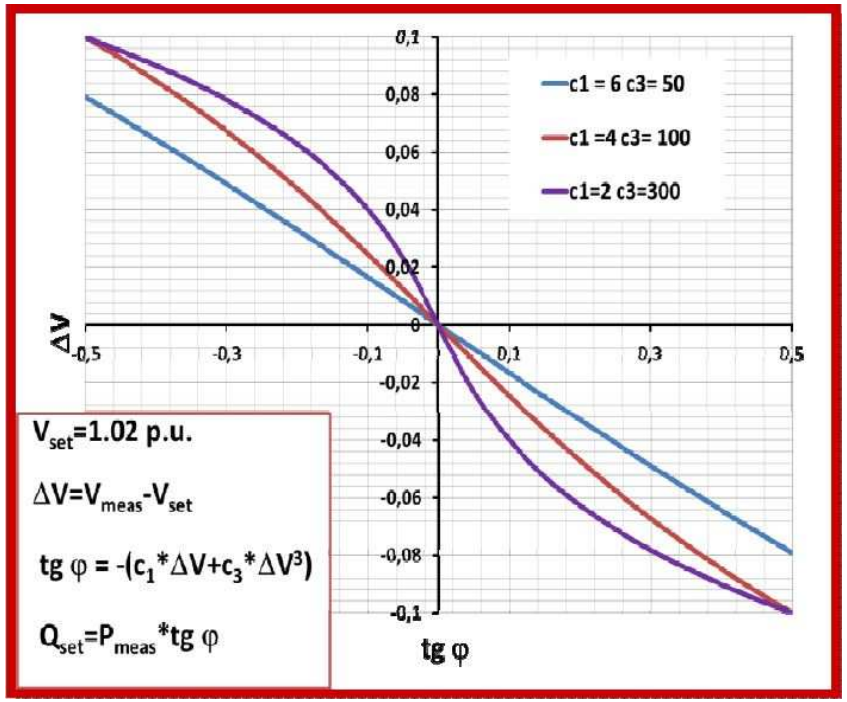


# DSAS for the integration of generation from renewables

## ISOLDE Project: voltage regulation algorithm

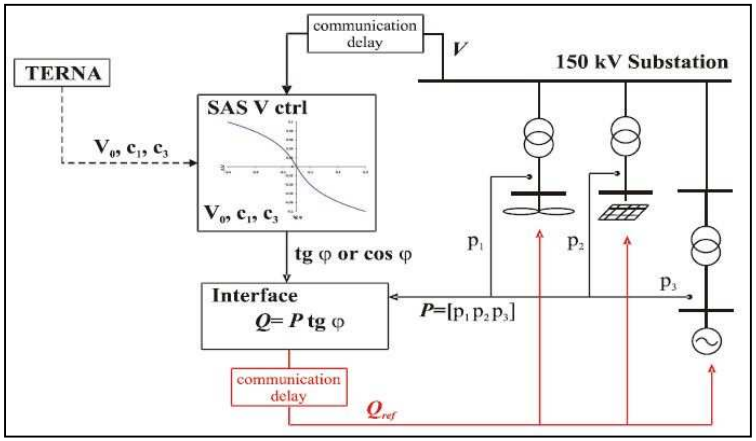
Each ISOLDE device coordinates the reactive power sources directly connected to the substation busbar by means of a control function: cos$\varphi$/tan $\varphi$ /Q/q = f($\Delta$V)

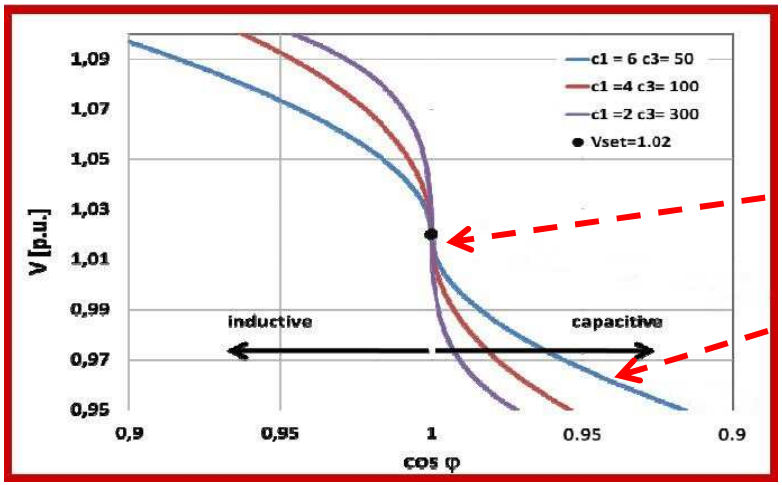


# DSAS for the integration of generation from renewables

## ISOLDE Project: control function for voltage regulation




Different **SASs can be coordinated/regulated by Terna remote control centers**, modifying the parameters of the control function.

The charateristic of the SAS controller is defined in order **to vary the exchange of reactive power as a function of the difference between the measurement of the busbar voltage and the optimum reference sent by the remote.**

The control function can be modified acting on:

- the optimal value
- the sensitivity

# DSAS for the integration of generation from renewables

GREEN ME Project

***Grid integration of REnewable Energy sources in the North Mediterranean***

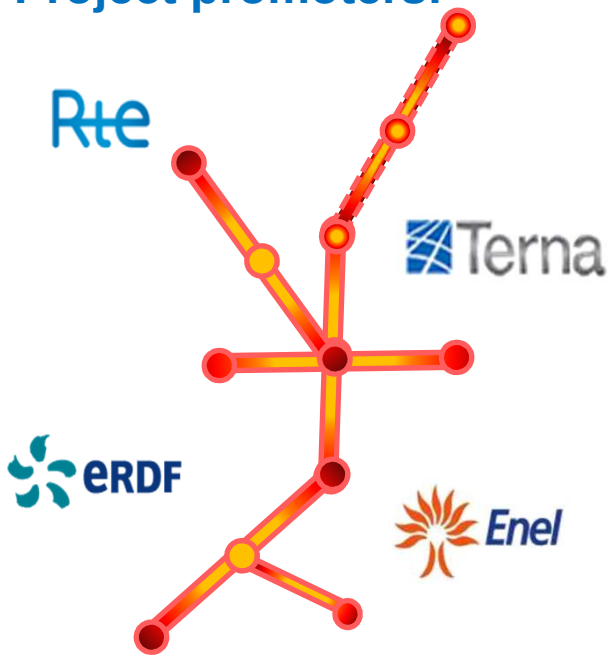
# DSAS for the integration of generation from renewables

## GREEN ME Project: main objectives

*Accommodating more renewables to meet the 20-20-20 targets:*

1. *to increase the observability, controllability and predictability of the distributed generation*
2. *to organize the exchange of data between DSOs and TSOs in order to manage together the energy flows and the voltage constraints*
3. *to improve the TSO-TSO power flow management*

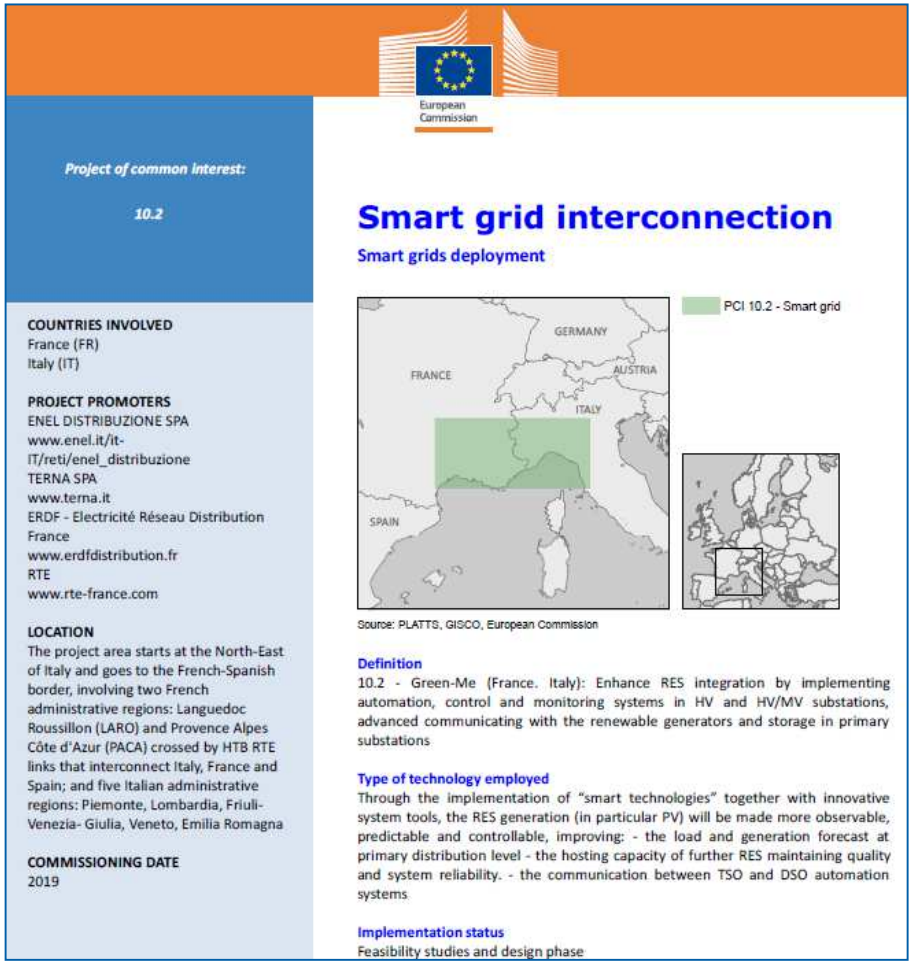
**Project promoters:**




**Location:** South-East France and North-West Italy

# DSAS for the integration of generation from renewables

## GREEN ME Project: Projects of Common Interest



European Commission

*Project of common interest:*

*10.2*

### Smart grid interconnection

**Smart grids deployment**



Source: PLATTS, GISCO, European Commission

**COUNTRIES INVOLVED**
France (FR)
Italy (IT)

**PROJECT PROMOTERS**
ENEL DISTRIBUZIONE SPA
www.enel.it/it-IT/reti/enel_distribuzione
TERNA SPA
www.terna.it
ERDF - Electricité Réseau Distribution France
www.erdfdistribution.fr
RTE
www.rte-france.com

**LOCATION**
The project area starts at the North-East of Italy and goes to the French-Spanish border, involving two French administrative regions: Languedoc Roussillon (LARO) and Provence Alpes Côte d'Azur (PACA) crossed by HTB RTE links that interconnect Italy, France and Spain; and five Italian administrative regions: Piemonte, Lombardia, Friuli-Venezia- Giulia, Veneto, Emilia Romagna

**COMMISSIONING DATE**
2019

**Definition**
10.2 - Green-Me (France. Italy): Enhance RES integration by implementing automation, control and monitoring systems in HV and HV/MV substations, advanced communicating with the renewable generators and storage in primary substations

**Type of technology employed**
Through the implementation of "smart technologies" together with innovative system tools, the RES generation (in particular PV) will be made more observable, predictable and controllable, improving: - the load and generation forecast at primary distribution level - the hosting capacity of further RES maintaining quality and system reliability. - the communication between TSO and DSO automation systems

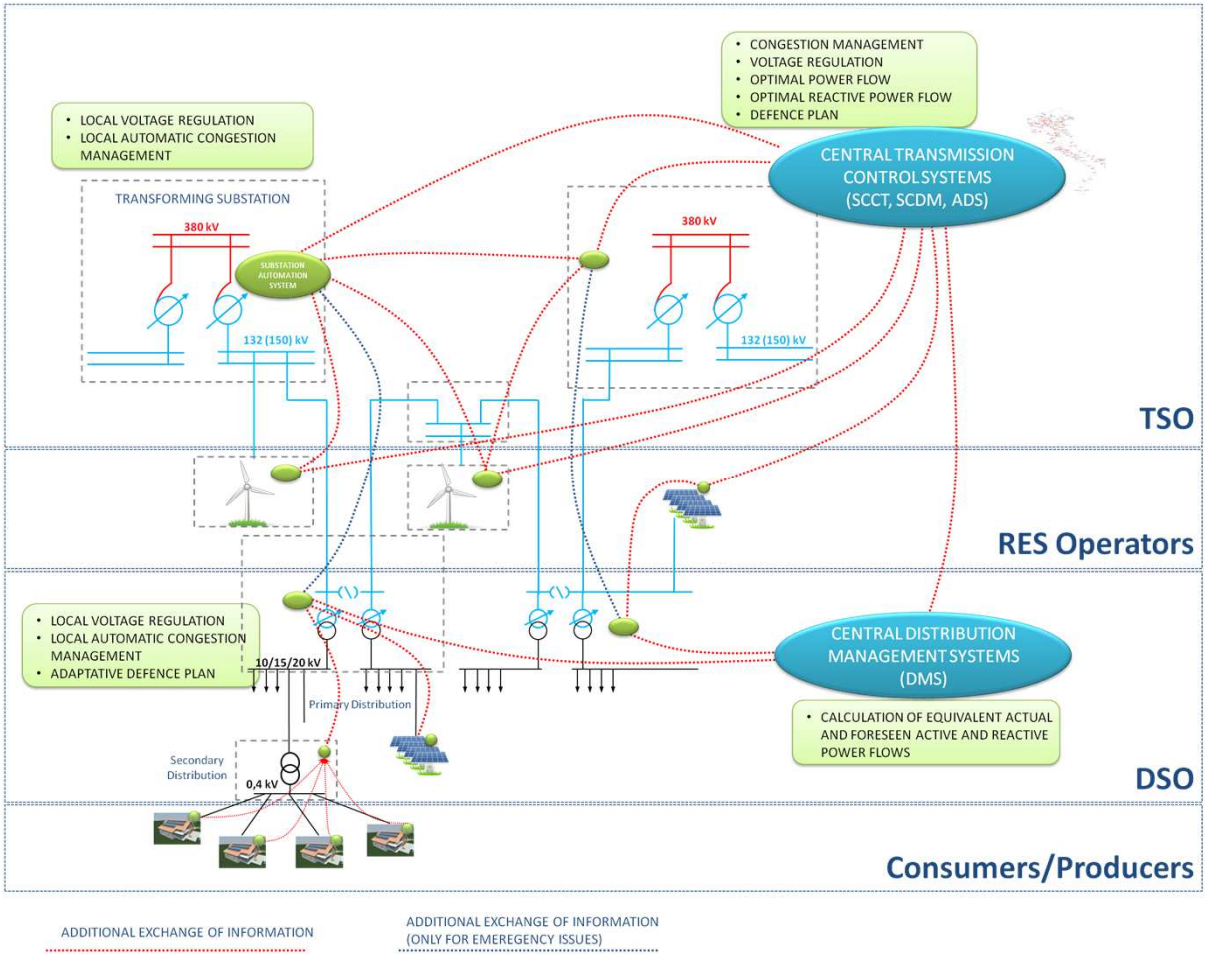
**Implementation status**
Feasibility studies and design phase

**GREEN ME Project is qualified as Projects of Common Interest (PCI)** according to Regulation No 347/2013 amended by regulation No 1391/2013.

The realization of the project relies on an adequate financing level, and on the confirmation, from each promoter, on the sustainability of the project.

# DSAS for the integration of generation from renewables

Development of local dispatching functions for the integration of renewables: **a possible system architecture**



# DSAS and Cyber Security

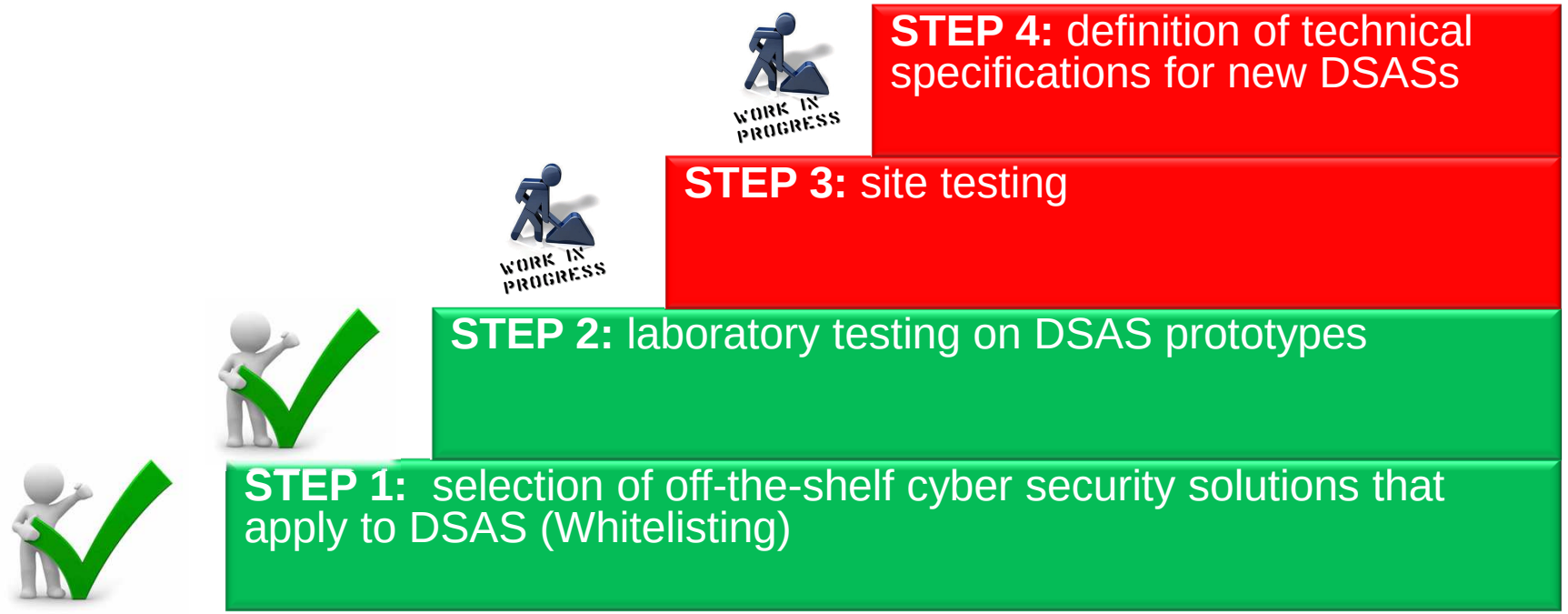
Defining solutions that apply to DSAS

- So far system networks were segregated, but the data retrieval made on the digital systems by the operation employees, that insert their USB key in the devices, can cause an unwanted cyber attack
- Moreover, the new maintenance and configuration tools, that need a remote access to the substation, require to open the grids, with a consequent big risk of attack

# DSAS and Cyber Security

## Defining solutions that apply to DSAS

The first “attempt”: Terna selected the Whitelisting approach: local devices are able to accept only preselected software and applications.



# DSAS and Cyber Security

## Feedback from laboratory test and lesson learned

Feedback

- Two off-the-shelf “application control” solutions based on the Whitelisting Concept were tested on two different DSAS prototypes
- Regression tests easily passed
- Intrusion tests passed

Lesson learned

- Whitelisting solutions are only the first of a wider set of cyber security solutions
- The personnel for operation and maintenance needs to be trained
- The “Fit and forget” approach doesn’t comply with the implementation of the cyber security solutions

# Future challenges

## 1 – 2 years

- Reduction of the cost of maintenance by means of the use of remote access to the DSAS (after having consolidated the Cyber Security Solutions)

## 5 years

- Real interoperability between components produced by different vendors, in order to increase competitivity (deep application of 61850).
- Integration into the DSASs of local load balancing functions, coordinated by the remote control centers, in order to improve the management of the dispersed generation (widespread implementation of solutions like Isolde and Green Me)
- Substation Process bus (digital communication extended to the field)

# Needs and Technologies from the past to the future: Terna experiences with the Substation Automation Systems

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