# THE RESILIENCE EVALUATION OF THE ITALIAN TRANSMISSION NETWORK

*GRID RESILIENCE WORKSHOP*
*“Enanching Power Grid Resilience: Operational and Planning Experiences in Transmission & Distribution Grids and Generation Facilities”*

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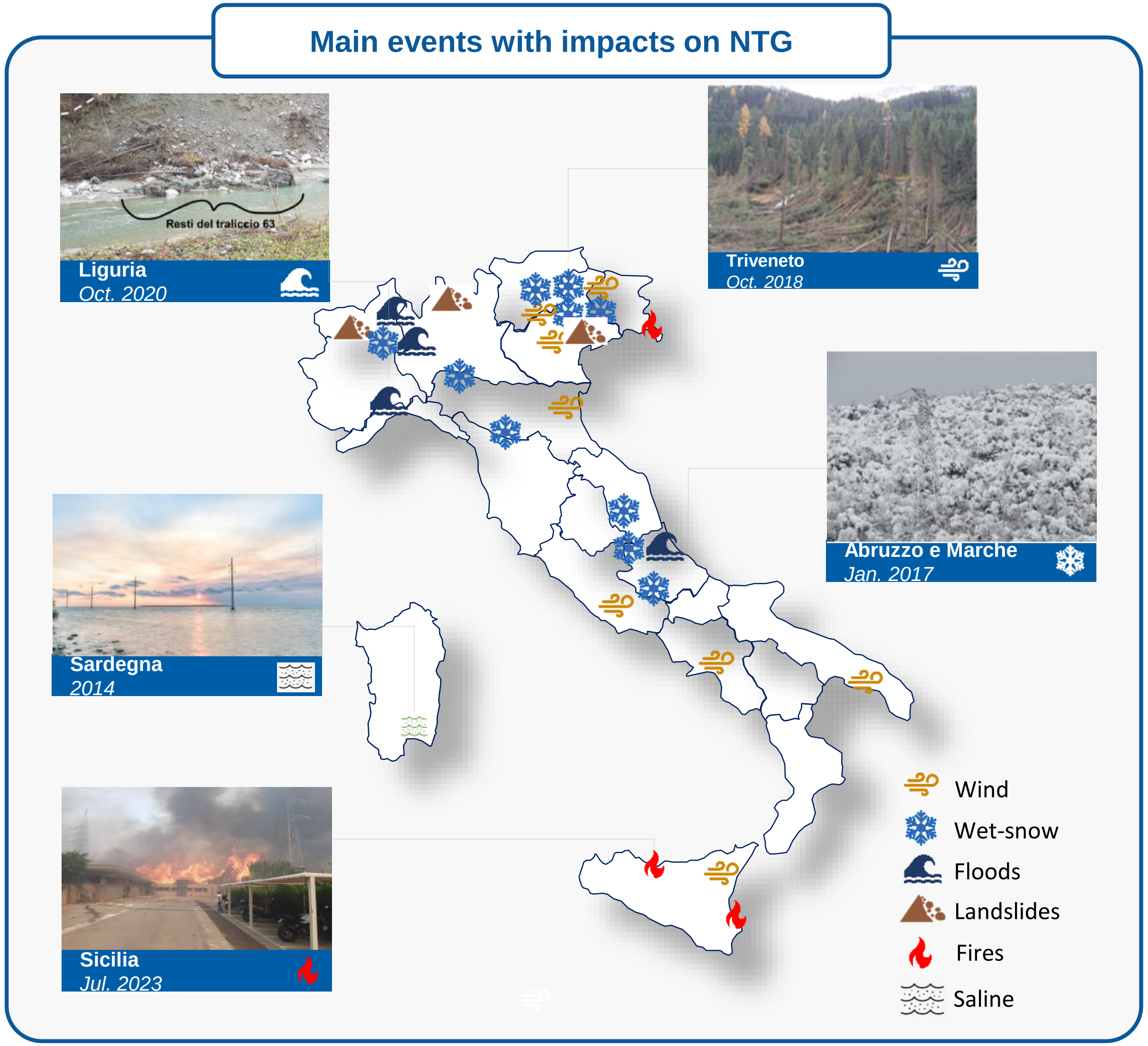
*23 January 2025*

Terna
Driving Energy

# Impact on National Transmission Grid (NTG)



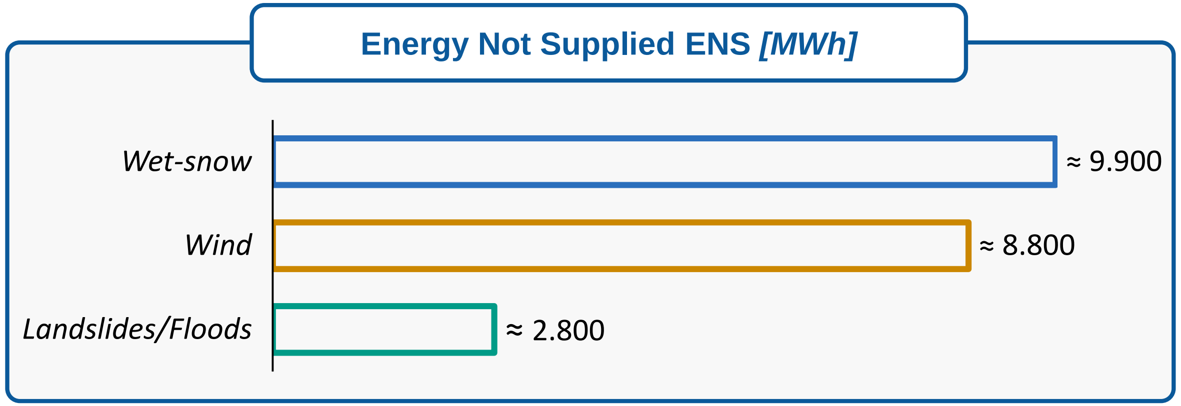

In the **latest 15 years, Italy** has seen an **increase in severe weather events** resulting in losses in various economic sectors, especially due to snow and wind gusts, with often catastrophic impacts for the country, which have also **affected extensive areas of the National Transmission Grid (NTG).**

**> 1700**

**Assets out of service**

**> 20 GWh**

**Energy Not Supplied**



# The main causes of failures on the NTG

## Wet snow sleeves and strong wind

**Wet snow sleeve formation** and **strong wind** action are among the **main causes of failure for the NTG**. The **load of the sleeve**, which cylindrically covers conductors and shield wire, or the **stresses produced by the wind** on the various components of overhead lines, **can result in the lines being out of service** if these are higher than the design limits, **causing**, for example, **the breakage of conductors, shield wires or supports.**

## Vegetation interference

The main indirect effect on RTN is **falling plants out of Right of Way**. **Trees overturning may impact conductors, ground wires, supports or their components causing them to break or may result in the reduction of the insulation distance, leading the line out of service**. **Modeling of the phenomenon and mapping of vegetation** at risk of overturning **is a crucial aspect** for detect an prevent interference.

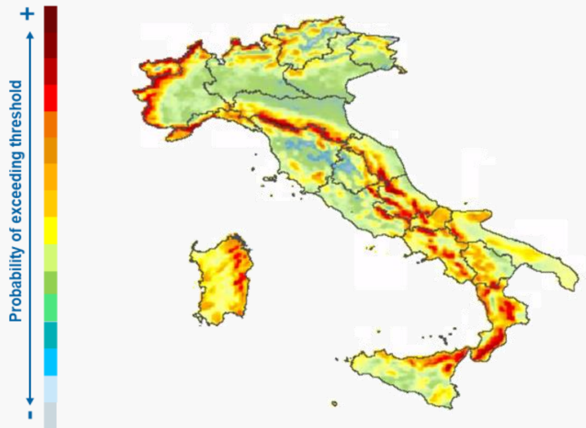


1 From Copernicus Project: https://land.copernicus.eu/

# The Terna Resilience Methodology

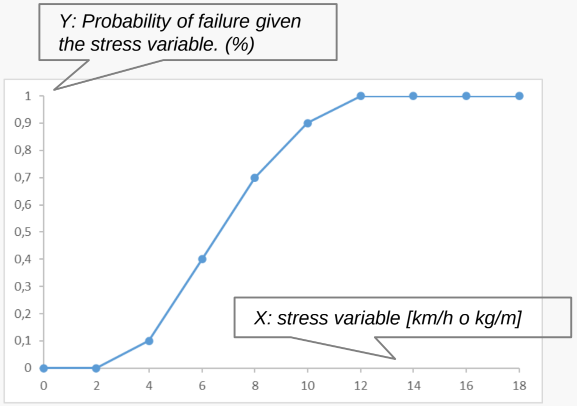
In order to address the **challenges of climate change**, is been defined a **Resilience Methodology** *risk-based*, characterized by the following key pillars:

## PROSPECTIVE CLIMATE HAZARD



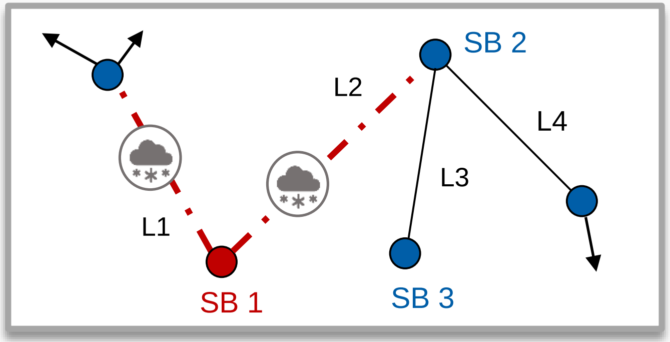

Use of specific **prospective climatological models** for each threat to determine the **probability of occurrence** of **severe weather events**, with high spatial resolution.

## ASSETS VULNERABILITY




**Vulnerability assessment** of **OHLs** (failure probability): **vulnerability curves**, which are function of the **threat intensity**, are built by adopting an **engineering approach** based **on technical standards**.

## CONTINGENCIES ANALYSIS




A **contingency analysis approach** to evaluate system resilience, quantifying **substations' outage Return Periods (RP)** and **EENS (Expected Energy Not Served)** after the simulation of **weather-induced multiple contingencies (N-k)**.

**The resilience methodology allows to assess the level of resilience of the grid, identify the critical areas and identify the intervention**

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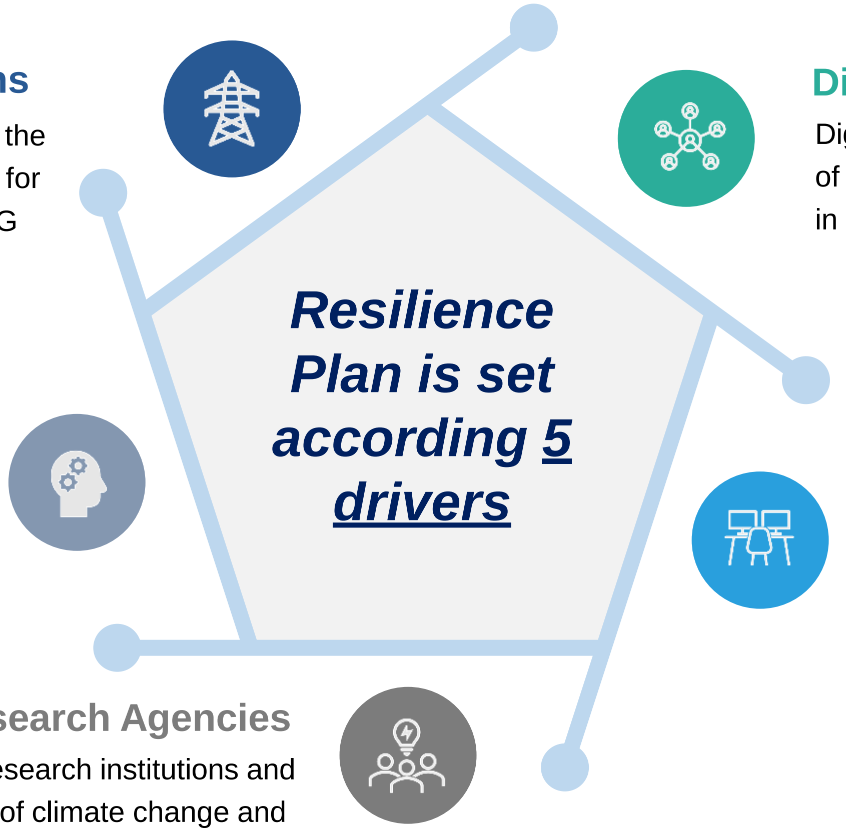
**the assessment of the benefit of interventions aimed at increasing the resilience of the electricity**

# Terna Resilience Plan

**Resilience Plan,** set out in Security Plan, represents a transversal plan that includes **all initiatives for the next 5 years** that Terna carried out to increase the resilience of the NTG. The **Resilience Plan 2024** is the 4th edition with **~ 0,8 Bln€ of investments**.




### Planning new interventions

Identify new solutions by expanding the basket of interventions with benefits for increasing resilience from of the NTG

### Digitalization

Digitization becomes an enabling factor for the development of new tools that can improve the prediction of risk situation in network operation and planning stage

### Technological innovation

Study new technologies that can be adopted for increasing the robustness of NTG assets following extreme weather phenomena

### New climate risk analysis

Extend the analysis and study to new weather phenomena with impact on the NTG, improving their modeling within the tools adopted by Terna

### Collaboration with Research Agencies

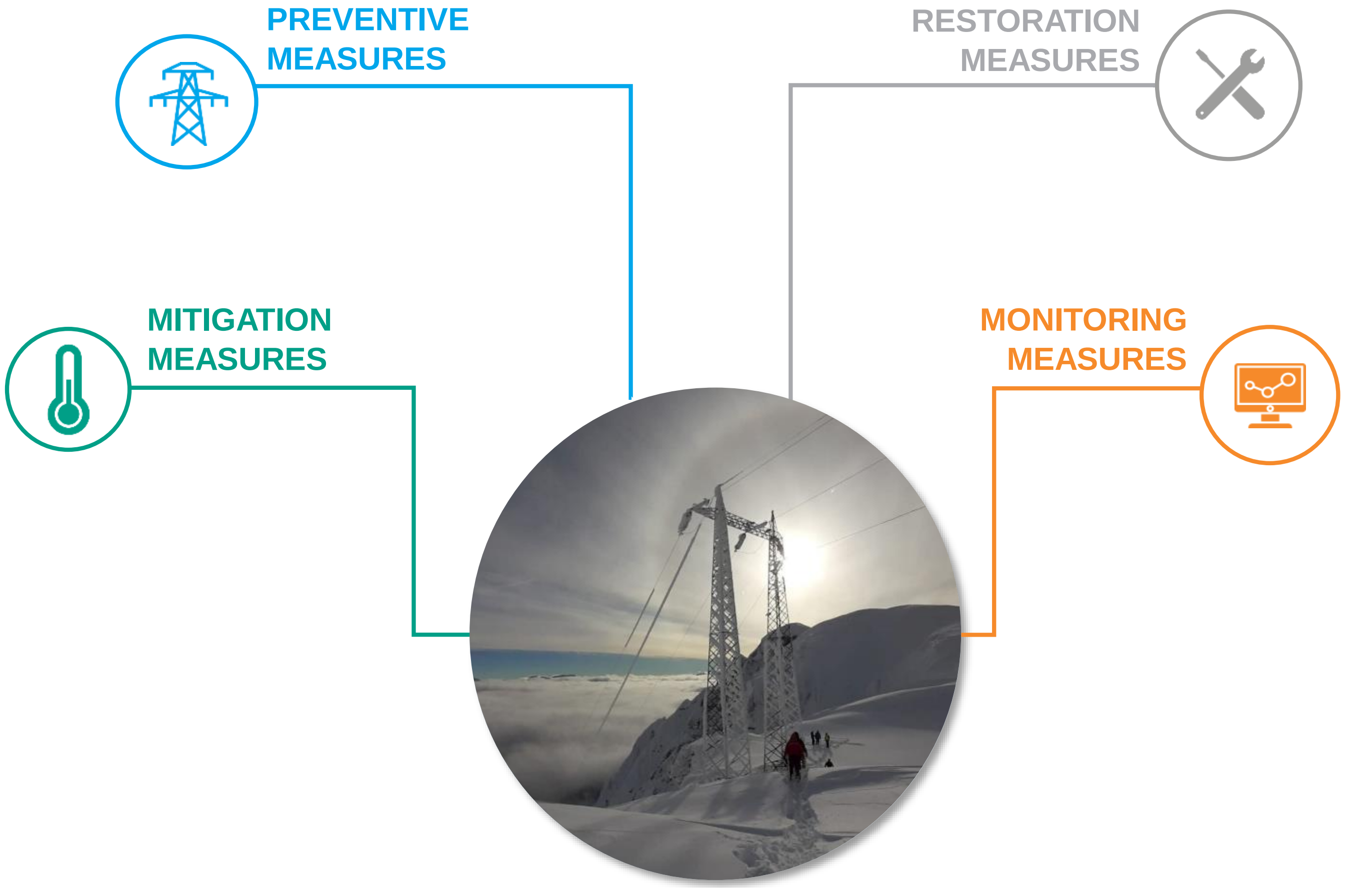
Strengthen collaboration with research institutions and universities to study the effects of climate change and to develop probabilistic models of complex natural phenomena

# Terna's Resilience Plan

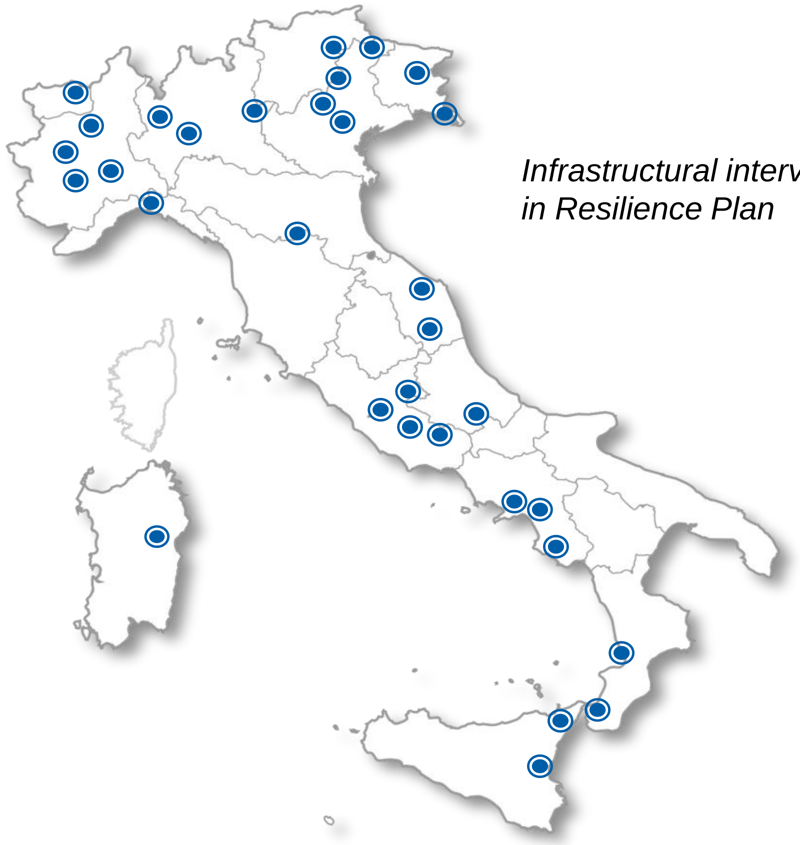
## TYPE OF MEASURES

In order to **fulfill an efficient mix between different technologic solutions** and thanks also to the application of the Resilience Methodology and the evidence obtained**,** **Terna has identified different types of interventions** for the most critical areas:

- **Preventive Measures** are implemented ex-ante, regardless of the actual occurrence of failures
- **Mitigation Measures** are capital light interventions to contain risks on the electrical system and reduce damage due to critical event
- **Measures for restoration** are Interventions implemented ex-post, in response to the actual occurrence of failures
- **Monitoring Measures** are innovative technological solutions aimed at anticipating critical situations



# Terna's Resilience Plan - Preventive measures




**32**
**# Infrastructural interventions**

**58**
**# Substations reducing risk of outages**

**~500 km**
**New lines building and reinforcement**

**INFRASTRUCTURAL SOLUTIONS**

Preventive interventions are infrastructural interventions aimed at increasing network resilience, including through technology diversification, increasing network meshing, and improving the reliability and robustness of existing assets:

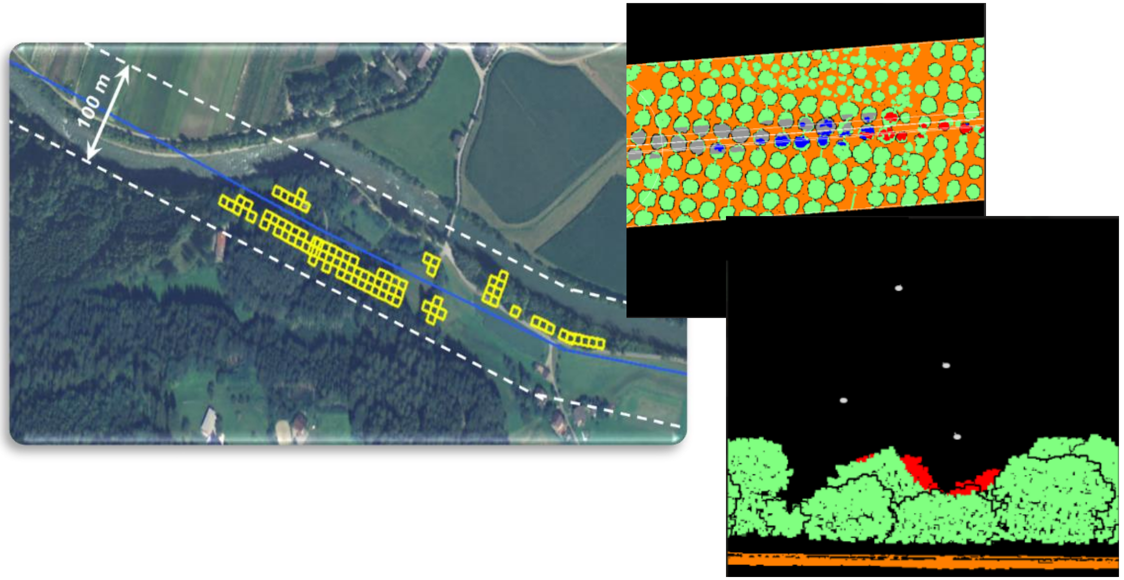
- **reinforce existing asset** improve the mechanical characteristics with total or partial reconstruction to better resist against extreme conditions;
- **overhead lines conversion into underground cables**: reduce the exposure of asset to the effects of severe weather events;
- **new lines building (OHL or cable)**: increase the grid redundancy through meshing of the transmission grid.

# Datasets for vegetation mapping - LiDar Interference Mapping

## LiDar[1] Mapping - A cartography serving the power grid

- As part of its **maintenance practices**, Terna uses its fleet of helicopters to carry out **the mapping of the terrain around the lines using LiDar**, a remote sensing system that allows to measure the distance of an object or surface from power lines using a laser pulse.
- The main objective of inspections is to **measure the actual distance between power lines and surrounding vegetation**, also out of ROW, to map possible tree interference and plan preventive cutting actions.

Applied **business practices and know-how in asset management** by employing them as inputs to modeling of tree disturbance by overturning **in the methodology, achieving a high degree of precision, realism and accuracy of risk analyses**




***Tree interference detection***

- *The LiDar mapping has a width equal to 50 meters per line side*
- *Mapped location and height information of vegetation around OHLs*
- *Spatial resolution up to 1x1 m*
- *Annual update of interference mapping*

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1. Laser Imaging Detection and Ranging

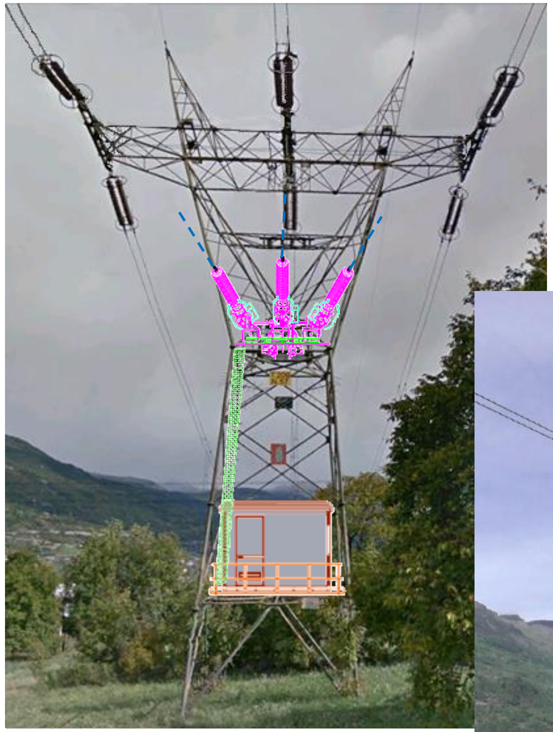
# Pole-mounted Switching Equipment (OMP)

## FEATURES

The designed improvement was based on the replacement of the existing manually operated disconnectors, in T configuration, with **new switching equipment** suitably associated with a protection, command and control system, positioned in a shelter, **all integrated into the structure of a lattice tower.**

- **Increase the flexibility of network operation**, thanks to the ability to interrupt rated and short circuit currents, in a selective manner
- **Interact with** neighbouring **substation**s **and be remotely operated**
- **Being an expression of technological evolution**, resulting in:
  - ❑ a compact solution
  - ❑ resilient to climatic conditions
  - ❑ sustainable on the territory
- **Solution protected by patent**

## THE DESIGN



# Pole-mounted Switching Equipment (OMP)

## BENEFITS DURING MAINTENANCE ACTIVITIES

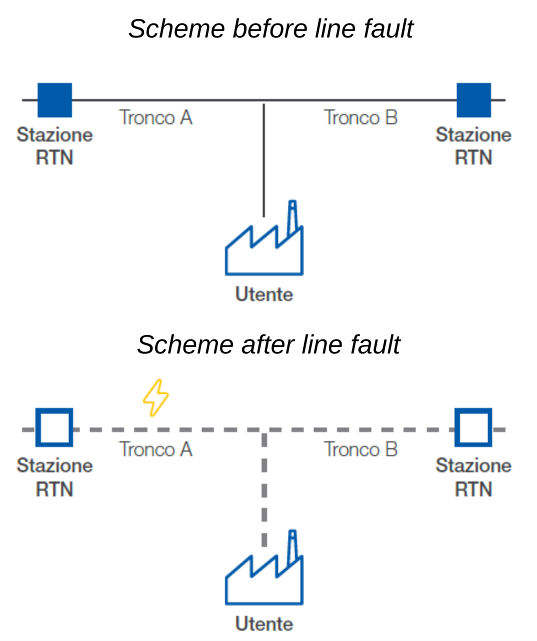
- **Variation of the grid configuration without interruption** of the power supply to the Users
- **Continuitiy of power supply** to Users
- **Flexibility in intervention scheduling** making it independent of utilities' production cycles
- **Maximizing the energy produced** by renaweble energy source (typically non-programmable)

## BENEFIT DURING FAULT

- **Minimize restoration time** after line fault
- **Selective intervention** and **automatic fault elimination** in a short time
- **No economic compenasation** for short interruptions nor for energy not supplied
- **Reduction of damage risk** for industrial users following long interruptions

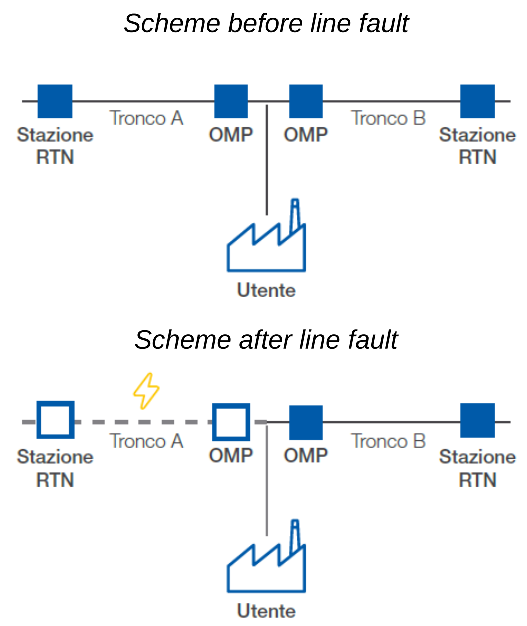
## BENEFITS

WITHOUT OMP



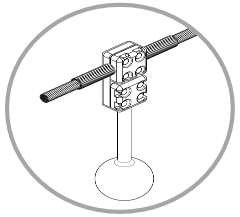
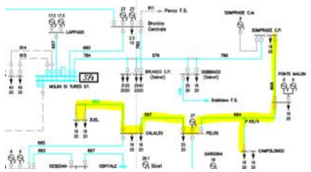

User, connected on banches of a «T» connection, is interrupted folloiwing a line fault

WITH OMP




With the adoption of OMP, significant impovement of the resilience of the User since only the branch affected by fault is out of service and continuity of supply is granted by other branch

# Mitigating measures – Capital light investment

| Type of solution | Related benefit | |
|---|---|---|
| **Anti-tortional devices** | The use of anti-torsional **devices increases the conductor torsional stiffness** on which they are installed. These devices avoid the rotation that cause the formation and consolidation of the wet snow sleeve |  |
| **Interphase spacer devices** | The Interphase spacer **avoids the contact between phases in dynamic and difficult situations**. This device reduces the "galloping" conductors phenomenon and contribute to increase the torsional resistance of the span. |  |
| **New "Icephobic" paint** | The use of **new conductors with hydrophobic paint or new conductors made with special components reduce the risk of wet-ice sleeve formation**. |  |
| **Anti-icing and De-icing current** | Consist in the use of **ballast load or re-dispatching current flow to increase joule-effect on the conductor** and avoid the wet-ice sleeve formation. |  |
| **Cutting down trees** | **Prevent vegetations from entering in the ROW (Right Of Way)** |  |

# The antitorsional device

- Limited torsional stiffness of conductors is the main cause of conductor rotation
- Anti-rotational devices increase the torsional stiffness of the conductor and reduce the formation of the cylindrical sleeve of wet snow

## BENEFITS

- **Capital light mitigation intervention** that **does not require authorization and has limited implementation time**
- The types of anti-rotational devices designed by Terna cover a wide range of conductors and ground wires used on overhead power transmission lines

## INSTALLATION CRITERIA

> The installation criteria, in terms of type (weight and size), number, and placement, depend on the conductor on which they are to be installed and the geometry of the span (length and height difference);

> There are some limitations to be taken into consideration;

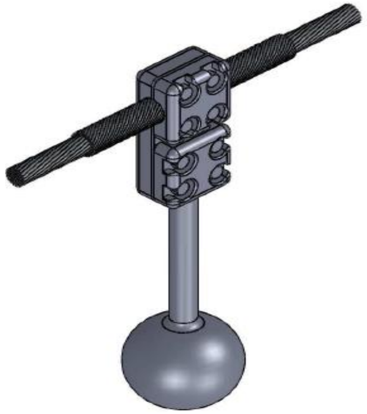
## ONGOING PROJECTS

Following the first trials in 2014, an operational program was implemented in 2017 that covered most Italian regions

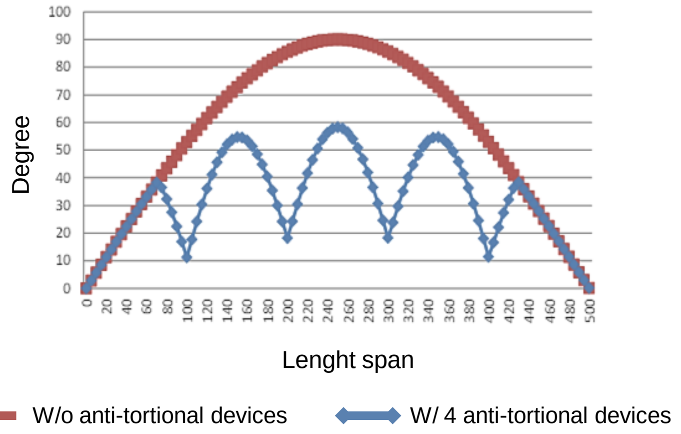
Today, more than 100,000 devices have been installed, affecting about 8000 km of NT lines. In the coming years, the installation campaign will continue on additional critical lines identified through the Resilience Methodology

## ANTI-ROTATIONAL DEVICES EFFECT

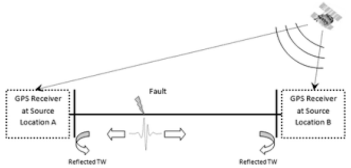
ANTI-ROTATIONAL DEVICE



ANGLE OF ROTATION OF A PHASE CONDUCTOR

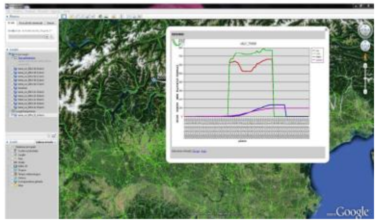


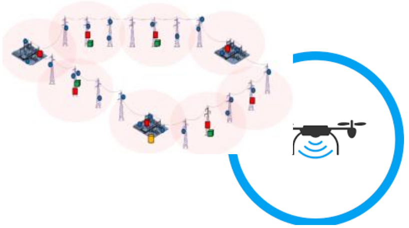
# Measures for restoration

| Type of solution | Related benefit | |
|---|---|---|
| **New emergency plan** | The optimal management of emergency plan consists in fast recovery devices, such as **mobile generators**, the operation (power supply) in **loading islands and coordination of the operating teams** |  |
| **New emergency power plants plan** | **Adaptation of production plants** to allow, following disconnection from the grid, autonomous start-up, **black-start and island operation.** |  |
| **New fault locators** | **Optimize and speed up the search for the fault.** |  |
| **Evolution of network protections** | • Use of **Automatic Slow Closing (RLA)**<br>• **Automatic sectionalizing device** to separate the failed section and put lines with multiple branches back into service and faster re-meshed of the transmission network due to failure |  |
| **Increased operational equipment** | • Strengthening **the vehicle fleet**<br>• Strengthening **satellite phone equipment**<br>• Expanded use of **helicopters** for inspections, personal transportation, and development of helicopter work methods and also for using **Lidar monitoring system** |  |

# Monitoring measures

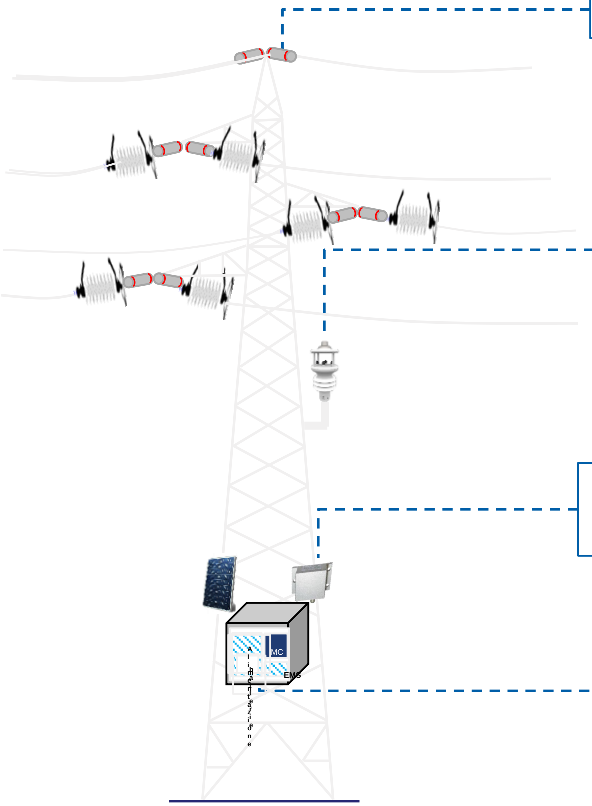
| Type of solution | Related benefit |
|---|---|
| **DSS** *(Decision Support System)* | • **WOLF (Wet-snow Overload aLert and Forecasting)** is a forecast and alert system for «wet-snow» overload;<br>• **WIND-TRASM** for strong wind warning and alarm to assess the risk of falling plants on the lines<br>• **SALINO** for alerting salt deposition on insulators and preventing discharge |
| **Remote monitoring** | • Wireless Sensor Network, the **Smart Tower, Smart Substations and IOT for the Grid**<br>• New technologies such as **satellite or Drones/UAV** (Unmanned Aerial Vehicle) |
| **Predictive Operation & maintenance** | • **Predictive and Adaptative analysis** are able to allow to have more reliable analyses and to improve and optimize interventions<br>• **Data mining, Edge computing, Data hub, Data Storage** allow to create a flexible and solid data management architecture and to improve analysis quality<br>• **Machine Learning and AI** |





# IoT 4 The Grid

## Sensors, DigiL and IoT Box: A new Support 4.0



### Sensor force

One force sensor installed on each dead clamp armament of conductors and groud wire

### Weather station

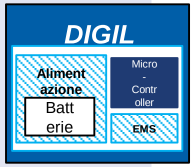
Monitoring wind intensity and direction, temperature, humidity and radiation

### Vibration and tilt sensor

Monitoring vibration and support inclination

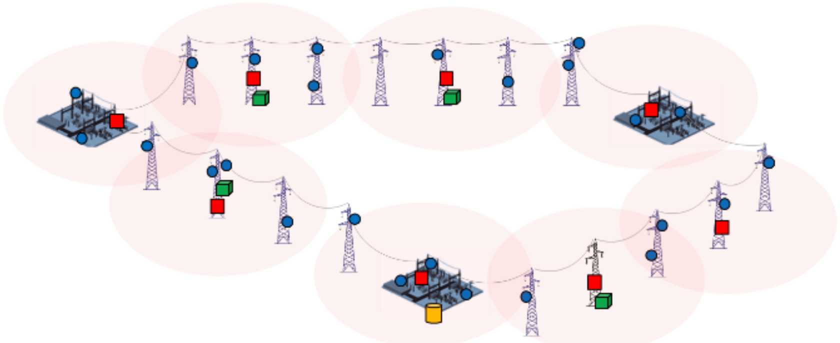
### DIGIL/IoT box

Data collection from sensors and transmission to Central Platform




## Architecture Overview

The heterogeneous structure of Terna's transmission grid requires the development of a **modular solution set in terms of Sensors, Gateways, Batteries** to cover the different needs



**Sensors**
- Different kinds of monitoring and data collection sensors (temperature, vibration, etc.).
- Depending on the type of sensor and data, it can be positioned differently

**IoT BOX**
- Collecting encrypted data from geographically close sensors, decrypting and forwarding to higher levels of the architecture.
- Located at the mid-height of the support

**Batteries**
- Power supply to support the IoT BOX, usually consisting of batteries and/or photovoltaic panels.
- Located at the base of the tower that features the IoT BOX.

**Edge**
- Hardware set up for real-time calculation of analytic data from sensors.
- Located in the stations

# Conclusions

The increase in severity and frequency of weather events impose **new challenges for grid operator, requiring adoptions of new tools, procedures, measures** both in planning and operation aiming to grant appropriate level of quality of service.

**Climate risk analyses** must be able to intercept, **in a forward-looking manner**, the frequency and intensity of the occurrence of weather extreme events as well as their impact on electrical infrastructures in order **to identify and plan new interventions to increase the resilience of the electricity grid in an effective and efficient manner.**

**Research in developing new technologies** is an enabling factor for integrating new technological solutions supporting the **development of a more resilient power system.**

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