A methodology for the evaluation of grid resilience: Terna's perspective

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Evolution of climate risk

Climate change is now and will be in the future one of the most **significant challenges to be addressed globally and locally, as critical infrastructure** may be seriously damaged by meteorological extreme events related to climate changes. In Europe, **damages from climate hazard** impacts to critical infrastructure **could increase 10-fold by the end of the Century.**

In the **last 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 area of the National Transmission Grid (NTG).**

> 1700
Assets out of service

> 20 GWh
Energy Not Served

The **future climate projections** about the intensity and frequency of weather events **requires the adoption of new probabilistic risk-based approach methodology** in order provide useful information to cope with climate change impacts and strength the resilience of the Italian transmission network, **supporting Terna** in the **planning and decision making of new grid investments.**

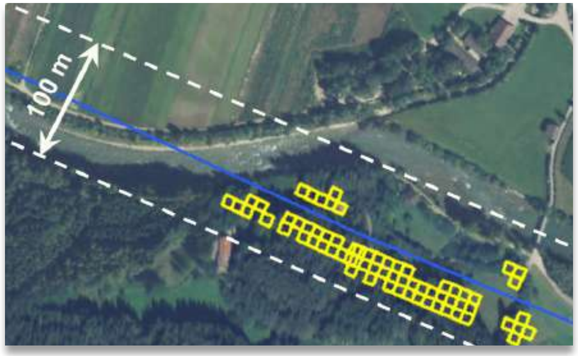
Climate change in Italy and the impact on the NTG

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**. **Modeling of the phenomenon and mapping of vegetation** at risk of overturning **is a crucial aspect** for detect an prevent interference. They were carried out by means of **LIDAR image processing**, obtained from aerial overflights of the NTG, and based on the **Corine Land Cover database**[1] representative of the vegetation type.



Terna Driving Energy

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

Terna's path toward a more resilient power grid

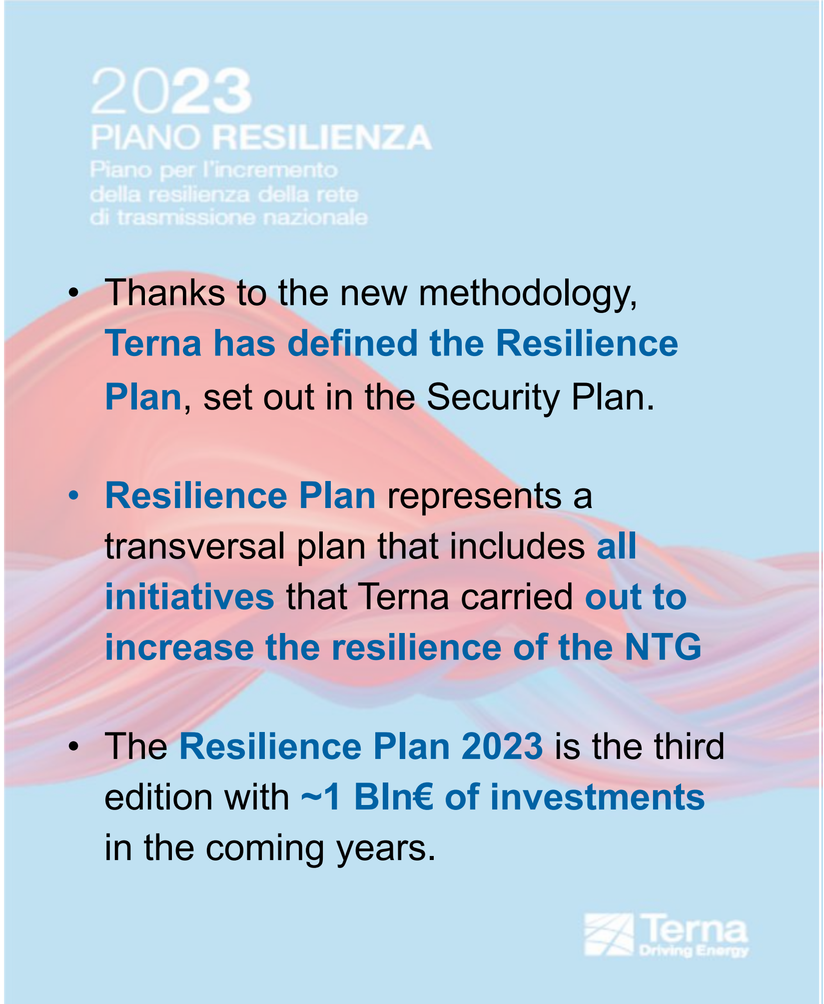
Terna's Resilience activities *(from 2017)*

- **Starting from 2017,** Terna is identifying different types of **interventions to increase the resilience of the network** included **in Terna'Security Plan**.
- **For wet-snow events** Terna has implemented the **installation of anti-torsion devices** and adopted **tools and procedures for emergency** (e.g vehicle, communication tools).

Resilience Methodology *(from 2020)*

- **From 2020**, Terna has defined, with *Ricerca del Sistema Energetico* (RSE), the risk-based **Resilience Methodology**, a **new prospective and probabilistic approach** to calculate the benefit for increasing the resilience of the NTG for **wet-snow e strong wind**.
- **Resilience Methodology**, after a public consultation, has been approved by ARERA with Resolution 9-2022 as **Annex A76 of National Grid Code**.

Terna Resilience Plan



- Thanks to the new methodology, **Terna has defined the Resilience Plan**, set out in the Security Plan.
- **Resilience Plan** represents a transversal plan that includes **all initiatives** that Terna carried **out to increase the resilience of the NTG**
- The **Resilience Plan 2023** is the third edition with **~1 Bln€ of investments** in the coming years.

The Terna's Resilience Methodology

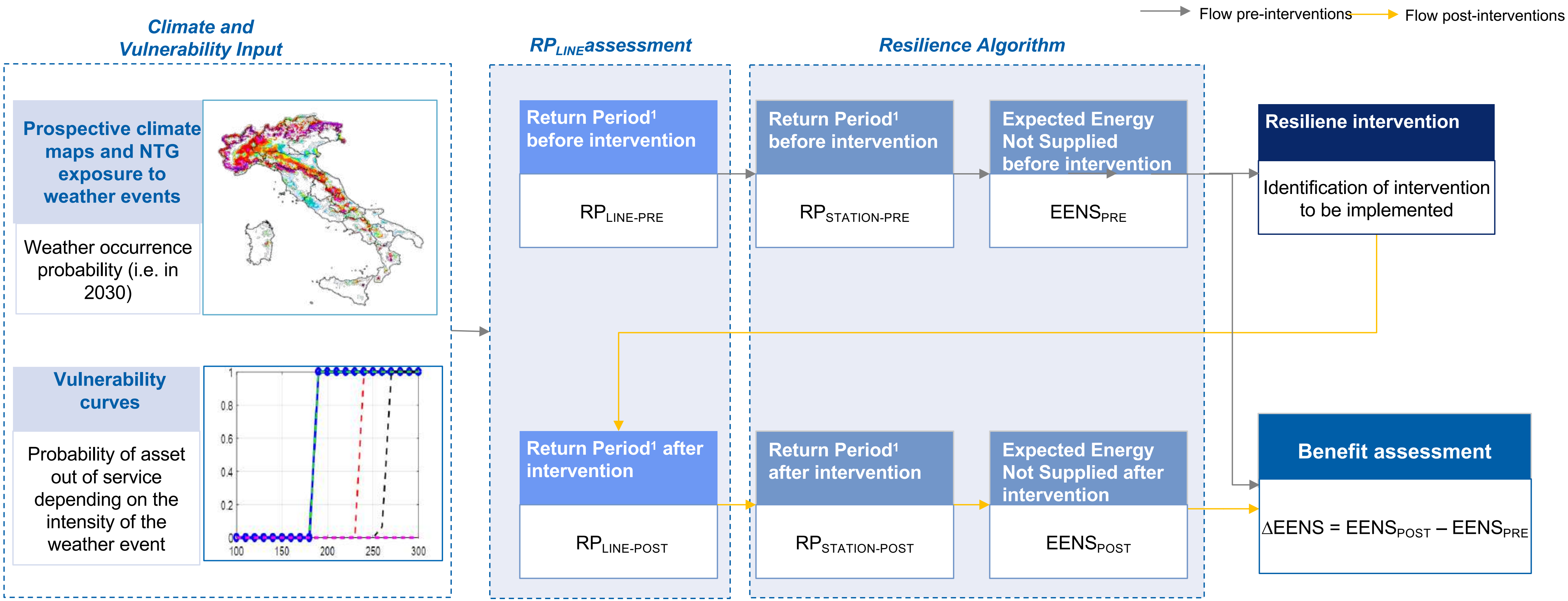
The **Methodology for calculating the increase in power grid resilience** is characterized by the following **three key elements**:

Innovative, scalable and replicable approach for weather events of different nature that, through the **development of forecast climate scenarios, allows the identification of areas of the territory most exposed to the effects of severe weather events**, associating with them the relative probability of occurrence (climate hazard)

Engineering approach for estimating the vulnerability of different components of electrical overhead lines to **direct and indirect stresses** caused by severe weather events by determining specific vulnerability curves defined by **using real technical and orographic parameters**

Probabilistic N-k approach for analysing multiple and simultaneous out of service produced by weather events in order to quantify the probability of occurrence of such multiple contingencies and assess their impact (in terms of **Expected Energy Not supplied**) on the portion of the power system exposed to the severe weather event

The steps of Resilience Methodology



The Resilience Methodology is aimed at assessing the risk of power outage of station connected to the National Transmission Grid in the face of severe weather events and **captures the increase in resilience of the power system** of the identified interventions, taking into account climate projections and asset vulnerability

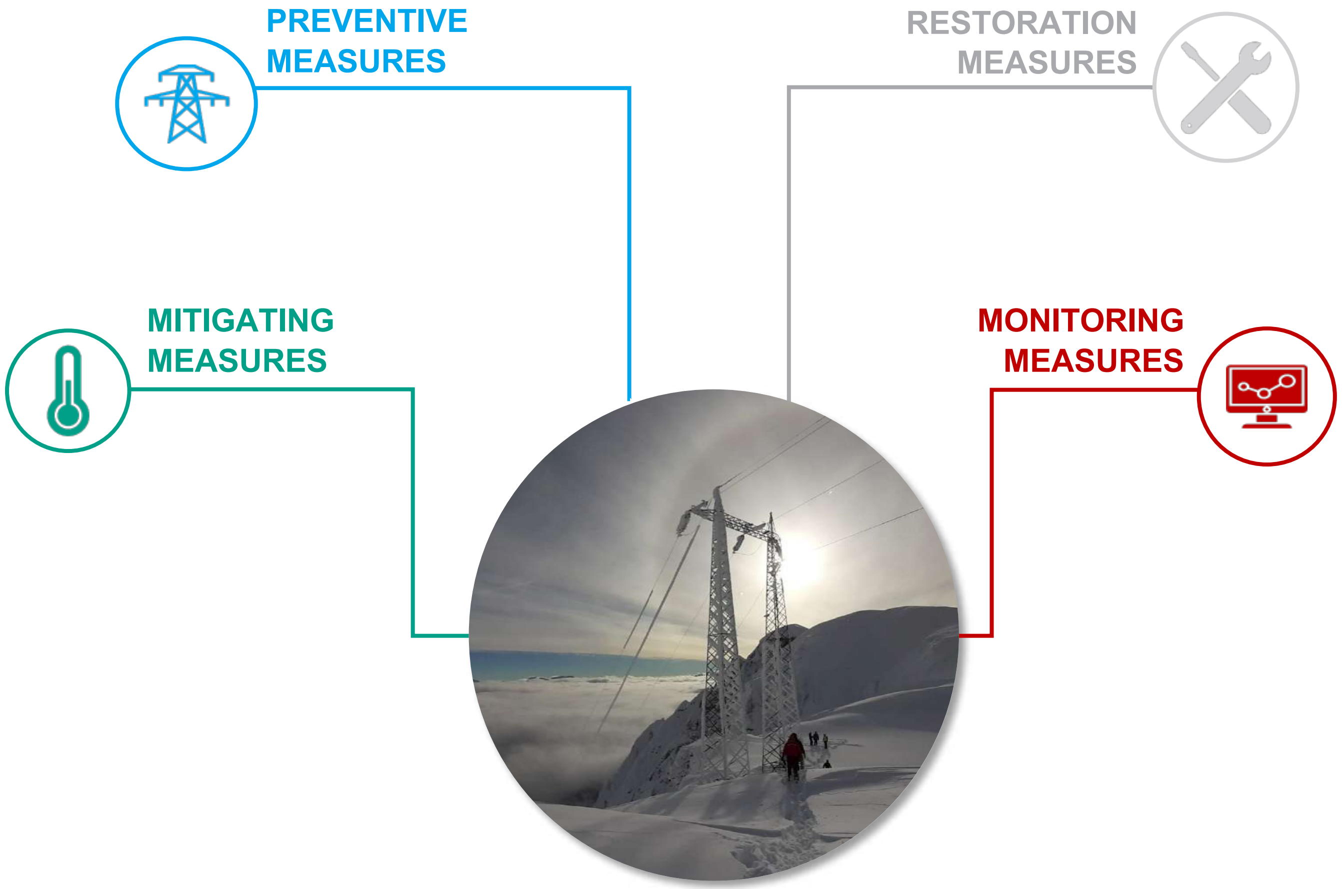
1 Average time between two failures due to the occurrence of a specific weather event

Terna's Resilience Plan

TYPES 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

31
 # Infrastructural interventions

55
 # Substations reducing risk of outages

~500 km
New lines building and reinforcement

INFRASTRUCTURAL SOLUTIONS

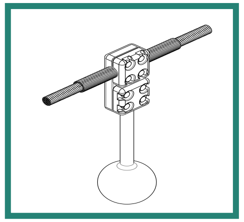
Preventive interventions are infrastructural interventions aimed at increasing network resilience, including through technology diversification, increasing network meshing, and improving the reliability and robustness of existing assets:

- **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.

Terna's Resilience Plan - Mitigating, Restoring & Monitoring

MITIGATION

Anti-tortional devices
avoid the rotation that increasing the conductor torsional stiffness



New "Icephobic" paint
use of new conductors with hydrophobic paint reduce the risk of wet-ice sleeve formation

Interphase spacer devices: avoid the contact between phases

RESTORATION

New emergency plan
fast recovery devices, such as mobile generators, the operation *(power supply)* in loading islands

Advanced operational equipment
- reinforcing the vehicle fleet
- reinforcing satellite phone

- Expanded use of helicopters for inspections, workers transportation

MONITORING

Remote monitoring
New technologies such as satellite or Wireless Sensor Network.

Monitoring tools
Forecast and alert systems able to foresee severe conditions in grid operations and to suggest possible real-time solutions

Final consideration

The increase in severity and frequency of weather events needs a **change in planning stage,** moving from deterministic approach to a **new probabilistic risk-based method** considering also prospective climate models and N-k assessment.

Successful implementation of the **Terna Resilience Methodology** and its application to develop **Resilience Plan** to increase the resilience of the National Transmission Grid assets

The **application to the NTG** demonstrates the **capability** of the methodology to **simulate** the **effectiveness of different resilience enhancement solutions**, thus allowing to **quantify the associated benefits** in terms of grid resilience improvement and so represents a **fundamental step** in the identification of the **optimal portfolio** of **resilience interventions** in an output-based perspective

Technological innovation and **cooperation between TSO/DSO and university/research center** are one of the **enabling factors** to meet the **new challenges arising from climate change**.

Terna
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