Italian National Resilience Plan 2017

For a more reliable grid

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***Abstract* – Global warming, also referred to as climate change, is the observed century-scale rise in the average temperature of the Earth and its related effects. Many scientific studies show that the climate system is warming. In 2013, the Fifth Assessment Report issued by the Intergovernmental Panel on Climate Change (IPCC) concluded that "It is extremely likely that human influence has been the dominant cause of the observed warming since the mid-20th century". The largest human influence has been the emission of greenhouse gases such as carbon dioxide, methane and nitrous oxide.**

Future climate change and associated impacts will differ from region to region around the globe. Negative effects include increasing global temperatures, rising sea levels, changing precipitation, and expansion of deserts in the subtropics. Warming is expected to be greater over the land than over the oceans and greatest in the Arctic, with the continuing retreat of glaciers, permafrost and sea ice. Other likely changes include more frequent extreme weather events such as heat waves, droughts, heavy rainfall with floods and heavy snowfall, ocean acidification, and species extinctions due to shifting of temperature regimes.

Considering the increase in extreme meteorological events related to this global warming, in the absence of preventive actions, climate change is likely to make the national energy infrastructure increasingly vulnerable. Considering this critical situation, the Italian Regulatory Authority for Electricity, Gas and Water System (AEEGSI) asked the Italian TSO (TERNA) and all the DSOs serving a minimum of 50.000 consumers to work jointly for the implementation of the first National Resilience Plan (NRP).

In particular, with Article 37 of Annex A of the Deliberation 653/2015/R/eel and with the Resolution 2/2017 – DIEU "Guidelines for Presentation of Work Plans", the AEEGSI requested that this first NRP should focus on the resilience of the national grid referring to intense ice and snow events of the last 15 years.

With a unique transparent process of involving stakeholders[1] at every step, an ad-hoc round table lead by Terna has been launched to discuss in more details practical approaches, to build common position on specific objectives and the methodology.

On March 2017, Terna successfully released the first version of the NRP structured as follow:

- **The first section provides an analysis of the extreme events of the last years that have caused difficulties in the daily operation of the national transmission grid;**
- **The second section presents the definition of the Resilience of the grid;**
- **The third section reports the main different technological solutions for the resilience increase;**
- **Finally, in the last section, it's described how the methodology is applied and which are the technical solution identified by Terna in each critical area.**

Keywords – Trasmission System Operator (TSO), Distribution System Operator (DSO), National Resilience Plan (NRP), National Electricity Transmission Grid Development Plan (NETGDP), Italian Regulatory Authority for Electricity, Gas and Water System (AEEGSI), Risk Indicator (IRI), Resilience Indicator (IRE), Energy Not Supplied (ENS), Loss Of Load Expectation (LOLE), Return Time (TR), Number of Low Voltage Consumers Not Supplied (NUNS).

I. INTRODUCTION

Climate-related risk management has become a major focus for public opinion as a result of the escalation and intensification of adverse weather events and natural disaster that have led to significant damage of the electrical infrastructure and the occurrence of critical grid situations. Minimizing the impact of these exceptional events and the quickly recovery of the energy supply requires new approaches to make the network more secure, reliable, disruptive and - in the end – resilient. It is therefore key to act on this front, i.e. to implement timely and cost efficient adaptation measures to reduce upstream the risk and to increase the capability of the system to react.

The first National Resilience Plan (NRP) has been implemented in accordance with Article 37 of Annex A of the Deliberation 653/2015/R/eel, published by AEEGSI on December 23th 2015 and modified by the Deliberation 545/2016/R/eel, published on September 29th 2016.

[1] Among which big DSOs, Italian Electrotecnical Committee and Ricerca sul Sistema Energetico (RSE) research center

Moreover, the Resolution 2/2017 – DIEU "Guidelines for Presentation of Work Plans", published by AEEGSI on March 7th 2017, requires that the NRP:

- Shall contain a punctual analysis of the severe weather events occurred in the last 15 years as a basis to detect the most critical areas;
- Shall contain a technical examination, as well an economic cost and benefit analysis, of each identified mitigation action.

Terna is framing the NRP taking into account possible interactions with the National Electricity Transmission Grid Development Plan that is published every year pursuant to the Ministerial Decree of April 20th 2005 and in compliance with the Legislative Decree 93/11 of June 1st 2011.

II. HISTORICAL CRITICAL EVENTS

In accordance with the Deliberation 653/2015/R/eel, the first step of the process to define the NRP consists of analyzing the extreme events occurred in the last 15 years that caused unplanned unscheduled outages of the relevant interconnectors, together with a significant amount of Energy Not Supplied (ENS) to end users. Based on these events, the Terna is to design a number of solutions to increase the resilience of the transmission grid in the identified critical.

In this first release of the NRP, the main focus is on the intense ice and snowstorms that have caused difficulties in the day-to-day operation of the national transmission grid as reported in the figure below.

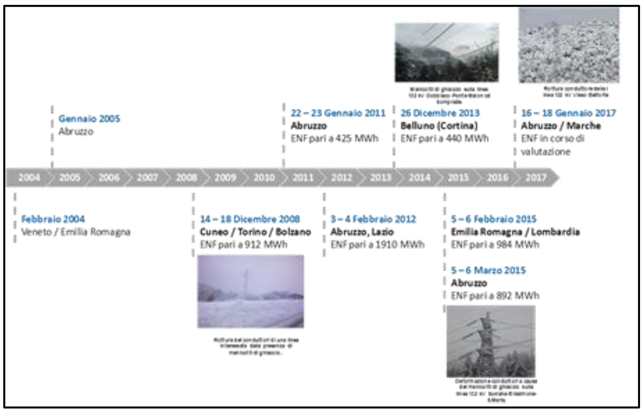

Figure 1 - Main severe events in the last 15 years

Heavy ice and snow falls entail to the formation of ice sleeves around the conductors and may cause breaks' tripping or, in the worst case, the collapse of one or more pylons. The phenomenon of ice sleeves depends on a combination of several factors (e.g. frozen rain, wet snow, humidity and wind speed) which increase the ice sediment around the conductor. This process represents the major reason of conductor collapse, leading to forced asset outages, energy not supplied, inability of available generation resources to meet the customer demand and the operating requirements of the power system and, in the end, lots of impact on the economics.

III. DEFINITION OF RESILIENCE OF THE GRID

The resiliency of the Transmission Grid is defined as the ability of the system to withstand stress situations caused by extreme events (**Functional Safety**) or, in case of temporary disconnection, the ability of recover normal operating conditions in the shortest possible time (**Restoration** and **Survivability**).

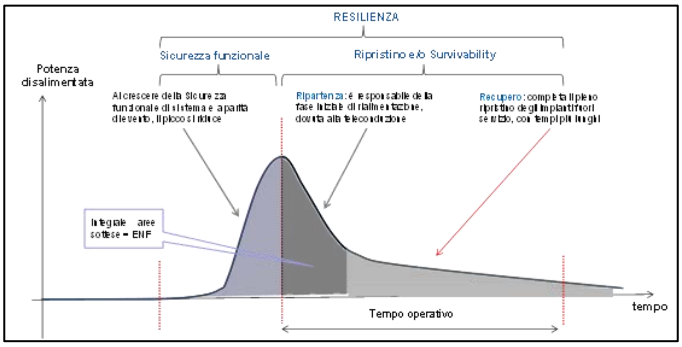

Figure 2 - Phenomenology of a severe meteorological – standard stages of the system state after an extreme event

The Functional Safety, defined as the ability to withstand stress situations caused by extreme events, can be classified into three levels:

- **Functional Plant Safety**: depending on the safety standards of the specific plant;
- **Structural Functional System Safety**: depending on the grid structure (e.g. the meshing of the grid, number of infeed, …);
- **Non Structural Functional System Safety**: depending on the operating procedures and the deployment of suitable devices to prevent/ limit the damages to the equipment and/or to the bulk power grid produced by a severe event.

Referring to *Figure 2*, as the Functional Safety increases, the peak of power non-supplied falls down (y axis).

Restoration is defined as the ability of the Transmission System Operator to come back to normal state in the shortest possible time after the occurrence of a severe meteorological event, meaning that the energy not supplied to the final customers is kept to the minimum. Restoration can be divided into two operational phases:

- The **Reboot**: is the re-energization of the consumers under emergency conditions, without resorting all the network elements and using, albeit limited, the available power grid resources;
- The **Recovery**: it usually follows the Reboot stage and ends with the restoration of the full functionality of the power grid.

Finally, the **Survivability** is defined as the ability to re-energize a consumer, located in a specific grid area affected by a severe meteorological event, employing innovative or non-conventional systems, devices, methodologies, applications or back-up components to interwork in order to perform the required functions, and without resorting to full access to the power grid.

IV. TECHNOLOGY SOLUTIONS

To increase the power grid resilience, it is possible to adopt different options:

- Radical, structural refurbishment of the assets;
- Ad-hoc, punctual mitigation and predictive solutions that help to minimize the effects of severe meteorological events.

Radical structural interventions on the assets

In this field, it is possible to:

1. Rebuild old overhead (OH) lines, preserving their path and the general layout of the project, but improving the mechanical characteristics;
2. Turn, partially or totally, an overhead transmission line into an underground cable, making the electrical system substantially immune to any risk driven by extreme ice and snow events;
3. Realize new transmission lines in order to increase grid redundancy. In this case, planning of new lines must take into account the need for long permitting processes and the public opposition.

Punctual mitigation and predictive solutions

These remedial are meant as “quick-wins” aimed at to forecast the risks related to a potential meteorological event and to mitigate its negative effects on the net.

In this field, the most effectiveness solutions adopted by Terna are:

1. “WOLF Trasm” forecast system. “WOLF” - standing for Wet-Snow Overload aLert and Forecasting - is a wet-snow overload forecast and warning software. The tool is capable to predict the mechanical overload of wet-snow over electric power lines in Italy, calculate the minimum current required for anti-icing and generate different alarms to warn the regional control centers. "WOLF Trasm" represents the evolution of WOLF to allow to compare the predictions of the daily anti-icing currents delivered by WOLF with the real time current flowing on the line;

2. Remote monitoring and alert system. This doing envisages the installation, on the OH transmission lines most exposed to severe meteorological events, of devices for the measurement of weather conditions and for monitoring the conductors’ thermal regime.

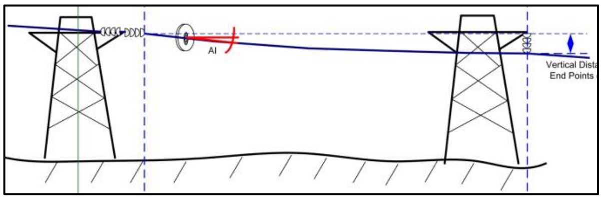

Figure 3 - Remote monitoring and alert system

Such devices - remotely connected to the Terna regional control centers - can forecast the genesis of ice sleeves by analyzing the overloads on the conductors and, thanks to the real-time communication with dispatching centers, allow real-time Operators to implement the most appropriate countermeasures (e.g. topological modification, change of the generation and load pattern, etc. to boost power flow across the line);

3. Anti-rotational devices: the limited torsional rigidity of the conductors is the main cause of formation of cylindrical ice sleeves around the conductor. In fact, when the snow sticks onto the conductor surface, it tends to facilitate the rise of eccentric loads, with consequent rotation of its axis and further growth and consolidation of the ice sleeve.

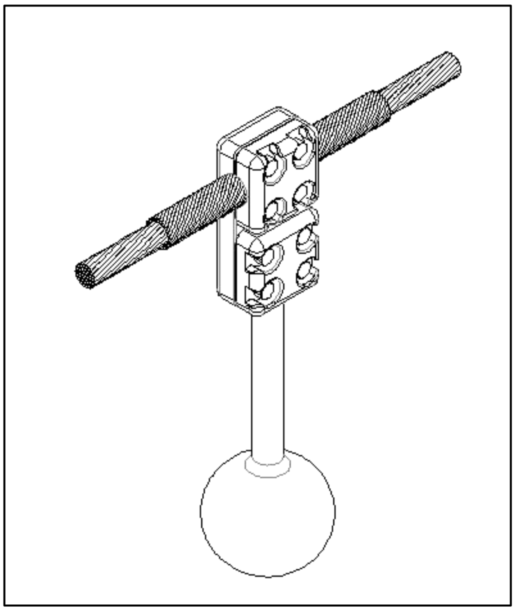

Figure 4 – Anti-rotational device

The deployment of anti-rotational devices strongly increases the torsional rigidity of the conductor on which they are installed, hindering the rotation that is at the basis of the sleeve formation and consolidation;

4. Stabilizer Isolators. The sudden leave of an ice sleeve from a conductor gives rise to a swing effect that reduces the interfacing distances between conductors,

and then leads to the non-self-restoring contact between phases.

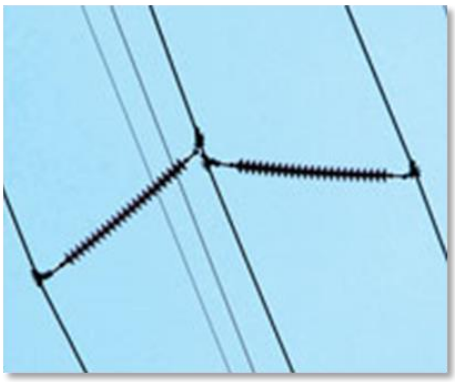

Figure 5 - Stabilizer Isolator

The Stabilizer Isolator (shown in Figure 3) maintains proper interphase isolation between the phases and ensures that safety distances are maintained even in very critical dynamic situations.

5. DC anti-icing devices are based on the possibility to prevent and remove the ice from a conductor simply heating the conductor itself via a direct current (DC) injections.

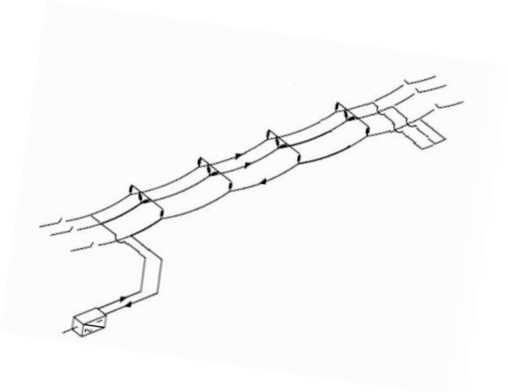

Figura 6 - DC anti-icing device

A similar solution entails the installation of a "ballast loads" (typically reactive, see Figure 7) that heats the conductor thanks to the injection of reactive power.

Figure 7 - Reactive "ballast loads"

6. Cutting down trees. It might happen that, during ice and snow severe storms, the mechanical overloads by the ice over the conductors make them to touch the tallest tree below, thus causing the disruption of the tower. It is therefore important to have continuous monitoring and control of the vegetation growth in and around the line corridor, to prevent plants from entering the interface space of the conductors.

Another possible mitigation/preventive solution work with new "Ice-phobic" coatings capable to reduce the adhesion of water and ice to the conductors. Thanks to these equipment, the ice sleeve has greater difficulties to grow as the water and ice drop away from the conductors.

V. THE RESILIENCE INDICATOR

The Resolution 2/2017 – DIEU "Guidelines for Presentation of Work Plans", published by AEEGSI on March 7th 2017, defines, for the first time in the literature, the *Resilience Indicator* (IRE). In particular, the resilience analysis is based on the *Risk Indicator* (IRI) of disconnecting final consumers. IRI is defined as the product of the probability that an event produces a fault and the magnitude of the damage caused by this fault. The probability of occurrence is defined according to the *Return Time* (TR) of the transmission line, that is the time interval between two following events of a pre-defined minimum climatic event leading to the structural collapse of the line (CEI EN 50341-2-13). Regarding the magnitude of the damage after a fault, it's defined as the *Number of Low Voltage Consumers Not Supplied* (NUNS). Therefore:

$$\mathbf{IRI = NUD/TR}$$

Where

- the fault probability is given by the inverse of the return time TR;
- the magnitude of the damage is given by the number of low voltage consumers not supplied NUNS.

Meanwhile, the Resilience Indicator IRE is defined as the inverse of the IRI:

$$\mathbf{IRE = 1/IRI = TR/NUD}$$

Starting from the calculation of the Return Time of the power lines in a grid area connecting different HV substations (SSs), it's possible to identify the Return Times of each SS. In particular, the evaluation of the Return Time depends on:

- The Return Time of each line that is connected to the SS;

- The structure of the grid near which the SS is located[2].

The probability that a specific SS will not be supplied, is therefore related to the outages of the transmission lines directly connected to the SS, as well as to the unavailability of those electrically close interconnectors which feed the SS.

VI. SOLUTIONS TO INCREASE THE GRID RESILIENCE

According to the methodology described in the previous paragraphs, the TSO can:

- Evaluate the benefits in terms of increase of the resilience of the system for every possible technical solution;
- Prioritize the solutions portfolio.

The first release of the NRP, in accordance with what agree upon in the various working tables with the AEEGSI and major IT Distributors, reports the identified technical solutions for three different areas:

- Bellunese;
- Reggio Emilia;
- Abruzzo and Marche.

The following figure shows the first solutions proposed by Terna in the NETGDP 2017 that will be updated in the next plan.

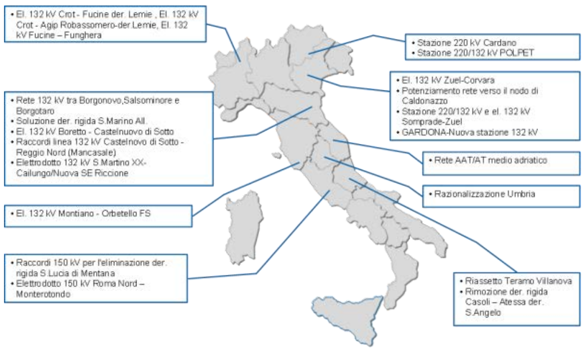

Figure 8 - Technical solutions for increasing resilience of the transmission grid

Each of the detected technical solutions increases the resilience of the grid. Via the application of the methodology described in paragraph V, one can assess such a gain and thereafter prioritize the solutions.

VII. CONCLUSIONS

In the context of the power system, resiliency includes the ability to harden the system against — and quickly recover from — high-impact, low-frequency events. Recent extreme weather events — such as the heavy ice and snow falls occurred in Italy in the last 15 years — have demonstrated the need for resiliency.

This paper describes innovative technologies, strategies, tools, and systems that Terna is developing and applying to address the challenge of resiliency. Enhanced resiliency of the power system will be based on three elements —damage prevention, system recovery, and survivability — each of which has been discussed in detail.

This paper also addresses the challenges put forth the first National Resilience Plan (NRP) that has been implemented pursuant to Article 37 of Annex A of the Deliberation 653/2015/R/eel. This represents the first step toward developing a more comprehensive and cost-efficient action plan aimed at increasing Italian power system resiliency. The next steps are to target all geographical areas in the Country, develop enhanced and up-to dated map of the climatic risks for the national grid, and continue working with the Regulator, large DSOs, research entities, universities, technology providers and other stakeholders to identify current gaps and to better prioritize when building resiliency.

REFERENCES

[1] Deliberation 653/2015/R/eel: http://www.autorita.energia.it/it/docs/15/653-15.htm

[2] Deliberation 545/2016/R/eel: http://www.autorita.energia.it/it/docs/16/545-16.htm

[3] Resolution 2/2017 – DIEU "Guidelines for Presentation of Work Plans": http://www.autorita.energia.it/it/docs/17/002-17dieu.htm

[4] Standard: CEI EN 50341 (EN 50341-2-13)

[2] The purpose of this is to capture the impact on system security resulting from a proper mesh network.