REGULATORY INCENTIVES FOR IMPROVING THE RESILIENCE OF ELECTRICITY DISTRIBUTION GRIDS IN ITALY

Luca LO SCHIAVO
ARERA – Italy
lloschiavo@arera.it

Carlo TURCONI
ARERA – Italy
cturconi@arera.it

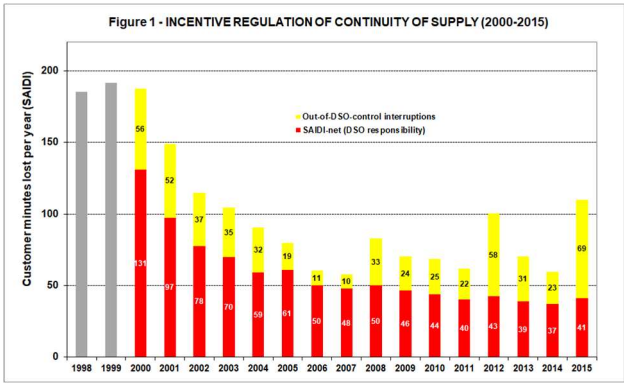
Ferruccio VILLA
ARERA – Italy
fvilla@arera.it

ABSTRACT

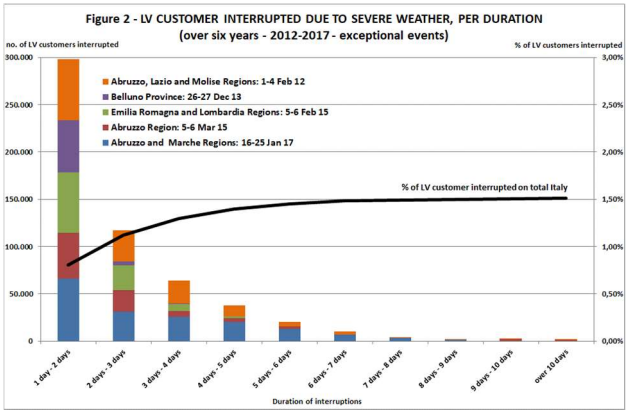
In adopting the regulation for the regulatory period 2016-2023, ARERA (the Italian Regulatory Authority for Energy, Networks and Environment) has paid close attention to electricity grids resilience, and launched a multi-year initiative to increase the resilience of both transmission and distribution grids, intervening on three different aspects: (i) improving network planning in order to better consider the risk of disruptions due to extremely severe weather events, (ii) introducing new incentive schemes aimed at increasing network capability to cope with this kind of events, and (iii) promoting faster supply restoration even under emergency conditions, ensuring appropriate customer protection from very long interruptions. This paper illustrates the above regulatory initiatives, focusing in particular on those relevant for distribution systems.

INTRODUCTION

Since 2000, an incentive regulatory mechanism for Distribution System Operators (DSOs) aimed at reducing SAIDI, and from 2008 a further mechanism aimed at reducing SAIFI+MAIFI[1], have been enforced by ARERA [1]. Figure 1 shows the trend, over the last four regulatory periods (2000-2015) of SAIDI, separating the effect of interruptions considered for rewards and penalties (so called "SAIDI-net"), from the effect of interruptions attributed to force majeure which are excluded from the above incentive regulations. Figure 1 shows that in Italy there has been a noticeable increase in interruptions due to extremely severe weather events, causing very long interruptions of the electricity supply.



During these events, on one hand, structural disruptions of transmission and distribution grids were recorded, due to the overpassing of the design limits of the infrastructures, like for instance : disruptions of overhead lines in bare conductors due to the growth of huge ice sleeves that provoke a mechanical stress beyond the design limits (enforced at the construction time); on the other hand, although DSOs must have their own emergency plan, difficulties in restoring the service under emergency conditions were observed for a series of causes, including those of exogenous nature in respect of DSOs, such as the non-viability of roads (for instance in case of heavy snow events).



From the customer viewpoint, interruptions caused by force majeure can reach a very long duration. Figure 2 shows the number of interrupted low-voltage (LV) consumers in five severe weather events occurred in the period 2012-2017 in relation to the duration of the interruption. The Italian power system has 37 million LV customers: so this is a problem that affects around 1.5% of the whole customer basis in 5 years.

Due to the exclusion of force majeure events from the SAIDI and SAIFI+MAIFI incentive regulations, DSOs were not stimulated to improve the quality of service to those customers that are connected to the weakest portions of the electricity distribution networks and therefore bear the highest risk to be disconnected in case of extremely severe weather. This is the reason why in 2007 ARERA introduced automatic compensations for customer interrupted for more than 8-12-16 hours respectively in urban, suburban and rural areas (8 hours in all areas from 2020 on), *regardless the cause* of the interruption. Compensations (currently, up to 900 € for LV household consumers, in case of an interruption lasting 10 days) are

[1] In Italy MAIFI refers to interruptions with duration from 1 second to 3 minutes.

to be paid either by DSOs/TSO for interruptions (or part of their duration) of their responsibility, or by a mutual fund for interruptions (or part of their duration) due to force majeure. This mutual fund is fed both by consumers, through a minor tariff component (0.875 €/year for LV household consumer) and by DSOs and TSO, according to an indicator of their performance to avoid very long interruptions (yearly interruption duration, of their responsibility, exceeding 8 hours).

THE ITALIAN APPROACH TO RESILIENCE OF ELECTRICTY GRIDS

Resilience of electricity grids has been considered also in the "Italian Energy Strategy" (SEN), prepared and approved in 2017 by the Ministry for Economic Development and the Ministry of the Environment [2], in order to cope with the intensification of extremely severe weather events. According to SEN (that *per se* has no direct effect), grid operators are invited to identify specific investment plans and to define new resilience standards. The recent Integrated Energy-Climate National Plan pays attention to resilience as well [3].

On the regulatory side, in cooperation with the Government's address, ARERA has investigated how to increase the resilience of electricity grids according to two aspects: on the one hand, increasing network robustness by raising, where economically sustainable according to a risk evaluation, the design limits that identify the infrastructural capability to withstand extreme stresses; on the other hand, improving the effectiveness and promptness of recovery, i.e. the system's capability to return to acceptable working condition, even by means of temporary measures.

For example, for an electric distribution system exposed to snowfall with "ice sleeves" along the bare conductor of the overhead power lines, increasing network robustness can be performed by raising, to an economically sustainable level, design limits of stress in relation to loads caused by ice and wind. Temporary re-powering could happen, for example, supplying electricity through mobile power generators installed in areas where the network has been damaged due to stresses exceeding design limits, until full recovery of the electric supply.

It is important to emphasize that increasing resilience cannot be limited to increasing network robustness, as a system with high resilience entails higher costs (that increase beyond proportion to the expected increase in network robustness). These higher costs might not be justified in relation to the benefits that can be obtained, provided that it is possible to estimate these benefits with a sufficient level of confidence. Therefore, the overall performance of the system's resilience can be improved only by means of an adequate balancing of actions, aimed at improving both network robustness and system recovery capability.

The regulatory objective has been to setup a range of incentive mechanisms, not only financial but also reputational, which are consistent with (i) the twofold component of resilience, thus insisting not only on increasing network robustness but also on improving efficiency and promptness of service restoration, (ii) the need to limit as far as possible the overlapping of effects among different incentive mechanisms, in particular those that are already in place for the continuity of supply, aimed at improving SAIDI-net and (SAIFI+MAIFI)-net indicators, due to DSOs' responsi-bilities, and (iii) the perspective of ever increasing integration of tariff and quality regulation, projected towards a "forward-looking" approach that will consider increasingly both the investment plan for network development and network management activities (medium-term business plans).

Finally, for the purpose of identifying measures to increase the grid robustness, ARERA has promoted the coordination between the Italian TSO and major DSOs (in Italy, the first 5 DSOs cover around 95% of the whole customer basis), so that they can work to select most efficient solutions, according to a "whole system approach": in a given area, the structural reinforcement should be carried out on the distribution network or on the transmission network, and not blindly on both networks, in order to allocate capital resources paid by the tariff in the most efficient way, avoiding a dangerous dispersion of resources.

RESILIENCE PLANS FOR DISTRIBUTION GRIDS

With Decision 31/2018/R/eel [4], ARERA introduced, after a wide consultation process [5], the obligation for major DSOs (directly connected to the national transmission grid - altogether 28 DSOs serving 99.3% of the Italian consumers), to prepare and publish every year - as part of their Network Development Plans – their own "Resilience Plan", a rolling three-year plan of investments selected by each DSO to increase the robustness of its own distribution grid. Robustness represents the capability of distribution system to cope with several risk factors due to exogenous conditions, for instance: ice sleeves on overhead lines in bare conductors [6]; heat waves that cause breakage of junctions in underground cables; flooding of distribution substations caused by heavy rains or by floods of watercourses; very strong wind.

Investments correspond to a plurality of projects, each one referring to a distribution line, with the possibility of being extended to its own back-feeding line(s) too.

Each project must be identified, among other parameters, by forecasted costs, estimated benefits, and by expected starting and completion dates.

Benefits must be estimated by DSOs mainly as lower customer outage costs thanks to the highest network resilience that can be obtained through the project under consideration; this benefit is valuated using regulatory values for avoided interruptions (12 €/kWh not supplied

for household consumers and 54 €/kWh[2] not supplied for the commercial and industrial consumers), and a given duration of interruptions, assessed looking at interruptions occurred in emergency conditions: 16 hours for damages to overhead lines and 8 hours for underground cables[3]. Other minor benefits have been considered as well.

In order to assess the improvement in probability and magnitude of damages occurring due to extremely severe weather events impacting on the distribution circuit(s) involved in each project, ARERA has focused its attention on the concept of risk index (IRI). The risk index is given by the ratio between the number of consumers benefiting from the project (NUD) - which measures the impact or damage of a disservice - and the return time of the event (TR - given by the inverse of the annual probability that a disruption occurs for a given specific risk factor). This approach is functional to the merit selection of most cost-beneficial projects that can increase the grid robustness, in relation to the various risk factors. Each DSO shall first identify risk factors relevant for its own network and then define resilience-aimed projects on the basis of its own technical, economic and financial assessments, using as much as possible common risk analysis methodologies.

Despite an enormous effort of study and harmonization carried out in the 2016-18 period, DSOs are currently identifying resilience-aimed projects to increase grid robustness through the application of not fully homogeneous risk analysis methodologies yet, even in relation to the same risk factor (for ice sleeves, see [7]).

The activities of risk analysis and identification of resilience-aimed projects by DSOs make use of the implementation by the Italian Research Institute for Energy (RSE – *Ricerca sul Sistema Energetico*) of a dataset of meteorological reanalysis relating to the period 2000-2018 and to the entire Italian territory, with a spatial resolution of 4 km and resolution time of 1 hour [8]. This dataset allows, in the final analysis, to correlate with good accuracy the impact of the various risk factors that occurred from 2000 to the actual behavior of the electricity grid.

In Table 1 are shown investments of the five major DSOs (serving 95.5% of the Italian customers) included in their Resilience Plans 2018-20, for each considered risk factor: 525 M€. To give an idea of the commitment that DSOs intend to make, it is useful to underline that in Italy the annual level of investments in the electrical distribution (excluding metering) reaches about 1,400 M€ in 2017, of which around 670 M€ for distribution lines.

Table 1 – Investments in resilience 2018-20 with any ratio benefits/costs

Risk factor	Resilience plans 2018 – 2020		
	No. of beneficiary LV consumers	Discounted benefits (k€)	Discounted costs (k€)
Fall plants on overhead lines for too much snow	24.773	16.763	3.221
Heat waves	3.517.392	252.627	114.419
Heavy rains or flood of watercourses	143.024	71.968	17.645
Ice sleeves	1.277.253	903.872	389.718

In Table 2 are shown investments of the same DSOs included in their Resilience Plans 2018-20, for each considered risk factor, but selecting only resilience-aimed projects with ratio benefits/costs > 1 (that account for 254 M€ in three years). This means that 271 M€ of investments have ratio benefits/costs < 1. As evident, investments of Table 2 are included in investments of Table 1.

Table 2 – Investments in resilience 2018-20 with ratio benefits/costs > 1

Risk Factor	Resilience plans 2018 – 2020		
	No. of beneficiary LV consumers	Discounted benefits (k€)	Discounted costs (k€)
Fall plants on overhead lines for too much snow	24.773	16.763	3.221
Heat waves	1.954.506	233.949	37.781
Heavy rains or flood of watercourses	142.309	71.070	16.174
Ice sleeves	919.217	843.019	196.518

FINANCIAL INCENTIVES FOR IMPROVING DISTRIBUTION GRIDS ROBUSTNESS

With Decision 668/2018/R/eel [9] - after a two-round consultation process [5][10], technical meetings with DSOs and the Italian TSO, and cooperation with RSE – ARERA introduced an incentive mechanism aimed at improving the resilience of electricity distribution grids, applicable to the Resilience Plans prepared by DSOs according to Decision 31/2018/R/eel.

The incentive mechanism is "bilateral" because it can provide both rewards and penalties; it has a duration of 6 years and is focused on resilience-aimed projects, defined by DSOs in their Resilience Plans, whose completion date is between 2019 and 2024.

All projects[4] with TR "pre-intervention" lower than 50 years, regardless of their cost-benefit ratio (387 M€), are eligible to penalty in case they are not committed within the expected completion time (with 1 semester max delay allowance). Resilience-aimed projects with TR "pre-intervention" lower than 50 years that show a ratio benefits/costs > 1 (222 M€) are eligible both to penalty and to reward. The reward for a resilience-aimed projects is

[2] Substantially, same values as used to size rewards and penalties in SAIDI and SAIFI+MAIFI incentive regulations (updated to 2016 prices).

[3] Values deriving from continuity data communicated by DSOs to ARERA in relation to the extremely severe weather events occurred in the period 2012-17, excluding the interruptions restored within 1 hours since their occurrence (i.e. interruptions solved in ordinary conditions).

[4] Projects related to protection and automation systems are excluded from the incentive mechanism.

equal to 20% of the positive net benefit (equal to benefits minus cost) and is recognized to the DSO if the date of completion of the project has been respected. The reward is halved in the event of a delay of one semester in project completion.
The penalty is due for a delay of at least two semesters in completing the project: for a delay of two semesters the penalty is equal to 10% of the final cost of the project; for a delay of three semesters or more the penalty is equal to 25% of the final cost of the project. In this case the DSO shall prepare also a detailed report on the causes of the delay, on the actions taken to recover this delay and on any extra costs that derive from the delay. This report must be sent to the ARERA and to the Ministry granting the distribution licenses (Ministry for Economic Development) and must be published on the website of the DSO, on the Resilience Plan publication page.
For each of the two 3-year period 2019-21 and 2022-24, an ex-ante cap on rewards is set, equal to 25% of the estimated costs of all resilience-aimed projects whose expected date of completion falls in the correspondent 3-year period.
Further, the reward recognized for a project is halved if, in the five years following the completion of the project, only one interruption of at least 8 hours occurs in the portion of grid object of project, due to the same risk factor because of which the project was conceived and carried out.
The cancellation of the total penalties for each one of the three-year periods 2019-21 and 2022-24 is envisaged, in case projects whose dates of actual completion coincide with the estimated completion dates cover at least 90% of the customers (NUD) beneficiary of all projects considered in the incentive mechanism.
The estimate of the maximum tariff impact related to the incentives to increase the robustness of the Italian distribution grid is currently possible only on the basis of the Resilience Plans for the three years 2018-20 sent to the ARERA in June 2018 by the five major DSOs. On the basis of these Resilience Plans, and in the hypothesis that the subsequent plans have the same consistency of the 2018-20 Resilience Plans already presented, ARERA estimates that net rewards (rewards minus penalties) could reach, in the case of maximum compliance, about 92 M€ over a three-year period (less than 1 €/customer per year). This amount corresponds to the cap to rewards above explained and is expected in the hypothesis that the five major DSOs carry out all the projects exactly within their planned schedule and, for this reason, penalties are not imposed.
For comparison purposes, it is interesting to highlight that the tariff impact of SAIDI and SAIFI+MAIFI incentive mechanisms from 2000 to 2015 has been around 2.5 €/customer per year (ranging between 1.5 to 3.9 €/customer per year in single years), and that the average allowed revenue per customer for the distribution service (metering excluded) is around 125 €/customer per year.
An issue still left open, but which is very important for ARERA, is the additionality of investments to increase the robustness of the grid compared to the historical investment trend. In other words, DSOs should demonstrate an extraordinary investment effort in a limited period to gain access to the incentive mechanism. Since the consensus was not reached with DSOs during the consultation process, ARERA intends to start a strict monitoring of investments for renewal of the network, and reserves the faculty to define new regulatory accounting obligations for recording and reporting these investments, both in physical and economical units, in order to allow ARERA to make its own specific evaluations on the topic of additionality.

EFFECTIVENESS AND PROMPTNESS OF THE RESTORATION SERVICE

As already mentioned above, the second pillar of system resilience refers to supply restoration (after the occurrence of interruptions), in other words the capability of the system to return to an acceptable operating state, even with provisional measures, in an effective and prompt manner.
After the introduction in 2007 of guaranteed quality standards on the maximum duration of the interruptions, with automatic compensations for affected customers regardless the cause of the interruption, ARERA has introduced new regulation to make network operators more responsible in restoring the service. With Decision 127/2017/R/eel [11] the regulator established that network operators (DSOs and the TSO) have to be charged of compensations to customers who suffer particularly long interruptions (see the introduction of this paper) for the duration exceeding the initial 72 hours, up to a maximum of 10 days, even if the interruption is originally caused by *force majeure*. The above rule does not apply if DSOs are impeded to restore the service for reasons of workers' safety or because a prohibition coming from a public authority.
Furthermore, with the consultation document 645/2017/R/eel [5], ARERA has proposed further rules, aimed at fostering a quick restoration service even under emergency conditions. The main objectives behind these rules are:
a) reward the pre-warning readiness in case of forecasts, even in the short term, of possible severe meteorological events, in order to minimize the service restoration times in case of effective occurrence of the meteorological phenomena;
b) reward the ability of grid operators to deploy and organize resources in the best way (eg: means of clearing roads from snow, amphibious vehicles usable in the event of flooding); this means to reward the availability of specialized resources in the territory affected by a given risk factor, in the hours immediately following the occurrence of the interruptions;
c) foster greater coordination with the institutions responsible for crisis management and with other essential local public services dependent on the electricity service.
ARERA intends to pursue the above objectives identifying

"qualified actions" aimed to rapidly restore the supply, according to four criteria [12]:
- *risk reduction*: minimizing the risk, for example through targeted exercises and/or simulations in coordination with the relevant Institutions, in addition to specific communication campaigns to users;
- *readiness*: intervening promptly, integrating DSOs activities with the Civil Protection organizations, using weather forecasts for 2-3 days;
- *response*: managing the emergency in the best way, updating the information (eg: estimated time to resume the service) to users via radio/smartphone channels or other means for which battery-powered terminals are sufficient, using distributed generation for operation in intentional island, using unconventional means to clear roads in case of snow or to access to electricity installations in case of flooding;
- *recovery*: verifying the activities carried out, by publishing a report on the event containing first evaluations of improvement of the recovery procedures following the success, carrying out a survey on the satisfaction of the managers of other public services impacted.

The incentive mechanism for rewarding qualified actions has still to be defined in detail; an important aspect is to prove that such qualified actions are additional initiatives for resilience, in respect to those already contemplated by the current Emergency Guidelines [13].

CONCLUSIONS AND NEXT STEPS

The regulatory initiatives on system resilience are a expected to be a powerful boost for ensuring the reliability of the electricity grid in face of the changed climate conditions that have been particularly evident in recent years because of the occurrence of weather events that are becoming increasingly severe.

In this regard ARERA has paid great attention (i) in avoiding overlaps with the financial incentive mechanisms already in place, in particular with those relevant to continuity of supply (SAIDI and SAIFI+MAIFI), and (ii) to the perspective of ever increasing integration of tariff and quality regulation, in the frame of a forward-looking regulatory approach that will consider also time and cost forecasts made by grid operators in their investment plans and business plans.

Further, the Italian standardization body for electricity (CEI – *Comitato Elettrotecnico Italiano*), has been mandated by ARERA to carry out the activities of harmonization of the risk analysis methodologies - initially developed by DSOs for many risk factors - aimed at the publication of overall Guidelines, without prejudice to the concepts of IRI, NUD and TR illustrated above.

Consistently with the above viewpoints, ARERA intends to develop two further incentive mechanisms:

i) the first one aimed at improving the robustness of the national transmission network; the implementation of this regulation should be facilitated by experience cumulated by Italian TSO with the preparation and publication of 10-years Network Development Plan of the national transmission grid and with Cost/Benefit Analysis for assessing development projects [14][15];

ii) the second one, aimed at promoting greater effectiveness and promptness in the service restoration by the DSOs, once the interruptions have occurred, after further deepening of the concepts illustrated above.

REFERENCES

[1] ARERA, Decision 22 Dec 2015, 646/2015/R/eel.
[2] Ministry for Economic Development (MiSE), Ministry of the Environment (MATT), 2017 Italian Energy Strategy.
[3] MiSE, MATT, Ministry for Transport Infrastructure [MIT], Integrated Energy-Climate National Plan, January 2019.
[4] ARERA, Decision 25 Jan 2018, 31/2018/R/eel.
[5] ARERA, Consultation paper 21 Sep 2017, 645/2017/R/eel (Chapter 1 “Context and overview” available in English).
[6] Italian Standardization Body for Electricity (CEI), CEI EN 50341-2-13:2017, “Overhead electric lines with voltage higher than 1 kV in a.c. Part 2-13: National Normative Aspects (NNA) for Italy (based on EN 50341-1: 2012)”.
[7] e-distribuzione and CESI, “Resilience enhancement of MV distribution grids against snow storms”, CIRED 2019, Paper no. 1618.
[8] RSE, M. Lacavalla, R. Bonanno and S. Sperati, “Realization of a high-resolution meteorological reanalysis dataset for the study of relevant weather events for the Italian electrical system”, Deliverable RdS 18000345, PAR 2017.
[9] ARERA, Decision 18 Dec 2018, 668/2018/R/eel.
[10] ARERA, Consultation paper 20 Sep 2018, 460/2018/R/eel.
[11] ARERA, Decision 9 Mar 2017, 127/2017/R/eel.
[12] Ministry of Civil Defence & Emergency Management (New Zealand Government), “Lifeline Utilities and CDEM – Directors’s Guideline for Lifeline Utilities and Civil Defence Emergency Management Groups [DGL 16/14]”, June 2014.
[13] Italian Standardization Body for Electricity (CEI), CEI 0-17 “Guidelines for the preparation of emergency plans for electricity distributors”.
[14] ARERA, Decision 4 Nov 2016, 627/2016/R/eel.
[15] TERNA, Attachment A-74 to the Grid Code.

DISCLAIMER

The opinions expressed in this paper are only the personal opinions of the authors; they do not necessarily represent the official position of ARERA and do not commit ARERA to any course of action in the future.