



APE

APPUNTI DI ENERGIA

Blackout: Is Spain Far Away?

September 2025

The Calm After the Media Storm

In newspapers, news "ages" at the speed of light, and so the general public has almost forgotten, at least in our country, **the blackout that paralyzed the Iberian Peninsula on April 28th.**

Not so for industry professionals, who, after carefully examining official communications and following expert posts discussing causes and responsibilities, are now evaluating the adequacy of the initial **countermeasures** undertaken by the Spanish grid operator and regulatory authority, while awaiting the final results of the **investigation commission** established by ENTSO-E, the organization of European transmission system operators (TSOs).

ENTSO-E - European Network of Transmission System Operators, comprising 40 TSOs from 36 countries across Europe.

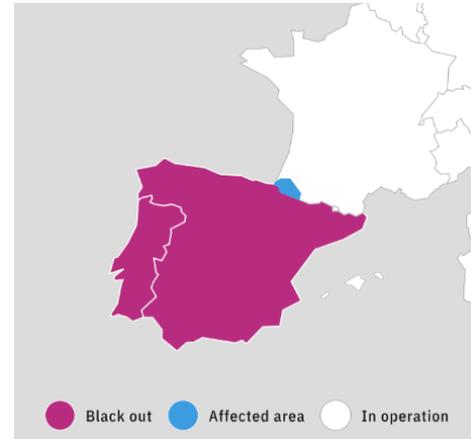


Figure 1 : Iberian Blackout

An "Epochal" Incident

Yes it is, because, as has been rightly emphasized, this is **the first blackout to occur in an electrical system managed with a very high share of generation from non-programmable renewable sources**, i.e., a system with characteristics quite different from the traditional one.



The incident can therefore represent a wake-up call for the entire continental Europe and, more generally, for other electrical systems with similar characteristics.

It is important to identify causes and circumstances that led to the disruption in order to evaluate whether the criticalities, and therefore the mitigation interventions to be implemented, can be confined to the Iberian Peninsula (particularly Spain) or must have a broader scope.

Multiple Factors (and Responsibilities)

The documents released so far - the reports of the Spanish governmental committee and TSO, the information published by ENTSO-E with frequent updates - have allowed for the formation of a **coherent picture**.

It is important to always keep in mind that:

(1) the organization, structure and phenomena that govern the management and functioning of the electrical system are much more **complex** than the plot of a sophisticated and thrilling detective story. Nevertheless, a few weeks after the incident, there was an unprecedented sequence of "plot twists" on phenomena that played a key role, and still some aspects **have not been completely clarified or sufficiently emphasized**; the Government Commission report

(2) as has been correctly highlighted, events like the Iberian blackout are not the result of an unfortunate isolated circumstance, but of **numerous contributing causes** and **concurrent vulnerabilities** that start from far away: not a single culprit, therefore (renewable sources, conventional generators, grid operator, regulatory authority; in the background, the same interconnected network at continental level), but **distributed responsibilities** among different parties and important criticalities to be addressed with a collaborative and systemic approach.



- ENTSO-E
- Government Commission report
- Red Eléctrica
- Lo Schiavo, Delfanti

The Electrical System



RSE View

Before entering into detail about what happened in the Iberian Peninsula on the day of the blackout, we report here some basic information on the functioning of electrical systems, necessary for a better understanding of what occurred.

The **electrical system** is a **very complex** reality: geographically extended, seat of physical phenomena and processes that evolve on different time scales, from milliseconds (and less) to hours. It is fundamentally composed of generators (including storage systems), networks at various voltage levels (particularly distinguishing two types: transmission, at the highest voltage levels, which in Europe is **interconnected** at continental level, and distribution, at lower voltage levels, which operates at local level), user facilities. To this are added infrastructures and systems for monitoring, control, protection, defense...



Figure 1: European continental network: one large 'synchronous' area from Portugal to Turkey, from Estonia to Malta, with an offshoot extending to North Africa (source: ENTSO-E). The main inter-area oscillatory modes discussed below are highlighted.

A Dynamic Equilibrium

In the electrical system, **instant by instant**, the balance between **generated power and consumed power** must be guaranteed: a sensitive indicator of this balance is the **frequency** of the network, regulated thanks to a complex control architecture that acts on generators to maintain the quantity within a narrow band around the reference value of 50 Hz (in Europe and many other parts of the world). Frequency is a "**global**" quantity of an **interconnected** system in alternating current: in an ideal stationary situation it has the same value in all nodes.

The other fundamental quantity is **voltage**, regulated by generators or other devices. Voltage varies node by node and its control has a more **local** impact.

The introduction of **non-programmable renewable sources** and the contextual **reduced presence of conventional generators** introduce additional **complexities** in electrical system management: **adaptations** and new **solutions** are needed that are gradually being implemented at operational, technological, regulatory, and policy levels.

Network, Rules and Services

In the liberalized electrical system, like the European one and other countries, generators (and load) operate according to market rules, while the **network**, which is recognized as a **natural monopoly**, is granted to an **operator** (for transmission called *Transmission System Operator*, in Italy Terna). In accordance with regulatory body provisions, the TSO sets technical connection **rules** and **manages** the system by arranging appropriate control interventions in normal, emergency and blackout recovery conditions, both on network components and on facilities connected to it (particularly generators). The objective is to guarantee the **quality** and **security** of supply in an **economically efficient** manner, appropriately controlling operational quantities (frequency, voltages, currents) according to current or expected conditions, also taking into account the most probable failures. For this purpose, operators use "**services**" (such as frequency and voltage regulations) generally provided by conventional generators.

Network Codes and new Scenarios

Services are defined and specified in **network codes**: these were created when the generation fleet essentially consisted of large thermoelectric and hydroelectric plants, while non-programmable and distributed generation (e.g., photovoltaic) was negligible, so that, considering also technical-management aspects, no particular requirements were imposed on it.



With the growth of photovoltaic and wind generation, which also involves the decommissioning of many conventional plants that provided regulation for system operation, **service needs have changed**. It has become necessary to adopt a new approach, with a process that is still ongoing: network codes place increasingly stringent **requirements** on non-programmable renewable generation plants **in support of system stability**, which would otherwise be increasingly difficult and expensive to guarantee; at the same time, regulation progressively "opens doors" to **new resources**, also distributed and not only generation but also load, for participation in service provision.



Terna



ARERA

Focus: voltage

Voltage in an electrical system must be controlled within predefined intervals (typically within $\pm 10\%$ of nominal value), for correct equipment operation and to guarantee active power transfer. Voltage is regulated primarily by **conventional generators**, whose activation has lead times from a few minutes (hydroelectric plants) to hours (large thermoelectric plants). **Network devices** such as synchronous compensators, inductive or capacitive reactor banks, static compensators (SVC) are also used, whose activation is immediate. Generation connected with **inverters** (as in wind and photovoltaic plants) also has the potential to control voltage, although under current rules its use is limited. In alternating current systems, voltage is closely related to **reactive power** "injected" or "absorbed" by generators, user plants, devices dedicated to voltage control, but also by transmission lines, which present different behavior depending on the flows passing through them:

- A **lightly loaded ("discharged") network tends to "generate" reactive power** with the consequence of inducing **high voltages**: devices in voltage regulation must then "absorb" reactive power to contain voltage itself; the opposite happens in a heavily "loaded" network. With equal generation and load, the more the system is "**meshed**", with many lines connected to each other, the more these will be "discharged" and contribute to raising voltage.
- During low load hours, transmission operators reduce network meshing, so that lines are more loaded and do not generate too much reactive power, or rather absorb it. In any case, "de-meshing" is implemented only when needed as it reduces redundancy and can make the network more vulnerable in case of failures.



Reactive power (Mvar)

Active power (MW)

A key element in the Iberian blackout is precisely the lack of involvement of unconventional plants in voltage control.

Reactive power is a component of electrical power that 'comes and goes': it does not produce useful work and contributes to grid losses; but it is unavoidable, 'like beer foam'.

Focus: oscilla- tions

Oscillations are called *electromechanical*, because they involve the *electrical quantities of the network and the mechanical quantities (speed) of the generators*. An analogy is found in *mass-spring systems in which masses oscillate relative to each other*. The masses represent the *inertia of the generators "consistent" with each other as they are located in highly meshed areas of the system*; the springs correspond to *transmission corridors*

In the circumstances of the Spanish blackout, two oscillations occurred, one extended to the continental system along the west-center-east axis, the other of more limited extent.

Oscillation countermeasures take priority in the control room.

The electrical system is **interconnected** between various countries, for supply security reasons (reserve sharing for **mutual assistance** between networks) and commercial reasons (**exchanges in the free market**). The other side of the coin is that disturbances originating in one area can **propagate** to other areas. Not only that, but in extended electrical systems, in case of high power transfers, "**slow**" **electromechanical oscillations** can establish themselves, with frequencies below 1 Hz, involving electrically (and geographically) distant areas: these are **interarea oscillations**. These manifest mainly with oscillations of power flows and voltage values along electrical corridors and with frequency oscillations in peripheral areas.

- Oscillatory behavior can be triggered by disturbances or appear spontaneously. The **modes** of oscillation (which describe which groups of generators oscillate with respect to which others, with what frequency and phase shift) and their damping depend on system characteristics, particularly the network, inertia distribution, operating point (injections and power flows), generator control systems.
- Persistent oscillatory phenomena are **potentially very dangerous** as they can cause disconnection of generation units and/or opening of connections, followed by cascading loss of remaining connections with potentially disruptive outcomes on a global scale. For an oscillation not to be dangerous, it is necessary that it has a high **damping**, i.e., it dissipates quickly. Various oscillatory modes are known in the continental system, particularly involving east-center-west and north-south areas (Figure 2), usually well damped.

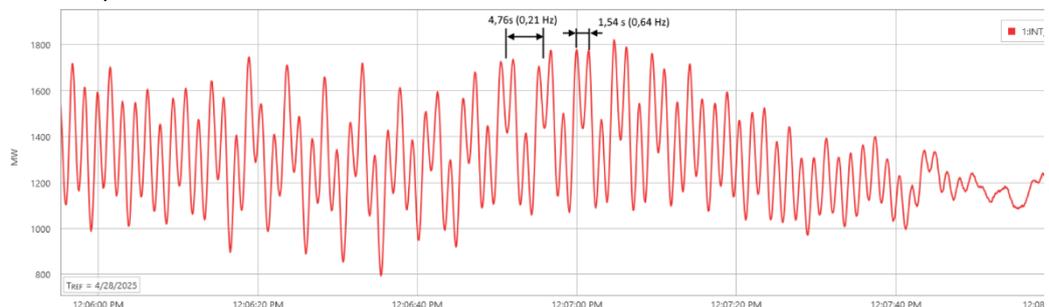


Figure 2: Power oscillations between Spain and France between 12:06 and 12:08 on 28 April 2025. The continent-wide oscillation, at 0.21 Hz, is superimposed on the more circumscribed one, at 0.64 Hz (source: Red Eléctrica)

Beyond interarea oscillations, **local (intra-area) oscillations** can manifest, faster than the previous ones (frequency of 1 Hz and above), mainly affecting one or a few plants that "drift" with respect to the rest of the system.

How are oscillations countered?

- In real-time operation, by **reducing power exchanges** between involved areas and **increasing network meshing** (line connection).
- With special control functions of conventional generators, called **Power System Stabilizer, PSS**. These are effective only if **tuned to the specific frequencies of oscillations** they must mitigate, so they may require updates. Devices interfaced with converters (DC links, non-programmable renewable generators, static compensators) can also be equipped with similar functions, but this solution is not yet very widespread and could be more exploited.
- To count on a global and robust solution to the problem, it is necessary to wait for the realization of **PSS-type systems fed in real time with "wide area" measurements**, i.e., on a continental scale. These are complex innovative measurements, of which few applications exist so far, including in Italy.

Today, interarea oscillations remain a **very feared** phenomenon, both for the scope of possible consequences and for the limits of control tools available.

Oscillatory problems increase with the dimensions of the interconnected system.

The European continental system, which also includes the Italian peninsula and Sicily networks, was extended to the **Baltic countries** in February 2025, completing a *roadmap* started in 2018-2019. Previously, in 2022, **Ukraine** and **Moldova** have been connected. Turkey's network has been part of the synchronous area, that also includes Italy (except Sardinia), since 2015.

The extension of interconnection is fundamental from a **political** point of view and for ever greater **integration of interested countries** in the European context, as well as to guarantee them greater **security** of supply; however, it poses new **challenges** to the stability of the continental electrical system, particularly in terms of interarea oscillations.

Every extension of the synchronous area is always preceded by thorough evaluation phases, first through extensive **simulations**, then with experimental **tests** of interconnected operation.

- To **simulate the oscillatory stability** of an electrical system, especially when wanting to expand the network or optimize control systems, complex dynamic models are used. These, however, are difficult to set up due to the **network dimensions** and **data uncertainty**. Moreover, oscillations depend greatly on the specific network configuration, connected components, and the system's **operating conditions**: these vary increasingly compared to the past due to high penetration of non-programmable renewables and the electricity market.
- In the electrical system, **poorly damped oscillations** can therefore occur, especially in unexpected operating situations or due to malfunctions of power plant control systems.



Identity Card of the Iberian Blackout

The summary of events is based on the sources 'linked' throughout the document

- Day and time of start: **April 28, 2025, 12:33**
- Extension: **Spain, Portugal** and a small area of France at the border with Spain
- Lost load: on the order of **30 GW**
- Transmission network restoration: **at 00:22 on April 29 in Portugal, around 4 am in Spain**. Supply in Spain was reactivated for 99.95% by 7 am and completed by 11 am.
- Particular signs: it occurred due to "**cascade**" interventions of protections due to **high voltages**, in turn induced by **countermeasures adopted to face interarea oscillations**, in a context of **scarcity of resources for voltage regulation**.

Context



- Voltage management problems on the Spanish transmission network, particularly for containing high values, have been known for years, with the consequence of a growing number of generator disconnection episodes: in January they caused the loss of the Almaraz II nuclear plant.
- A few days before (April 16, 22, 24) significant overvoltages manifested with consequent disconnections of generation plants.
- In the operation programming carried out the day before, several conventional plants were declared out of service for April 28: Red Eléctrica called into service for the blackout hour **only 11 conventional generators**, the year's minimum, concentrated mostly in the north of the country, while the majority of renewable plants is located in the south.
- In the day-ahead market (hourly) and in the intraday market (quarter-hour), the central hours of the day showed energy **prices** straddling between **positive and negative**. Energy demand was low and was covered for **about 80% by renewable sources** (of which about 55% from photovoltaic).

Events



- Initial situation of energy **export** from Spain to France, Portugal and Morocco.
- From 9 am on April 28, **atypical voltage variability** begins in Spain and Portugal, more marked from 10:30 but without violations of operational limits. The Spanish TSO explains this variability with the variation of generation mix and demand, exchange with abroad and adjustments in balancing; it rather highlights low voltages (for the 400 kV network, reductions of magnitude up to about 10 kV). Other sources instead detect fluctuations already with high voltages, especially after the exit from service of combined cycle generation plants.



Figure 3: Node voltages at 400 kV in the south of Spain from 9 a.m. to 12 noon. The operating limits in Spain are set in the range between 380 kV and 435 kV. (Source: Government Commission report).

- Before 12, particularly at 05:49, 8:52, 10:30, 11:06 and 11:23 according to the Spanish Commission report, low-intensity oscillations around 0.2 Hz occur, which dampen without recourse to particular interventions by the Spanish TSO.

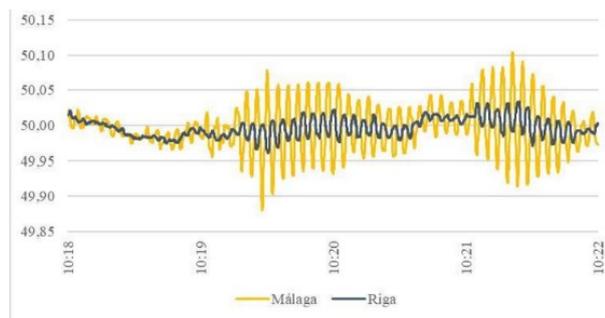


Figure 4: Frequency oscillations between Spain and Latvia on the morning of 28 April (source: GridRadar cited in INESC TEC, 'Retrospective and Lessons from a blackout', 7 May 2025).

- From 12:03 to 12:07, **an oscillation** of the northeast zone with respect to the southwest zone is triggered in the Iberian Peninsula, at **0.64 Hz**. It is a "forced" oscillation, i.e., induced by an external source (a **photovoltaic plant** in Spain, according to REE). **Simultaneously**, an **east-center-west interarea oscillation** at **0.21 Hz** of the **European continental system** presents itself.

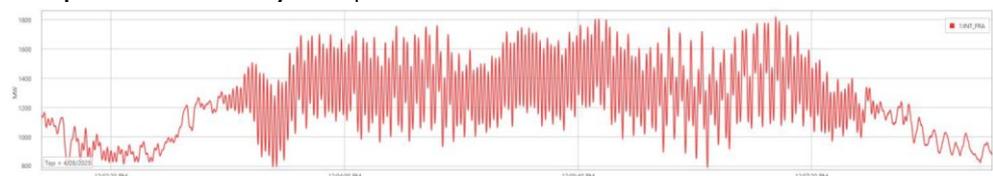


Figure 5: Spain-France power exchange between 12:02 and 12:08 (source: Red Eléctrica).



- To dampen the oscillation, **control room operators** of TSOs implement protocol measures: network topological maneuvers to **increase meshing**, switching the control mode of the France-Spain **direct current** connection (HVDC) to "fixed power", **reduction of export** from Spain to France, deactivation of inductive reactors to raise voltages, initially with low minimum values during oscillation.
- According to the reconstruction of Spanish TSO Red Eléctrica - REE, at 12:16 the 0.6 Hz oscillation reappears, with the consequence of still low minimum voltages. **A second oscillatory phenomenon, this time of the interarea type at 0.21 Hz, reappears between 12:19 and 12:22**: the Iberian Peninsula oscillates coherently with respect to the rest of the continent.
- The phenomenon is addressed similarly to the previous case. In particular, the increase in meshing has the collateral effect of **raising voltages** throughout the network, however without violations of operational limits.

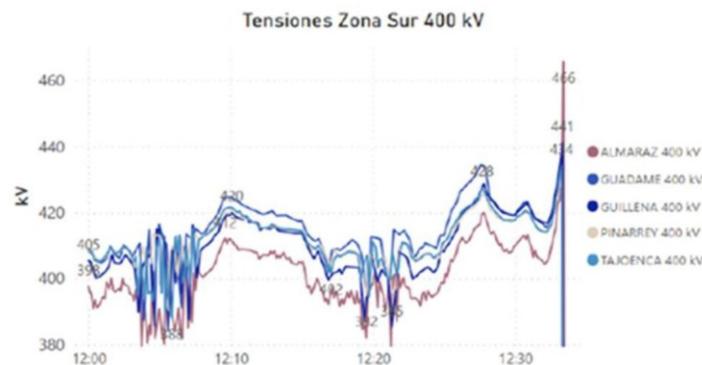


Figure 6: Voltages at 400 kV nodes in southern Spain from 12:00 to 12:33. In a context of high variability, disturbances can be observed at 12:03 and 12:19; finally, a very steep ramp starting at 12:32 occurred, leading to the blackout. The operational limits in Spain are set within the range of 380 kV to 435 kV. (Source: Report by the Spanish Government Commission)

- Around 12:32 (already from 12:22 according to REE) **voltages begin to rise** again, in conjunction with the decrease in export to France. Among possible causes, still to be verified, ENTSO-E lists: (1) the lesser contribution of reactive power absorption by generation groups controlled at constant power factor, which reduced production to reduce export to France; (2) the greater production of reactive power by transmission corridors, which were progressively lightened (particularly from southern Spain to France); (3) a growing contribution of reactive power from distribution networks. This could be related to the **loss of distributed generation** hypothesized by Red Eléctrica in its blackout report.
- At 12:32 and 12:33, seconds apart from each other, **generation losses** occur in the regions of Granada, Badajoz and Seville, for a total shortage of 2200 MW. The first event (355 MW) is due to the intervention of an overvoltage protection of the secondary winding (at lower voltage) of a collector transformer of several renewable generation plants (photovoltaic - PV -, wind, solar thermal type). The second event again concerns the loss of renewable generation (PV, solar thermal) in two 400 kV stations, for 720 MW; the third is a "distributed" event of generation loss in different areas for over 1100 MW.
- The rest happens in a few seconds:
 - a "**domino effect**" is triggered whereby each new generation loss, caused by high voltage, leads to future voltage increase, with consequent loss of additional generation for the same cause;

- **frequency declines**, "synchronism" with the rest of the continental system is lost and protections of interconnections with France and Morocco intervene to separate the networks. At this point **the Iberian network is isolated**;
- meanwhile **automatic load shedding** for underfrequency has begun, provided by the defense plan: the intervention occurs correctly, but is ineffective given the cause of the problem, indeed tends to further increase voltage in a now irrecoverable situation;
- at 12:33:24 "**zero voltage**" is recorded, a slang expression to indicate the **blackout**.

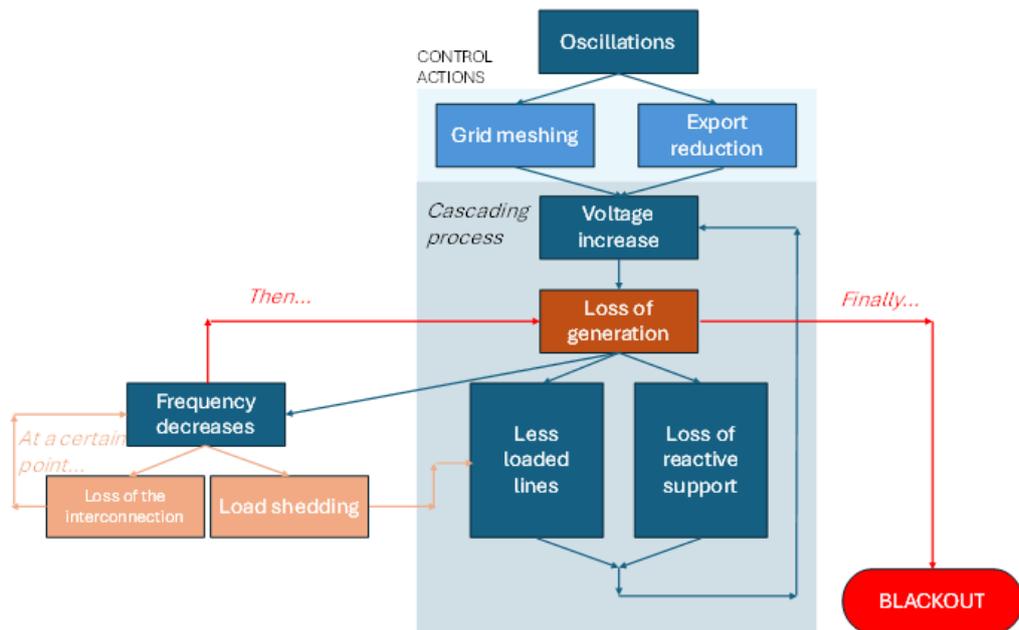


Figura 7: Outline of the blackout mechanism.

- The **restoration** of the system was then based on **refeeding** from French and Moroccan systems, as well as on the activation of **autonomous start-up** generation resources (black start). At 00:22 on April 29, transmission network restoration was completed in Portugal, around 4 am in Spain. There were difficulties, also due to the failure of telecontrol systems, so technicians had to go to stations to perform maneuvers, lengthening times.

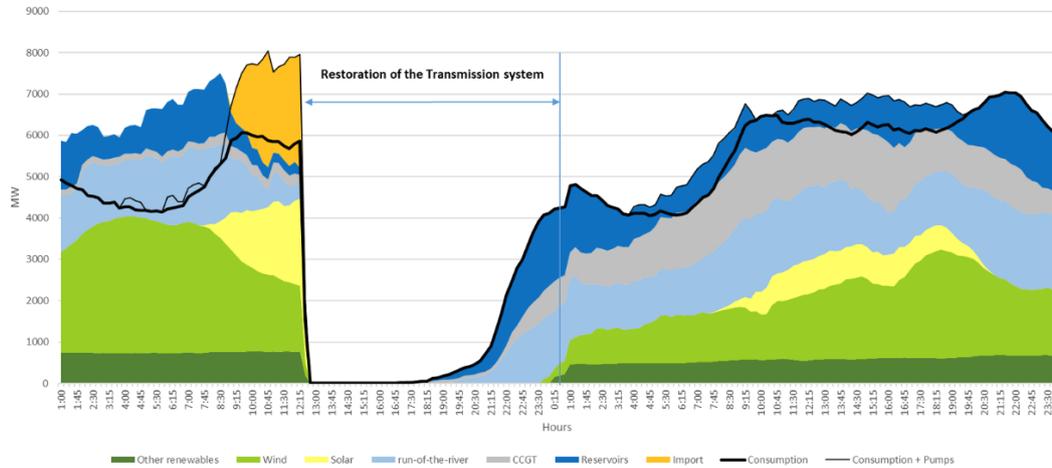


Figure 8: Generation and load trends in Portugal, 28-29 April (source ENTSO-E).

The System's "Flaws"

The TSO

Photovoltaic Plants

Conventional Plants

- The security criterion typically applied in the ENTSO-E system is the so-called "N-1", according to which the system must be able to withstand the loss of any single component without violations of operational limits, instability or load loss. The Spanish operator states that in the day-ahead predictive analyses the criterion was guaranteed. In reality, what occurred was the **almost simultaneous loss of three significant generators**, well beyond the reference disturbance. On the other hand, the plant losses have a systemic nature attributable to a **lack of voltage support**: this refers back to the responsibility of the Spanish TSO, which however found itself facing an unforeseen oscillation situation as a priority.
- The Spanish TSO did not consider activating, in support of voltage, replacement generation for a plant declared out of service the day before, despite the operation forecast being similar to the previous days. Similarly, it is not clear why, shortly before the blackout, control room operators requested the start-up of combined cycle plants, not considering a hydroelectric plant that would have had much shorter start-up times.
- At the **planning** level, perplexities arise about the fact that REE has not implemented significant interventions in recent years to increase voltage controllability, in the face of an increasingly critical situation.
- A **malfunction** in the control system of a **photovoltaic** plant is indicated as responsible for triggering the 0.64 Hz oscillation to which the 0.21 Hz one was superimposed.
- Photovoltaic plants, like other non-programmable renewable sources such as wind, in Spain **are not required to directly regulate voltage** but only the power factor, i.e., with a reactive power contribution proportional to the active power delivered. This does not guarantee adequate voltage control (the new regulation will allow it).
- It seems that some renewable plants (generally not only photovoltaic) **disconnected before time**, compared to the connection prescriptions in force.
- The Spanish TSO report also points the finger at the behavior of conventional plants: according to REE, some **would not have performed voltage regulation according to prescriptions**, particularly the voltage variability in the period preceding the event would be attributable to inadequate dynamic response. Moreover, **untimely disconnections** of plants would have been recorded: connection rules impose both voltage values within which operation must be without time limits, and values within which operation must be guaranteed for a certain time interval before disconnection from the network. This

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interval would not have been respected.

- Another key aspect is that of **distributed generation protection thresholds**. According to the current regulation, disconnection from the network of generation at voltage levels below 110 kV can occur after just one second from exceeding 110% of nominal voltage. This limit has long been updated in the regulations of other countries, including Italy.
- The network has a fundamental role for efficient electrical system management, to guarantee security even before commercial exchanges. Operating an extended **interconnection** like the European continental one is increasingly complex, and regional centers for security coordination are active within ENTSO-E.
- Phenomena like **interarea oscillations** remain among the most **dangerous**. In the reconstructions of the Iberian blackout published so far, the oscillations that appeared before the disruption have not been analyzed in detail. The figures on oscillatory modes preceding the blackout, reported by ENTSO-E, show only the western part of continental Europe: an extended representation would offer a more complete vision of the phenomenon. Certainly the question deserves investigation.

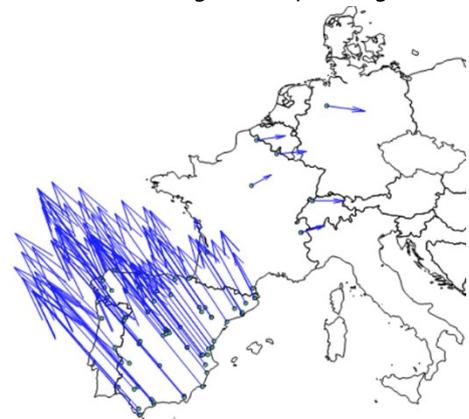


Figure 10: Mode of the second oscillation phenomenon prior to the Iberian blackout (source: ENTSO-E).

**The
 Regulator**

- In light of the blackout, an important responsibility of the Spanish regulator (CNMC) concerns the delay in approving the **revision of the operational procedure** (P.O. 7.4), which would have allowed the expansion of resources for voltage regulation. The revision had been ready for some time and was approved shortly after the blackout.
- Red Eléctrica draws attention to a problem that touches the regulatory sphere: when it is necessary to reduce generation for real-time balancing needs, the network operator must choose according to a national merit order in which renewable generation and conventional generation are placed on the same level. From the active power point of view this is correct, but this rule does not take into account the different behavior with respect to voltage control in force until now, which in the blackout scenario had the effect of increasing voltages in southern Spain.
- In its report on the outage, the Spanish TSO points out another operational issue related to photovoltaic plants. While not directly linked to the blackout, it falls within the regulatory framework and should be reviewed. Photovoltaic generation is known to enter and exit production based on energy prices. Specifically, photovoltaic generation stops producing when prices turn negative and resumes production when prices become positive again, with intervals dictated by the temporal granularity of the market itself. **Power variations** by photovoltaic plants, associated with **program variations** of production, **are problematic for system operation**, because they occur too quickly compared to conventional generator timings, with potential risks for frequency stability and significant voltage excursions. The Spanish TSO therefore hopes that these variations occur at longer intervals. From a technical point of view, this can be achieved with appropriate plant *retrofitting* interventions.

Counter-measures

- The new **operational procedure P.O. 7.4** was approved by the Spanish Regulator on June 12. It extends participation in voltage-related services to all technologies; it also introduces a market service for voltage support, penalties for non-compliance with obligations, zonal markets for additional reactive capacity. Implementation, however, will occur with times on the order of a year.
- The **Spanish government** has proposed an **anti-blackout package** that includes, among other things, strengthening regulator functions and requiring REE to modify standards and procedures, implement storage systems also hybridized with generation plants. However, the path is bumpy, a first proposal that also contained renewable development measures and to protect energy-intensive companies was rejected: the new proposal of July 2025 is a modified version that maintains the above-mentioned elements.
- The **Portuguese government** presented a package in July 2025 that provides, among other things, for doubling autonomous start-up capacity (black start), developing a national plan for storage, increasing real-time monitoring systems, reinforcing interconnections and identifying suitable areas for renewables.
- As for operating measures, from the days following the disruption **REE has kept more conventional plants running**. This has guaranteed greater voltage stability, but affects system operating costs.

Is Italy Like Spain?

If the Spanish electrical system is considered a large-scale "laboratory" for renewable sources, it is true that Italy has also reached high penetration levels of such sources. However, there are also profound differences.

A strong "shock" to the management of the **Italian electrical system** came from the **2003 blackout**. That event taught much and gave the "impetus" to promote projects and processes that have allowed strengthening system reliability to date: to name a few, monitoring systems, more in-depth security analyses, coordination procedures with operators, plant performance verification, field restoration tests. Naturally, since then **the system has strongly changed**, particularly non-programmable innovative sources were practically non-existent: the network operator and regulator of Italy must be recognized for not having underestimated the criticalities posed by the decarbonization of the system in progress and for having acted in time and with broad-ranging interventions, such as the distributed generation retrofitting campaign to adapt their protection systems.

- To give some examples, beyond network development interventions, Terna has been conducting for years a campaign of installation of **synchronous compensator**, machines capable of **controlling voltage**, providing **fault currents** as in conventional generators (necessary for voltage stability and correct protection operation) and contributing to system **inertia**.

Other voltage control devices have been deployed alongside compensators, including capacitor banks and power electronics-based devices like **STATCOM**. Terna has also planned several additional grid measures to support system stability.

- Terna's **network code** (Annex A.17 on wind plants, Annex A.68 on photovoltaics, Annex A.79 on electrochemical storage systems, connected to high voltage; Annex A.70 on distributed generation) provides stringent connection requirements: for wind, photovoltaic and storage connected to transmission, requirements include the possibility of **controlling voltage and frequency**; for all plants, precautionary **protection** logics for the system are provided.
- With the introduction of the **Integrated Text of Electrical Dispatching (TIDE)** (ARERA resolution 345/2023/R/EEL), the network code is being revised to allow participation in service provision by new resources, previously not enabled, and to evolve the services

Zero risk does not exist, yet in many respects Italy appears to be much better equipped than Spain...

... as well as the systems to cope with fluctuations.



Terna's grid development plan

themselves (also based on the results of pilot projects promoted under ARERA resolution 300/2017/R/eel), to increase security.

- The use of generators identified by Terna as "**essential for security**" remains important to guarantee stability (including voltage) where it is not possible to find sufficient resources with market mechanisms. In perspective, taking into account both network investments and the involvement of new resources, expensive use of essential generators is expected to decrease.
- Also regarding **frequency** stability, numerous initiatives at the level of connection rules are to be noted, also for distributed generation, as well as new services such as Fast Reserve designed to face the loss of regulation by conventional plants.
- And **oscillations**? **Italy, somewhat like Spain, is peripheral** with respect to the continental electrical system and subject to interarea oscillations. For this reason, the network operator has provided, and partly already installed, various structural interventions, including devices such as synchronous compensators and others. Not only that, but some **systems for oscillation mitigation** have already been implemented, based on measurements made in real time at remote points of the system. These are advanced applications, whose effectiveness has already been demonstrated and which will be further extended and enhanced in the future.
- To conclude the overview, a look at the "intensity" of network **investments** compared to those in renewable capacity: Italy clearly ranks first, Spain last.

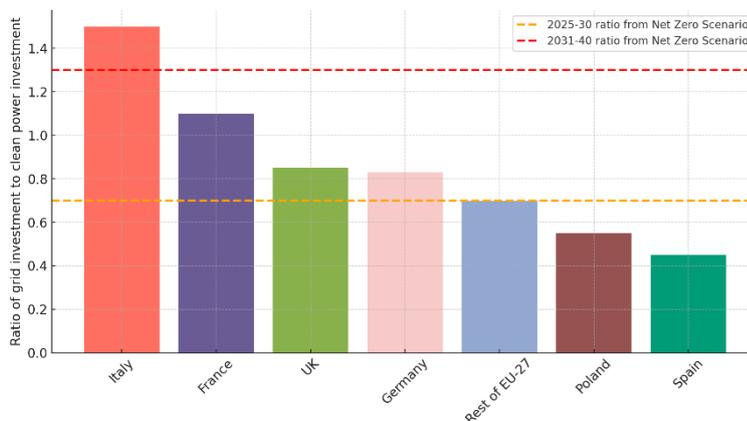


Figure 9: Grid vs. renewable energy investments in European countries. Dashed lines show the expected ratios for Europe in Net Zero scenarios (based on BloombergNEF 2025, cited in P. Ruiz and C. Hutters, "Facts and lessons learned from the Iberian blackout", Rabobank, 22 May 2025)



Rabobank

Open Perspective

Today's electrical networks must face increasingly complex challenges due to the growing integration of renewable sources, extreme weather events and other multiple contingencies. These factors introduce a high degree of uncertainty, which can lead to potentially critical situations for system stability and reliability.

To best manage these challenges, it is fundamental to adopt a more robust approach. The **introduction of probabilistic methods** to quantify and analyze risks in all phases of electrical system management, from **long-term planning** to **real-time operation**, marks a significant innovation. While still at the research stage at RSE, these methods are beginning to see initial experimental implementation by TSOs.

ENTSO-E's analysis of the Iberian blackout is not yet concluded, and new surprises may emerge. One thing is certain: the electrical system is in profound evolution and will require in the coming years to rethink many of the concepts, criteria and practices that we considered consolidated until recently, thanks also to the fundamental contribution of research.

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