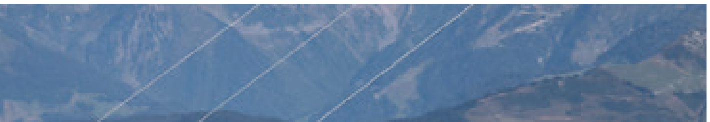
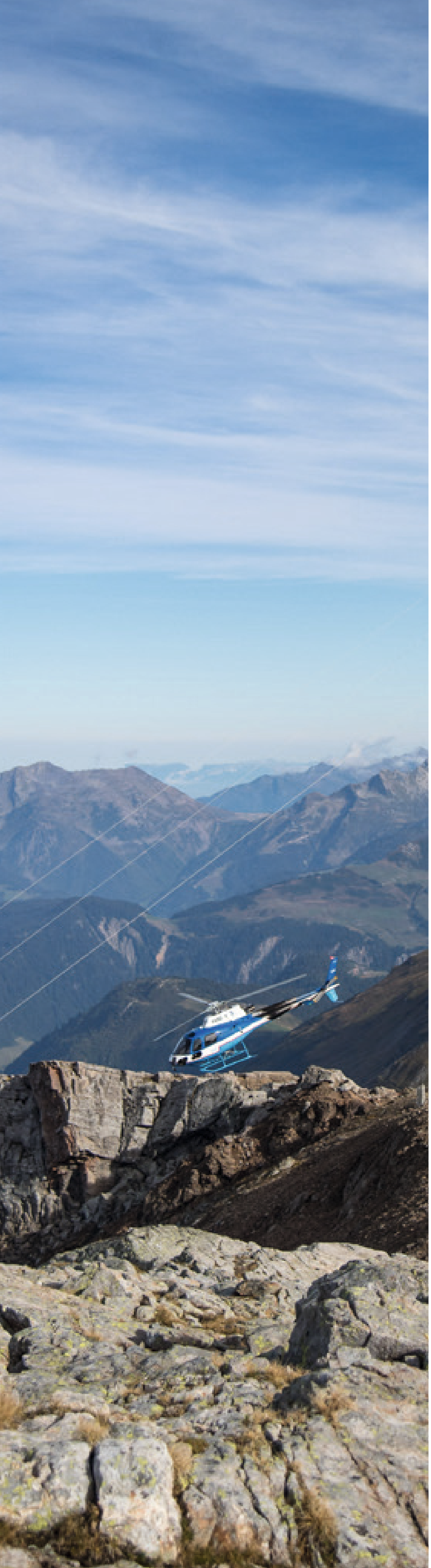
Le réseau de transport d'électricité

SAFETY REPORT

2024





Contents

1 Summary

The operational safety of the electricity system

RTE is responsible for ensuring a balance at all times between electricity production and demand, for carrying electricity flows from producer to consumer, and for managing exchanges between France and neighbouring countries. “Guaranteeing system safety” means controlling changes and reactions of the electricity system in response to the different hazards it may face (short-circuits, unforeseen changes in consumption or generation, unexpected unavailability of production or transmission installations, etc.) and doing so whatever the impacts on the electricity system of electricity market operations. More specifically, the aim is to determine in advance the countermeasures to these potential hazards, and to minimise the risk that the physical parameters governing electricity system operation (frequency, intensity, voltage) will deviate from operating ranges considered to be risk-free and heighten the risk of power outages.

The management of the electricity system is governed by a body of French and European rules.

System safety is defined as the ability to:

- Ensure normal system operation (keeping frequency, voltage, intensity and short-circuit levels within normal ranges) in nominal conditions and in the event of standard hazard conditions.
- Minimise the number of incidents and prevent major incidents in the event of adverse hazard conditions.
- Minimise the consequences of major incidents when they occur, particularly in the event of highly adverse hazard conditions.

RTE produces a safety report every year, under article 28 of the public transmission system grid-concession specifications (approved by the Decree of 23 December 2006).

This report on the operational safety of the electricity system is drawn up by examining:

- The Significant System Events (SSEs) that have occurred during the year and which reflect the operational safety of the electricity system;
- The management of operating parameters:
  - Supply-demand balance (SDB) and its impact on frequency control,
  - Flow intensity and control,
  - Voltage control,
  - The management of transient phenomena, and the operation of the Defence and Restoration Plan;
- The information and telecommunications systems needed to operate the electricity system;
- The company’s organisation.

2024 WAS MARKED BY AN INCREASE IN THE NUMBER OF COMPLEX CONDITIONS, BOTH IN TERMS OF THE FLOWS OBSERVED IN THE TRANSMISSION SYSTEM (WHICH ARE RISING) AND IN TERMS OF MARGIN PROVISION, PARTICULARLY DOWNWARD.

On the one hand, high generating fleet availability combined with stable consumption levels resulted in high export levels and, on the other hand, changes in the European energy mix led to new cross-border trading patterns that can give rise to cross-zonal transit flows in France.

Analysis of key indicators for the year reflects a satisfactory level of electrical system safety:

- **The number of Significant System Events (SSE) remained stable in 2024** compared to 2023[1]. Since 2017, there has been an upward trend in the number of SSEs, which has slightly more than doubled between 2017 and 2023.

- **2024 saw a rise in the number of recorded level-B SSEs,** a phenomenon that is examined in the chapter covering the highlights of the year 2024.

IN 2024, THERE WAS POSITIVE DEVELOPMENT IN SUPPLY-DEMAND MANAGEMENT AND FREQUENCY CONTROL (IN TERMS OF SECURITY OF SUPPLY) OWING TO SIGNIFICANT PROGRESS IN THE CAPACITY OF VARIABLE RENEWABLE ENERGY SOURCES (RES) TO MODULATE GENERATION IN RESPONSE TO MARKET CONDITIONS. HOWEVER, THE MANAGEMENT OF OVERPRODUCTION (WHICH GIVES RISE TO EPISODES OF NEGATIVE SPOT PRICES) MUST BE A FOCUS OF ATTENTION FOR BOTH SUPPLY-DEMAND BALANCING AND FOR THE ELECTRICITY SYSTEM AS A WHOLE.

For some years now, the French electricity system has experienced frequent shortfalls in the procurement of automatic frequency restoration reserves used in real time to control frequency (frequency-power system services). These shortfalls in automatic reserves, which are aligned with ever greater changes to the cross-border trading schedules between France and its neighbours, impact the quality of frequency control in France, which has deteriorated over the last two years (16 SSEs linked to frequency deviations in 2024 and 19 in 2023, versus an average of around 4 for the period 2017-2022).

RTE is taking various steps jointly with the authorities and with stakeholders, in France and in Europe:

- **Developments in the rights and responsibilities of RES generation,** so as to ensure their fullest contribution to supply-demand balancing and safe operation of the network (management of electricity flows, system services). Market mechanisms and contractual arrangements for network access must continue to bolster this development in order to tap into the flexibility reserves and services offers of the different contributors, in coordination with the distribution system operators.

- Measures to guarantee **adequate supply-demand margins, for both upward and downward margin provision,** and to improve the quality of frequency control (certification of new reserve capacities such as storage systems and distributed energy aggregators, the establishment of European exchange platforms, etc.).

1. Excluding low-level events (level-0 SSEs)

THE EXISTING INFRASTRUCTURE ENSURED EFFECTIVE CONTROL OF THE ELECTRICITY SYSTEM'S STABILITY AND ITS OPERATING ELECTRICAL PARAMETERS THROUGHOUT 2024, THOUGH SPECIAL ATTENTION MUST BE PAID TO HIGH-VOLTAGE CONTROL. FURTHERMORE, THE MANAGEMENT OF FLOWS CLOSER TO REAL TIME IS INCREASINGLY COMPLEX AND NOW BRINGS INTO PLAY BOTH THE CHALLENGE OF INSTANTANEOUS PRODUCTION/CONSUMPTION BALANCING AND THE CHALLENGE OF NETWORK FLOW CONTROL (WHEN IN THE PAST, THESE TWO STRANDS COULD BE MANAGED RELATIVELY SEPARATELY). THIS FURTHER HEIGHTENS THE NEED FOR RTE TO TAKE EARLY ACTION ON THE BASIS OF RELIABLE INFORMATION PROVIDED BY MARKET PLAYERS, MAKING IT EVER MORE IMPORTANT FOR MARKET CONTRIBUTORS TO ENSURE EFFECTIVE AND RELIABLE DELIVERY TO RTE OF THEIR GENERATION SCHEDULES.

With regard to intensity and the management of transit flows

The changes in the French and European energy mix are giving rise to greater flow variability in terms of location, direction and intensity. This means in particular that power flows come close to permissible levels in installations, which can create flow constraints. In 2024, the number of cases of power flows temporarily exceeding permissible levels in RTE installations remained within the average seen in previous years (2017-2023).

The Spanish border is a special area of focus: energy exchanges between France and the Iberian Peninsula continued to be substantial, and the loads on installations in the area (at interconnections and in 400 kV and 225 kV upstream networks) have often come close to operating limits.

Against a background of works, particularly in the installations close to the Swiss and Italian borders, complex operating conditions also required exceptional measures to guarantee the safety of the electricity system.

With regard to voltage

There were no challenges for low-voltage management in 2024, though it is a longstanding focus of attention in western France (and notably in Brittany) during winter periods, owing to production shortfalls in some areas and thus significant electricity flows between production areas and consumption areas.

The two automatic protection schemes against voltage collapse that were installed in the 2010s were therefore not activated in 2024.

In contrast, following a sharp increase in 2023, the number of breaches of high-voltage limits remained high in 2024 against a background of low consumption combined with structural changes in the electricity system (underground installation of distribution networks, increasingly decentralised electricity generation, constraints due to the local unavailability of installations or production facilities). However, no SSE was recorded for a voltage breach beyond the established scope of the operating policy.

RTE is proceeding with its power compensation installation programme to further improve control of high voltage: 590 MVAR of inductors (voltage-drop inductors) were thus connected in 2024, in addition to those installed for reactive power compensation of offshore connections. The study conducted by RTE in 2024 to update voltage compensation requirements nationwide by 2030 showed that this pace of investment needs to be maintained. In its 2025 network development plan (SDDR), RTE set out a strategy for reinforcing voltage compensation systems in certain parts of the country, entailing substantial investment.

The ongoing measures to develop the contribution to voltage control of production facilities connected to distribution networks also underpin the safety of the electricity system. On 23 June 2025, RTE presented market players a preliminary package of measures supplementing the 2025 SDDR, which included a section on the provision of voltage services by market participants.

With regard to system stability, dynamic phenomena, and network restoration capacity

In compliance with existing operating rules, specific situations required early action from RTE to decrease the output of certain nuclear reactors or modify the cross-border exchange programmes (countertrading) in order to prevent the onset of dynamic phenomena (local stability issues and inter-zone frequency oscillations at European level). These phenomena have given rise to Europe-wide studies.

Islanding procedures for nuclear units, whether scheduled or unplanned (due to an event either on the grid or on the unit itself), show a success rate in line with expectations defined jointly with the nuclear operator.

RTE IS DEVELOPING ITS SYSTEMS, AS WELL AS THE STRUCTURE AND ORGANISATION OF ITS OPERATING ACTIVITIES, WITH A FOCUS ON MAINTAINING AND ENHANCING SYSTEM SAFETY.

RTE's new SCADA[2] system for grid operation and supply-demand balancing became fully operational in October 2024 (StanWay system).

Since the spring of 2024, this new system has also provided input to network studies tools.

RTE is continuing to renew and develop its telecommunications networks, and to strengthen the cybersecurity of its infrastructure.

Lastly, RTE pressed on with organisational change and opened the second of 3 Electricity System Operation Centres (COSE). The setting up of these control centres, which will replace the 7 existing regional control rooms, is designed to streamline the organisation while improving advance and real-time response capacity, and refining the interactions between focal areas.

RTE IS PURSUING AND STEPPING UP ITS SAFETY-FOCUSED COOPERATION WITH EUROPEAN COUNTERPARTS.

Cooperation between transmission system operators and coordination centres in Europe is ongoing, underpinned by the implementation of the services stipulated in European regulations.

Throughout 2024, RTE and its European partners carried out assessments of the Moldovan TSO's (Moldelectrica[3]) compliance with European regulations. And 2024 also saw preparations for **the connection of the Baltic States to the Continental Europe Synchronous Area (completed in February 2025).**

Cooperation continues at a European level, with high expectations for system safety, as well as for the network code aiming to establish a European regulatory framework for the development of flexibility markets in Member States.

2. Supervisory Control And Data Acquisition
3. Moldelectrica joined ENTSO-E as an Observer Member at the end of 2023.

2 The operational safety of the electricity system

Every year, RTE evaluates the system's operational safety by recording **Significant System Events (SSE).** They are classified on a scale of severity from 0 and A to F. These events encompass incidents resulting from diverse causes. Though it has more gradations, RTE's classification is comparable to the Incident Classification Scale (ICS) put forward by ENTSO-E, with its four levels of severity.

Monitoring SSEs over several years gives a breakdown of low-level events (severity classification 0) and events with an impact on safety (ranging from severity classification A, for a localised, single and controlled incident, to classification F, for a widespread incident). It provides a measure over time of the effectiveness of the actions taken to improve the operational safety of the electricity system.

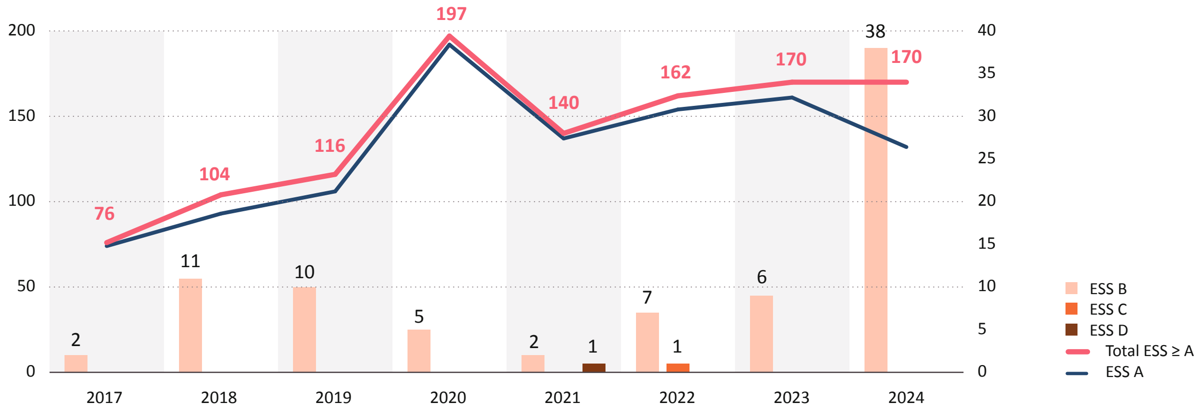
SSEs are classified by category:

- System Operation: events associated with grid operation (compliance with the regulations governing the management of flows, voltage and stability, and risk control), supply-demand balancing (margin monitoring and frequency control) and network restoration.
- Network: events affecting the availability of transmission system infrastructure (substations, connections, voltage compensation mechanisms).
- Control Systems: events impacting communication systems or tools that influence system operation (observability in the electricity system, SDB management, network studies, secure communications systems).
- Generation: events attributable to a generating unit (management of secure communication systems and implementation of safeguard actions).
- Distribution: events attributable to a distribution system operator (DSO), relating to the management of secure communication systems and the implementation of safeguard actions.

With 170 events classified as A or B, 2024 was characterised by a stabilisation in the number of Significant System Events (SSEs) compared with 2023, following an overall upward trend since 2017 (aside from 2020, which was an atypical year):

- In total, the number of level-A SSEs decreased in 2024 compared to 2023. Given that around 50 level-A SSEs in 2023 were linked to industrial action during the spring, **the number of level-A SSEs has risen, particularly in the System Operation category.**
- **There were more level-B SSEs in 2024 than the previous year** (38 compared to fewer than a dozen per year for the period 2017-2023) of which 23 **related to flow** (versus 3 in 2023) and 6 **to stability** (versus 0 in 2023) **issues**.

FIGURE 1 – TREND IN SSES WITH A SEVERITY CLASSIFICATION ≥ A



2024 was marked by:

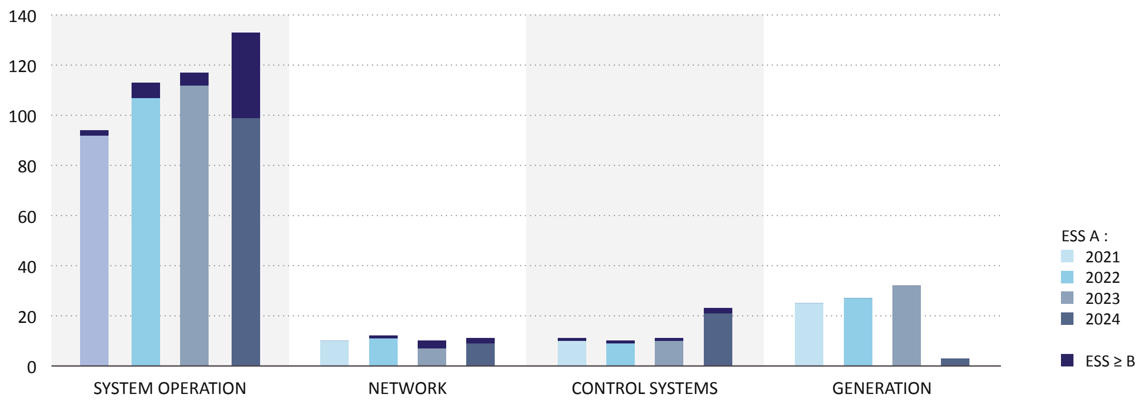
- System constraints caused by high export levels, compounded by network maintenance work;
- The growing complexity of frequency control, in particular during periods of negative spot prices;
- Improved controllability of RES generating units in response to shortfalls in downward margin provision, for supply-demand balancing (SDB).

These conditions highlighted underlying trends that have been observable for several years now, which may ultimately constitute a risk to the safety of the electricity system. These trends amount to:

- **More complex supply-demand balancing,** calling for the development of new flexibility mechanisms;
- **More complex management of the voltage plan** linked to the reduction of withdrawals from the transmission system caused by the dual effect of a drop in consumption and the growth in RES connected to the distribution network.
- **The variability of flows in terms of direction and intensity:** changes in the production mix of European countries are altering electricity flows within France and across the European power grid, leading in particular to increased exchanges between Northern and Eastern European countries and Southern and Western European countries, owing to the complementary nature of their production mixes. Depending on trading patterns, some countries, such as France, may be particularly involved to managing cross-zonal transit flows.

Although the number of SSEs remained stable, the 2024 breakdown by event category (System Operation, Network, Control Systems, and Generation) shows significant differences compared to previous years.

FIGURE 2 – CATEGORISATION BASED ON THE SSE CLASSIFICATION SCALE

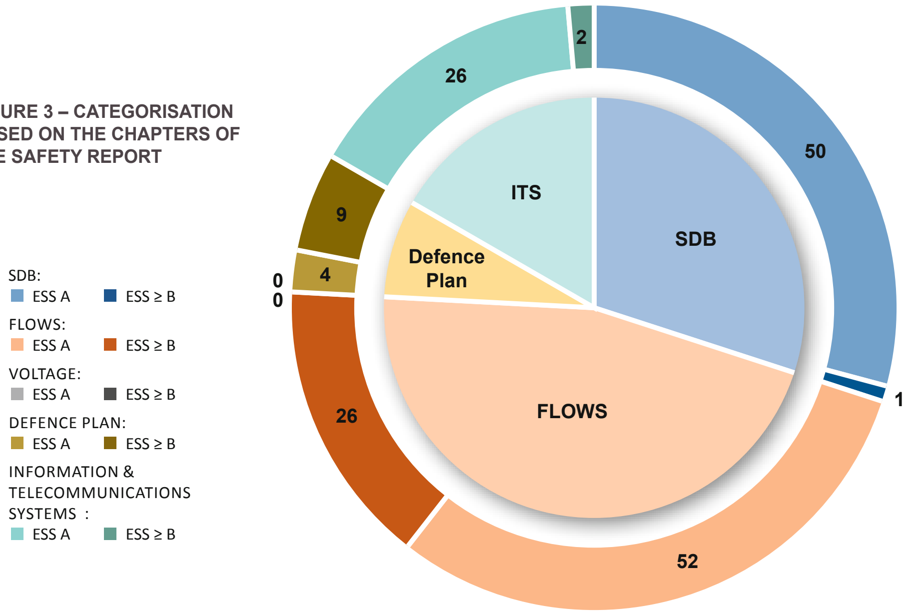


More specifically, the following points are worth noting for 2024:

- For System Operation:
  - **A reduction in the number of level-A SSEs:** a large number of level-A SSEs in 2023 were linked to industrial action in the generating fleet;
  - **A greater number of level-B SSEs associated with complex operating conditions** that led to acceptable risk levels being temporarily exceeded (23 level-B SSEs compared to 3 in 2023).
- The number of SSEs linked to Network events is stable (around 10 since 2021).
- **The number of SSEs linked to Control Systems rose** (23 in 2024 versus around 10 since 2021), primarily due to developments in the tools supporting the process of network studies (9 SSEs in 2024).
- Events classed under Generation relate to the use of the Alert and Safeguard System (SAS) communication system by generating facilities, and their failure to acknowledge system notices as expected. They were significantly lower than in previous years. This can be explained by the awareness-raising measures aimed at stakeholders and by the lower number of SAS messages sent (in response to industrial action or degraded SDB conditions).

The illustration below shows the breakdown of SSEs with a severity classification ≥ A by topics addressed in the remainder of this document.

FIGURE 3 – CATEGORISATION BASED ON THE CHAPTERS OF THE SAFETY REPORT



Frequency: supply-demand balancing

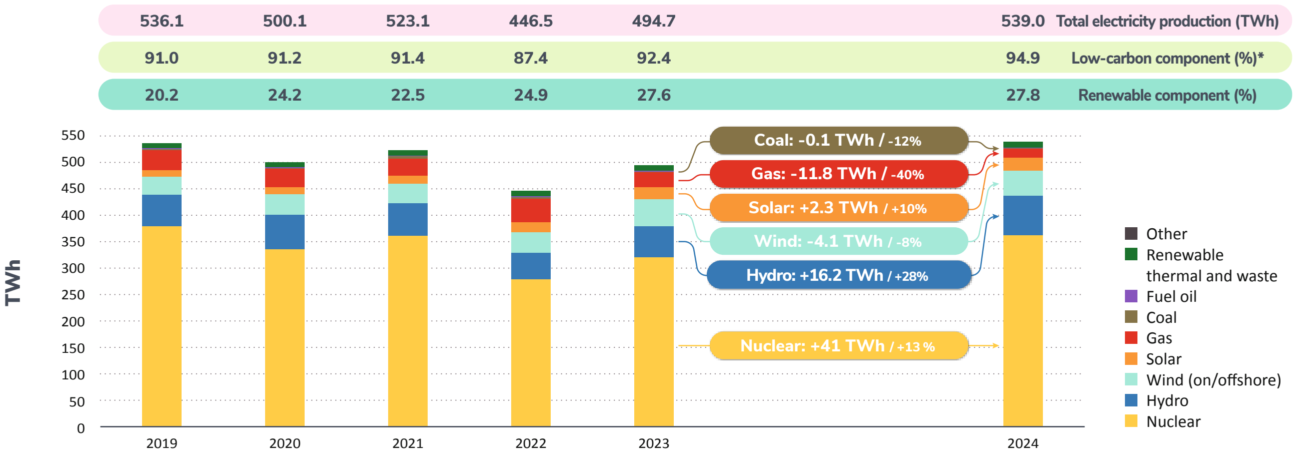
3.1 Production[4]

In 2024, for a second consecutive year, total electricity production in France saw a comparable increase across all sectors (+9% compared to 2023).

Electricity production reached 539 TWh in 2024, returning to its pre-pandemic and pre-energy-crisis level.

In 2024, nuclear generation stood at 361.7 TWh, an increase of nearly 13% compared to nuclear output in 2023 (320.4 TWh), confirming the sustained upward trend in the volume of generation that began in 2023 (+15% compared to 2022). As a reminder, the nuclear power sector experienced a production crisis in 2022 after the discovery of defects in a number of reactors, linked to stress corrosion cracking (SCC).

FIGURE 4 – TOTAL ELECTRICITY PRODUCTION IN FRANCE, 2019 TO 2024, BY SECTOR



* 50% of electricity generated from household waste is considered to be renewable. Hydro-output is 70% deducted from PSH energy consumption, EU Directive

4. Data from the 2024 Electricity Review published by RTE in February 2025.

On 21 December 2024, the Flamanville EPR (European Pressurised Reactor), the plant's third reactor and the first EPR to be built in France, was briefly connected to the grid before being taken offline. EDF has indicated that the reactor is expected to remain in the testing phase for several months before entering commercial operation.

In 2024, hydroelectric power plants generated 75.1 TWh, up 28% from the 58.9 TWh produced in 2023. This was the highest output since 2013 (75.5 TWh), achieved thanks to abundant rainfall, with 2024 being one of the ten wettest years since 1959. Onshore wind power generation fell in 2024 compared to 2023, despite the expansion of the fleet: it stood at 42.8 TWh in 2024, a decrease of 12.6% compared to 2023 (-6.1 TWh). This drop was due primarily to low wind conditions in 2024 compared to the previous year. However, the weather events at the end of 2024 resulted in a new production record for the sector (of nearly 18 GW), reached on 24 November 2024.

France's fleet of offshore wind farms, and its output, continued to grow with the complete commissioning of two new wind farms in 2024. Offshore wind production stood at 4 TWh in 2024, more than double that of 2023.

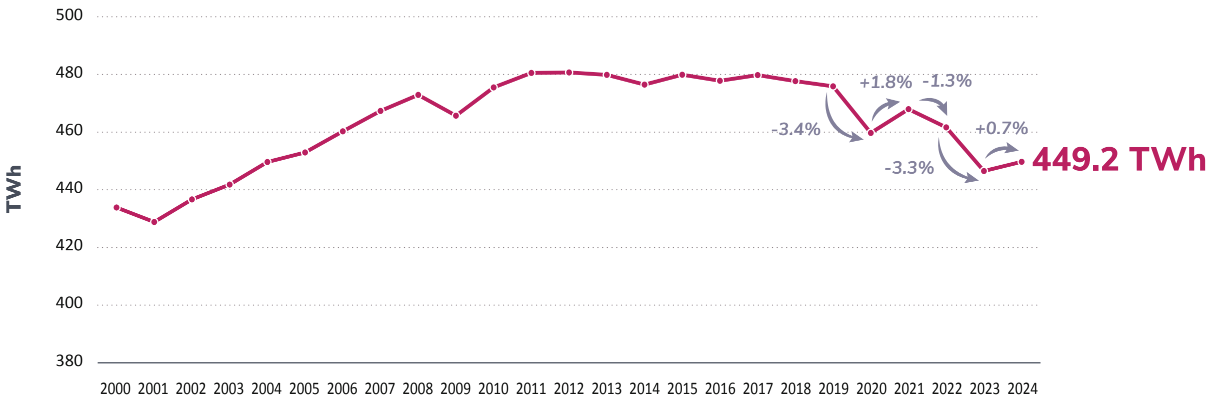
Solar power generation reached a record high in 2024 (as it has every year since 2006), with an output of 24.8 TWh. This represents an increase of 2.3 TWh (+10%) compared to 2023 production levels, driven by the development of the fleet, despite the fact that the past year was France's least sunny year in nearly thirty years. In 2024, for the first time, annual solar photovoltaic electricity production exceeded fossil-fuel thermal generation.

3.2 Consumption[5]

2024 saw a slight increase electricity consumption (allowing for climate hazards) in France (+3 TWh, equivalent to +0.7%[6]) compared to 2023, marking a departure from the downward trend of recent years, thanks to a marginally more favourable macroeconomic environment.

However, this figure remains well below those recorded in the 2010s (of the order of -30 TWh, or -6%, compared to average consumption over the period 2014-2019). These levels of consumption are caused by the dual effect of higher electricity prices and energy sufficiency measures taken during the energy crisis (which have had a lasting impact), as well as continued advances in energy efficiency over the last decade.

FIGURE 5 – VOLUME OF CONSUMPTION FROM 2000 TO 2024, ADJUSTED FOR CLIMATE HAZARDS AND SEASONAL EFFECTS



Aside from an annual representation of energy consumption, electricity use can also be presented as changes in residual consumption[7], which is more representative of instantaneous balancing requirements.

The two graphs below illustrate, firstly, the downward trend in residual consumption and, secondly, the changing profile of the curve, shifting downwards in response to increased wind power generation (approximately 7 GW over the period 2014-2024) and dipping further in the middle of the day in response to solar power generation (with, for example, a dip reflecting an additional 7 GW at 2pm, between 2014 and 2024).

5. Data from the 2024 Electricity Review published by RTE in February 2025.
6. These values include the volumes of electricity consumed internally in France.
7. Residual consumption corresponds to consumption deducted from variable renewable generation sources such as solar, wind and hydropower (run-of-river and storage). Hydroelectric power generation varies relatively little over the course of a day or a week.

FIGURE 6 – TREND IN RESIDUAL CONSUMPTION (MONTHLY AVERAGE AT 30-MINUTE INTERVALS)

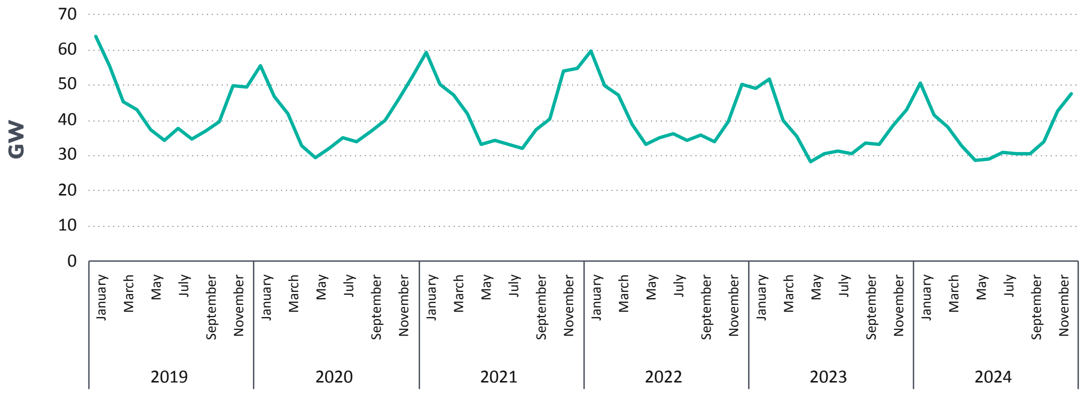
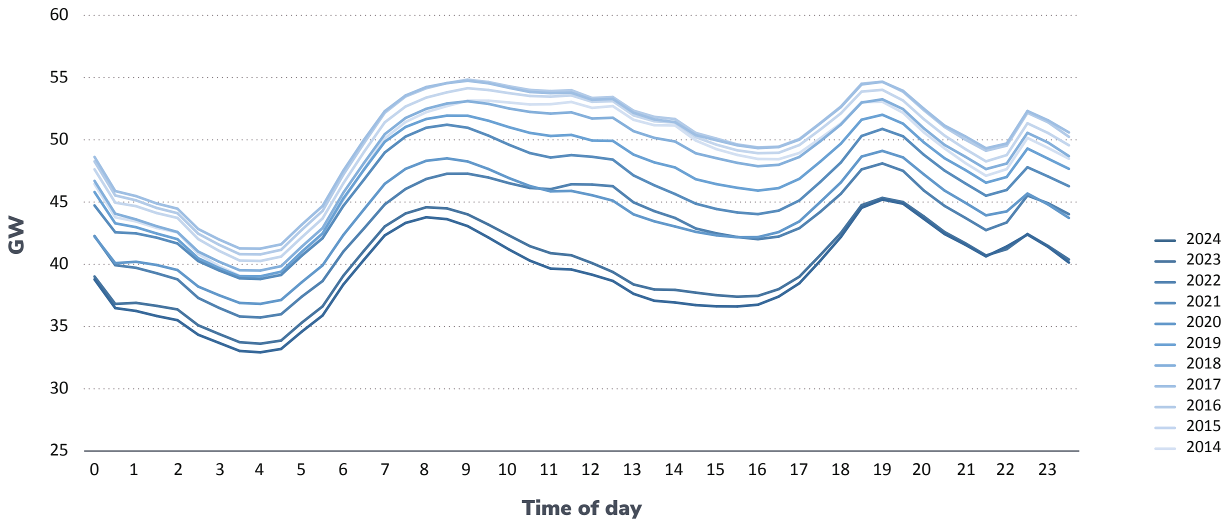


FIGURE 7 – TREND IN RESIDUAL CONSUMPTION IN GW (DAILY AVERAGE FOR THE YEAR AT 30-MINUTE INTERVALS)



3.3 Energy exchanges

In 2024, France's net balance rose to 89.0 TWh[8], the highest annual balance ever recorded. France was a net exporter to all its neighbours.

As with residual consumption, it is useful to show the distribution of energy exchanges, based on time of day, and how they have changed over the last five years.

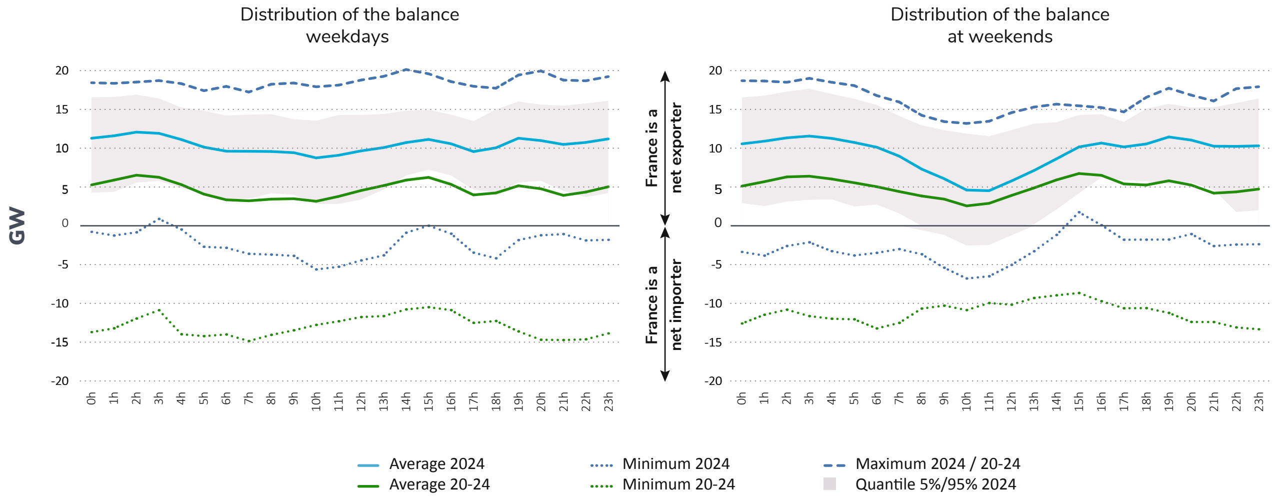
It is worth noting in particular that for weekdays the 5% quantile for 2024 (excluding 5% of the lowest values) is close to the average value recorded over the period 2020-2024. This illustrates the significant increase in energy exchanges seen in 2024.

The physical electricity flows between countries are essentially the result of commercial exchanges between market players. The European regulatory framework laid down in the SOGL (System Operation Guidelines) sets out the rules governing the safety and operation of the interconnected electricity system.

Capacity calculations for different timeframes thus ensure that the commercial exchanges are compatible with the distribution of the corresponding physical flows in the networks (according to their electrotechnical characteristics), and comply with both common operating standards and individual TSO operating rules.

The period from 2020 to 2025 has seen an acceleration in the implementation of the European regulations governing interconnectors (the CACM[9], SOGL, FCA[10] and EBGL[11] network codes and the Clean Energy Package directive).

FIGURE 8 – DISTRIBUTION OF THE FRENCH ENERGY EXCHANGE BALANCE ACCORDING TO TIME OF DAY



8. 2024 Electricity Review published by RTE in February 2025.
9. CACM: Capacity Allocation and Congestion Management.
10. FCA: Forward Capacity Allocation.
11. EBGL: Electricity Balancing Guidelines.

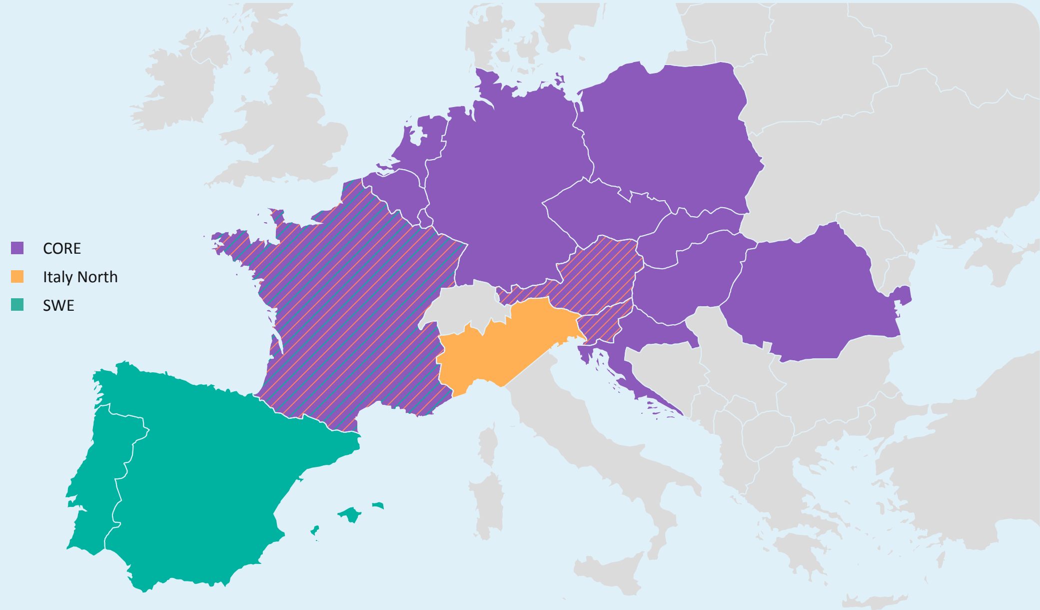
Capacity calculations use methods that aim at coordinating cross-border exchange capacities between countries so as to optimise the market, while at the same time complying with the operational safety rules stipulated by the TSOs.

Optimising electricity exchange capacities strengthens supply-demand balancing, particularly at times when the mechanism is under pressure, and thus helps ensure the operational safety of the electricity system. It also meets the requirements laid down in European regulations, notably in the Clean Energy Package or CEP.

These calculations are made for different time-frames, ranging from the long term (yearly and monthly capacity calculations) to intraday capacity calculations, and day-ahead updates (day-ahead capacity calculations). Capacity calculations for the balancing timeframe are due to come into effect by 2028. These will provide input to the balancing platforms, in the form of capacity values that are updated as close as possible to deadlines.

RTE is involved in 3 different Capacity Calculation Regions:

- Core
- Italy North
- SWE



Source: Coordinated Capacity Calculation | Coreso

Among other things, the text of the Clean Energy Package sets interconnection installations a minimum target of 70% capacity to be made available for cross-border trading, a target that must be reached by 2025. The expected increase in cross-border exchanges requires ever-greater coordination between the European TSOs, in order to work within the operational limits of the European electricity system and to manage resulting network congestion.

Several new milestones were reached in 2024 that have added to cross-border capacity:

- On 13 June 2024, at all French borders (except for the France-Switzerland and France-United Kingdom borders), the following came into service:
  - GOT (Gate Opening Time) 15.00, with the intraday market opening at D-1 15.00 instead of D-1 22.00, as was the case previously.
  - New Intraday Auctions (IDAs), with the launch of three new auctions on the intraday market, based on the same auction model as the Single Day-Ahead Coupling (SDAC) currently held at D-1 12.00 (Gate Closure Time, representing the cut-off time for submitting offers, with results published at 13.00).
- **In the Core Region,** two important new processes went live in 2024:
  - The Core Intraday Capacity Calculation IDC-C(a), enabling in particular the extraction of ATC (Available Transfer Capacity) from the flow-based domain that is required to open the intraday gate at 15.00 (see GOT 15.00 above).
  - The Core Intraday Capacity Calculation IDC-C(b), allowing for recalculations and therefore updates of the cross-border capacities of the Core Region (France-Belgium and France-Germany, when it comes to RTE) at D-1 21.40 for delivery day D. These results are also used as input for the 2nd intraday auction (IDA 2), which takes place at D-1 22.00.
- **In the Italy North Region,** in regard to day-ahead and intraday timeframes, capacity calculations were used only for exports to Italy. Exchange capacities between Italy and neighbouring countries (France, Switzerland, Austria and Slovenia) were established annually for the whole year. From November 2023 onwards, the calculation of **capacity from Italy to its northern neighbours** maximised intraday exchange capacities. Since 19 June 2024, a new capacity calculation process went live, optimising Italy's export capacities to its northern neighbours on a **day-ahead timeframe** (D-1).

EXTENSION OF THE CAPACITY CALCULATION REGIONS

In 2023, a new listing was submitted to the European regulators of the regions in which capacity calculation is applied, so as to include the future Franco-Irish interconnection, in the form of the Celtic direct-current power link now under construction, which will be incorporated into the Core Region as soon as it is open for trading. In addition, the new Central Europe electricity capacity calculation region has been established, merging the Core and Italy North capacity calculation regions. Its first objective is to implement a flow-based capacity calculation methodology for the consolidated Core-Italy-North area, initially only for day-ahead capacity. An amendment to the 'Determination of CCRs' methodology is expected in 2025, focused on incorporating new regions into the Central Europe Region, and for several months the relevant TSOs have held discussions on the future roadmap.

3.4 Supply-demand balancing and reserve margins

Supply-demand balancing in 2024 did not give rise to any particular alerts in relation to shortfalls in balancing offers to meet demand **(No EcoWatt alert was issued by RTE during the year, including the winter months).**

With regard to the management of reserve margins, in contrast to previous years, **there was a steady increase in the number of periods during which downward margin requirements took precedence.** In 2024, RTE frequently had to deal with shortfalls in downward margin provision and issue notices for lower output, aimed at renewable energy generators connected to the transmission system but outside the balancing mechanism.

RTE uses the following mechanisms to ensure that the electricity system's supply and demand are balanced at all times, and to control frequency:

- **automatic primary and secondary reserves provided through the modulation capacity of generation or storage facilities** (also known as frequency-power system services), as a first response to an unforeseen generation or consumption issue in the network.
- **tertiary reserves,** intended to complete the full and durable restoration of the supply-demand balance, and to restore any system services that were used during the hazard condition.

Operating margins are calculated for these various reserves, for both upward and downward margin provision, so as to deal with technical issues in the electricity system (such as the loss of a generating unit) or with differences between weather forecasts and actual weather conditions (temperature, sunshine, cloud cover or wind).

These margins are made up of contracted reserves and market offers in the balancing mechanism, or offers on the European tertiary reserve platform TERRE.

They must be at the required levels, which depend on the timeframes, and come under European regulations:

- **Fast reserves** are designed to deal at any time, and within 15 minutes, with the loss of the largest generating unit connected to the network (upward reserve), or the loss of the largest load or of exports on a direct-current line (downward reserve).
- **Slow reserves,** on the other hand, aim to address unanticipated issues that may arise in the hours ahead: a deviation from the consumption forecast, an unforeseen technical issue on the electricity generation side, an adjustment to a wind or solar power generation forecast, etc.

When these conditions are not met, RTE issues a system notice (one day-ahead for the following day, or intraday), a degraded mode notification (in near-real-time) or, where applicable, a system safeguard alert (also in real time).

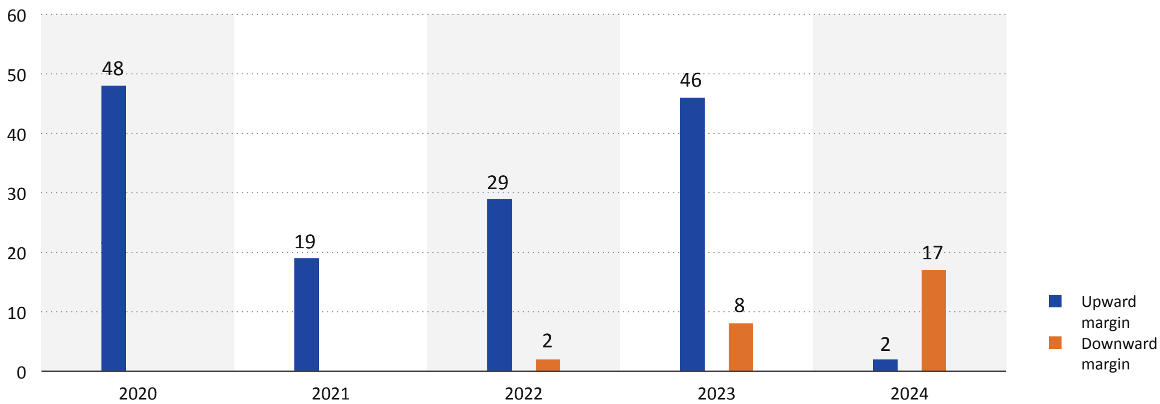
RTE publishes forecasts of the level of upward and downward margin provision on its website[12]. These figures are put out one day ahead and updated throughout the day, in response to information updates.

12. Balancing capacities - RTE Portal Services (services-rte.com)

Supply-demand balancing requires early action ahead of real-time, using 'upward' reserve margins (in anticipation of a production shortfall) or 'downward' reserve margins (in anticipation of a production surplus).

- Between 2020 and 2023, a significant number of Significant System Events (SSEs) arose when RTE had inadequate 'upward' reserve margins, mainly due to the reduced availability of the nuclear fleet. Given the high availability of the production fleet (and of the nuclear fleet in particular), such conditions were virtually non-existent in 2024 (2 events during the year).
- In contrast, since 2022, RTE has seen a very steady rise in the number of situations in which it has had inadequate 'downward" reserve margins, that is to say, situations with high volumes of electricity generation. These situations doubled in 2024 (17 SSEs during the year).

FIGURE 9 – LEVEL-A SSES LINKED TO SHORTFALLS IN MARGIN UPWARD MARGIN / DOWNWARD MARGIN



In order to balance the electricity system and ensure its operational safety, RTE is authorised to conduct balancing operations by modifying the generation schedules of production assets closer to real time, if normal market operations have failed to rectify the imbalance.

In accordance with the Energy Code, these balancing operations are carried out in compliance with the merit order list. More specifically, if supply exceeds electricity demand, the balancing measures are drawn first from the call programmes of the generating units with the highest variable costs.

In 2024, RTE activated 18 GWh of downward balancing services through the curtailment of wind generation and (to a lesser extent) solar output. Although these volumes remain small compared to the total volume of downward balancing activated to maintain the supply-demand balance, this is nonetheless a significant increase compared to previous years.

Renewable capacity balancing offers submitted to the balancing mechanism amounted to 10 GWh. In addition to these offers, RTE announced in the summer of 2024 that operating forecast conditions would sometimes require the implementation of additional measures to decrease renewable generation in real time. Such measures were carried out for the first time on 16 July 2024, with the transmission of safeguard alerts to stakeholders on eight occasions (level-A SSE) in order to reduce output representing a total volume of 8 GWh.

With this objective in mind, Law 2025-391 of 30 April 2025 (DADDUE2) extended the obligation to participate in the balancing mechanism to all generating facilities above a certain threshold, for both upward and downward provision: this will provide more leverage for system balancing.

The development of solar photovoltaic assets connected to the low-voltage network managed by the distribution system operators is impacting the quality of RES generation forecasts, as well as voltage control, and the flows observed in the system. Based on open data published by ENEDIS, there is now as much installed photovoltaic capacity in the low-voltage network (particularly on top of agricultural buildings) as in the HV(A) network: around 11 GW in each network (9 GW in 2023).

In the interest of balancing the system and safeguarding the operational safety of the electricity system, RTE is also able to activate consumption curtailment via the balancing mechanism. **In 2024, 6.8 GWh of demand response was activated over the year, with an average 65 MW of demand response, and a maximum volume of simultaneous consumption curtailment of 716 MW.**

Certified explicit demand response capacity is increasing and represented around 3.6 GW (that is to say, +0.4 GW in the space of one year). Implicit demand response (‘EJP’ peak-day tariff and ‘TEMPO’ time/day-of-use tariff) is also increasing and represented a capacity of around 600 MW (that is to say, +200 MW in the space of one year).

At European level, draft regulations, aimed at promoting the contribution of flexible resources and distributed energy resources to market mechanisms, were jointly submitted to ACER in May 2024 by the two associations of European system operators, ENTSO-E and EU-DSO Entity. This proposal included a new network code for demand-side flexibility (Network Code on Demand Response – NCDR), as well as amendments to existing codes (EBGL, SOGL, DCC).

The principles set out in the NCDR will support the efficient, transparent and non-discriminatory implementation of these markets. The scope of the code currently encompasses consumption and storage, as well as generating assets connected to the distribution or transmission networks.

ACER reviewed this legislative package via a consultation process that ended in December 2024, and which included members of associations of European transmission system operators, including RTE, and a number of European associations of flexibility stakeholders. ACER subsequently worked with the regulators to produce a proposal that was

voted in by the Board of Regulators on 5 March 2025, and forwarded to the European Commission on 7 March 2025.

In collaboration with UFE, the Union of the French Electricity Industry, RTE has worked with other network operators to ensure that the specific operational characteristics of the French electricity system are taken into consideration, and to put forward provisions that are realistic and of benefit to all. The diversity of European practices has not always allowed for these proposals to be taken into account.

During 2025, the European Commission will proceed to the comitology phase for the adoption of the regulations, consulting an Expert Committee of Member State representatives, which will provide assistance with the final drafting of these texts. The NCDR may come into force in 2026, along with the amendments it has brought to the existing network codes.

3.5 Frequency control

For the second year in a row, frequency deviated from the standard range (±50 mHz) for a cumulative total of over 250 hours, the limit set by the SOGL code as the parameter defining frequency quality in the synchronous area.

With 54 large and sustained frequency deviations in 2024, **European frequency control has deteriorated since 2022** (with 67 frequency deviations in 2023 and 31 in 2022). In 2024, these were primarily low-frequency deviations (68% compared to 50% in 2023).

France was involved to varying degrees in 50 of the 54 deviations, and was the main contributor to 8 of these (responsible for over 50% of the deviation due to its frequency imbalances).

This trend is also reflected in the number of SSEs linked to large frequency deviations: 16 level-A SSEs in 2024 (19 in 2023).

French frequency control was the main contributor to 9 of these SSEs: three were caused by IT issues, and the remainder were caused mainly by significant deviations from consumption and generation forecasts.

In 2024, RTE continuously monitored the performance of 295[13] frequency control entities (generating units, consumption units, storage units, and distributed energy resources). There was a **reduction in the number of deviations from expected performance,** primarily for hydropower in relation to **primary frequency control** and for **nuclear power** with regard to **secondary frequency control** (management of the power setpoint). The entities concerned have taken corrective action.

FIGURE 10 – LARGE AND SUSTAINED FREQUENCY DEVIATIONS

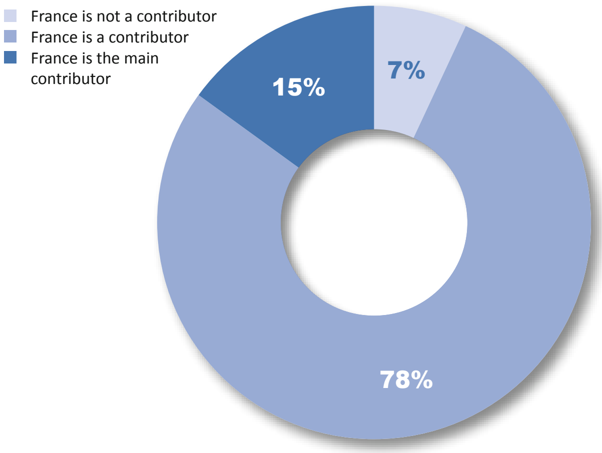
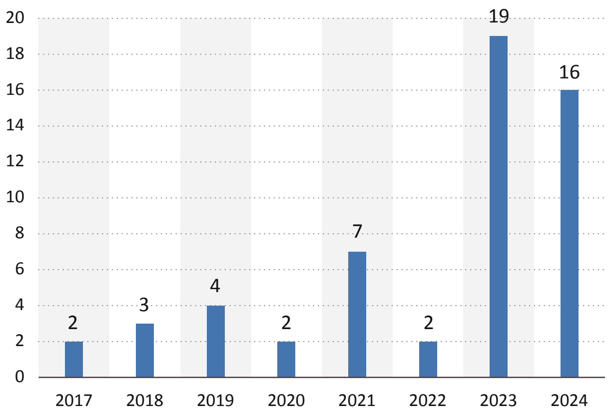


FIGURE 11 – NO. OF LEVEL-A SSES: FREQUENCY DEVIATIONS



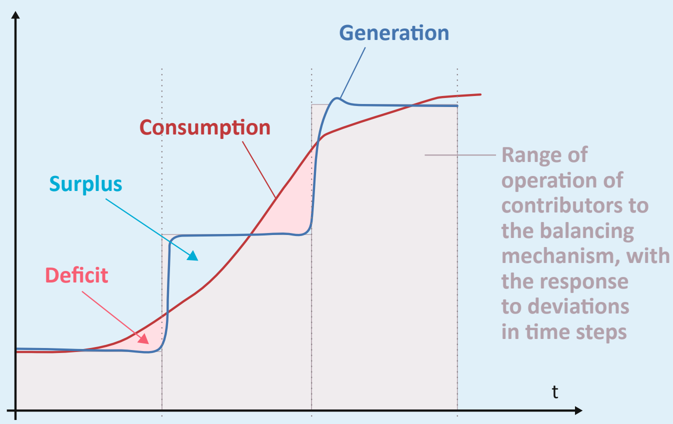
13. A figure that is down from 2023, reflecting the merging of certain entities.

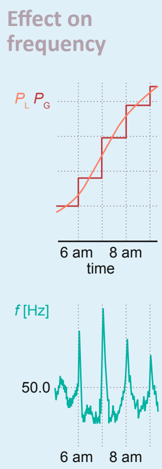
On-the-hour frequency deviations

On-the-hour frequency deviations occur when power generation and cross-border trading schedules are modified on the hour. These exchanges reflect the market product transactions between players in the European electricity market.

On the hour, the power generation of some European units may change very rapidly: frequency varies significantly until the automated control mechanisms are set in motion (resulting in the usage of all or part of the primary and secondary reserves).

ILLUSTRATION OF THE PHENOMENON:





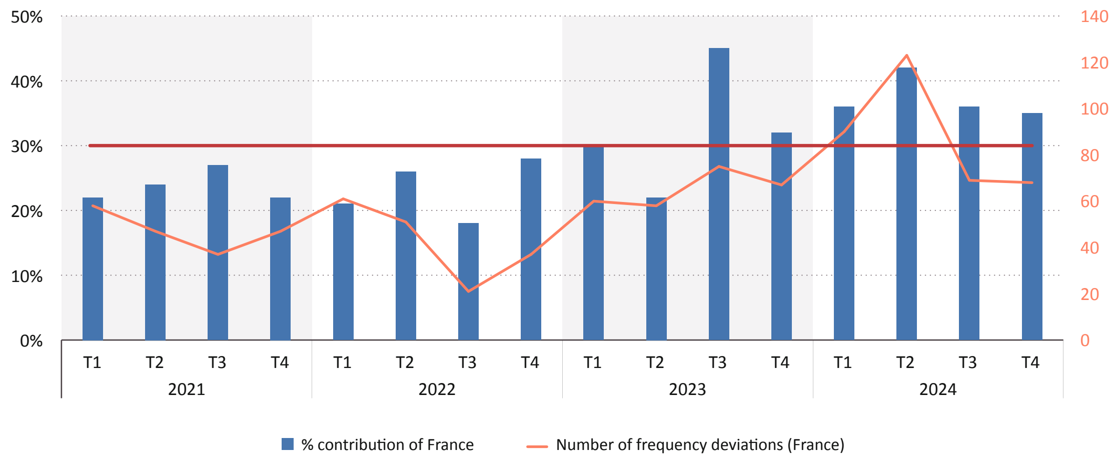
Source:
University of Stuttgart

The phenomenon of **deterministic frequency deviations on the hour,** characterised by short-lived frequency variations above 100 mHz during changes to the hourly synchronisation of generation schedules across Europe, is in line with previous years (165 deviations of more than 100 mHz were recorded in 2024, versus 143 in 2023, 112 in 2022 and 185 in 2021).

Since 2021, following a proactive joint decision by the European TSOs, there has been enhanced monitoring of each TSO's contribution to frequency control during changes in cross-border trading on the hour. This monitoring revealed that in 2024, **RTE exceeded the 30% threshold for contribution to deterministic frequency deviations in each quarter,** with a sharp increase in the number of contributions in the first half of the year. There was an improvement in the second half of the year, with fewer occurrences, though the contribution of France remained above the 30% threshold. RTE is working to reinforce its measures to control these phenomena.

	2021				2022				2023				2024			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
% contribution of France	22%	25%	27%	22%	21%	26%	18%	28%	30%	22%	45%	32%	36%	42%	36%	35%
Number of frequency deviations (France)	58	47	37	47	61	51	21	37	60	58	75	67	90	123	69	68
Total number of frequency deviations	266	187	139	218	287	193	114	134	198	263	168	211	247	296	193	195

FIGURE 12 – FRANCE'S CONTRIBUTION TO ON-THE-HOUR FREQUENCY DEVIATIONS



INDICATORS FOR THE QUALITY OF FREQUENCY CONTROL

In 2024, as in previous years, France met the two criteria stipulated by the European SOGL for quality of control in each of the load-frequency control blocks of the synchronous area. Based on a frequency control error calculated on a rolling average of 15 minutes, they must not exceed a given power threshold for more than 5% or 30% respectively of the time, on a yearly average.

Year	2020	2021	2022	2023	2024
Level-1 threshold (< 30%)	Level: 239 MW	Level: 238 MW	Level: 231 MW	Level: 205 MW	Level: 185 MW
	9.00%	9.20%	7.40%	10.80 %	11.70%
Level-2 threshold (< 5%)	Level: 452 MW	Level: 450 MW	Level: 436 MW	Level: 387 MW	Level: 349 MW
	3.00%	3.40%	2.30%	4.50%	4.50%

These indicators for frequency quality deteriorated slightly throughout 2023 and 2024, reflecting France's poorer quality of frequency control. However, this trend can be explained by:

- An update of the individual TSO thresholds, which meant that these thresholds were lowered for RTE from 1 January 2024 from 205 down to 185 MW for level 1, and from 387 to 349 MW for level 2, thereby increasing the length of time during which a frequency control error exceeds these thresholds;
- From a structural point of view, a lack of downward balancing offers signifies that very high positive frequency control errors cannot be addressed, even though the balance responsible parties tend structurally to adopt a slightly "long" position in order to control the risk of having to pay for their imbalances at negative imbalance settlement prices;
- More generally, the balancing mechanism lacks the fast reserve provision (with activation times of less than 15 minutes and power increment times of less than 15 minutes).

Since 2023, RTE has been working with RES generating units to encourage voluntary contribution to the balancing mechanism with a view to enhancing the depth of offers that can be activated. The emergence of offers with short deadlines and activation times would be an effective way of mitigating and limiting deterministic frequency deviations. In addition, should there be a reversal in the trend, the fact that there is no standardised technology in the sector enables the rapid withdrawal of a power restriction order, so as to quickly restore available power without resorting to the start-up of other generating assets.

For some years now, the French electricity system has also experienced **frequent shortfalls in automatic frequency restoration reserves, which contribute to frequency control.**

The scheduling of secondary reserves by those responsible for these reserves is above contracted volumes on average. There were deficit conditions for less than 5% of the time in

2024[14], compared with an average of around 22% in the period 2020-2023.

In addition, **the total annual duration of shortfalls in primary reserves remains in line with the average of the last four years** (a cumulative total time of 6.02 days of failure in 2024 compared to an average of 6.85 days a year for the period 2020-2023).

In regard to these primary reserves, 2024 saw a continued increase in the contribution of storage units (batteries), resulting by the end of 2024 in a total of 600 MW of certified batteries (500 MW certified in 2023 and 198 MW certified in 2022), against a French requirement of 486 MW. The contribution of consumer sites returned to a level similar to that of 2022, with a contribution of 124 MW as at the end of 2024 (compared to 114 in 2023).

Shortfalls in the scheduling of reserves diminish closer to real time owing to the frequency restoration measures taken by RTE, but these shortfalls must continue to be a focus of attention in frequency control.

RTE remains vigilant in regard to the real-time restoration of the reserves needed by the balancing mechanism, due to low spare capacity for secondary aFRR reserves. The obligation for FAT 300 re-certification (aFRR full activation time of 300 seconds), required at European level, has resulted in a 25% decrease in certified aFRR capacity provided by nuclear power plants. This reduces balancing flexibility for system service restoration: in order to restore the same volumes, RTE may have to call on more units for balancing than it did before the switch to FAT 300.

One of the challenges of restoring reserves arises when generating units providing system services are shut down to reduce output for downward supply-demand balancing. This is the case of hydropower, which impacts secondary reserves. Primary reserves are less compromised, as RTE's system balancing measures make limited use of volumes certified for FCR and applied to primary frequency control (batteries and loads).

The interruptibility scheme which governs the contribution of consumer sites to Defence Plan measures was not activated in 2024. The annual call for tenders for capacity up to 1 200 MW enabled the contracting of a volume of 756 MW over the course of 2024 (compared to 531 MW in 2023).

14. For the period from 1 January 2024 to 18 June 2024 (inclusive). From 19 June 2024 onwards, the tendering mechanism for secondary reserves was operational, and contributors were no longer required to submit capacity offers.

Active work is proceeding to transpose European regulations into French texts.

The European Electricity Balancing code

The implementation of the European Electricity Balancing code also offers additional means of flexibility for the balancing mechanism, at the European level. This code aims to pool reserves, and to establish cross-border mechanisms for automatic activation and real-time balancing of supply and demand.

More specifically, RTE is taking part in the two projects to set up European platforms, namely, MARI (Manually Activated Reserves Initiative) for managing fast reserve products (with an activation time of 15 minutes), or mFRR, and PICASSO (Platform for the International Coordination of the Automatic frequency restoration process and Stable System Operation) for managing secondary reserves, or aFRR.

It should be noted that since 21 November 2023, in preparation for connection to the PICASSO platform, secondary reserves have been activated in compliance with the merit order list (France) and no longer in proportion to the operating programme. RTE connected to PICASSO on 2 April 2025 and is due to connect to the MARI platform in January 2026.

In 2024, the balancing volumes activated on the TERRE platform accounted for around 19% of upward balancing volumes and 5% of downward balancing volumes. The remaining balancing operations were carried out by drawing on offers in the French balancing mechanism. This low volume is partly explained by the limited pool of standard offers, the features of which are not well suited to the characteristics of the French fleet.

Approval of a new European methodology for probabilistic dimensioning of FCR

At present, the European primary reserve (FCR, or Frequency Containment Reserve) is calculated to respond to a major incident, defined as **the simultaneous loss of the 2 largest generating units in service (two 1 500 MW nuclear reactors), that is to say, 3 GW.** This response requirement is then shared among the various countries that make up the Continental Europe Synchronous Area.

A new methodology – replacing this deterministic approach with probabilistic dimensioning for FCRs, taking into account load and generation patterns, and system inertia (in other words, the system's own characteristics) – was submitted to ACER and to European regulators on 17 January 2024, and was finally approved in January 2025. This methodology should determine an adequate volume of FCRs intended statistically to reduce the probability of insufficient FCR capacity to once in 20 years.

Note: For comparison purposes, this 3-GW FCR provision is not verified to date. The Continental Europe Synchronous Area saw three incidents in 2019 and 2021 that exhausted the reserves and therefore degraded frequency (which dropped to the region of 49.8 Hz and even to 49.74 Hz), prompting the TSOs to call into question the current dimensioning of FCRs.

4 Current: the management of network flows

THE PHENOMENON OF CASCADE OVERLOAD

Overly high currents of any duration in a power connection cause overheating and, if not controlled, may:

- Damage the components of the power connection, and potentially lead to the failure of the conductor;
- Create risks for persons and property by causing the expansion and elongation of cables, which come nearer to the ground, breaching the safety distances between the line and its environment, and possibly causing short-circuits.

Maximum values are therefore set for each installation:

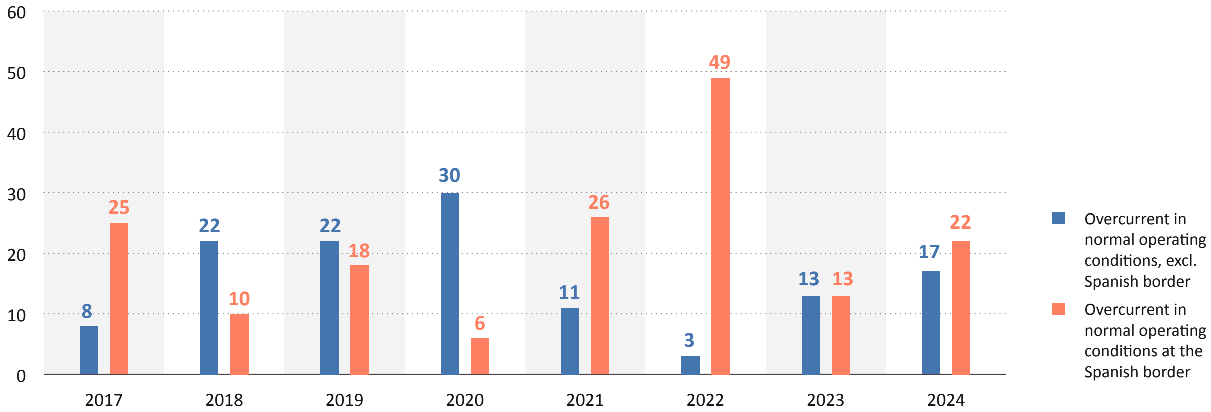
- A maximum operating current (MOC) that is not time-limited but is only reached occasionally and for a limited time;
- A transient current (TC), above that of the MOC but for much shorter time periods (less than 20 minutes).

In order to avoid the risk of exceeding these current values, the 225 kV and 400 kV systems in France are equipped with so-called overload protections. If excess current is not eliminated within a given time from when it started (from a few seconds to 20 minutes, depending on the magnitude of the recorded overload), the affected installation is automatically disconnected from the network by the activation of its overload protection.

The power flows carried by this installation prior to the trip are then transferred to nearby installations. Depending on the severity of the phenomena, there may be further overloads and then more disconnections. Successive load transfers can build up and produce cascade effects leading to the loss of a major part of the electricity network

The power flow risk control policy applied by RTE ensures that such a cumulative effect cannot arise from a single unforeseen issue. It is also one of the rules stipulated in the European SOGL.

FIGURE 13 – OVERCURRENT EVENTS EXCL. INCIDENT CONDITIONS



Excluding incident conditions, the number of one-off cases of 225 kV and 400 kV overload remained within the average of the last few years. **These overcurrent conditions were always rectified within the permitted timeframes and did not jeopardise the safety of the electricity system.**

The Spanish border still accounts for a significant portion of the cases of exceeded line flow limits.

The exchanges between France and the Iberian Peninsula continue to be intensive and call for regular real-time limitation through countertrading[15] operations, in order to comply with operating rules. The loads of installations in the area (interconnections and upstream 400 kV and 225 kV networks) often come close to operating limits, and the number of overload protection activations remains high, though within the average of the last seven years.

Despite these efforts to pre-empt changes to cross-border trading schedules and the distribution of these exchanges along the border, **uncertainty remains over the flows observed real-time at the interconnections with the Iberian Peninsula.** The ramping up of mechanisms for shared European balancing reserves, and potential supply-demand balancing errors in the Iberian Peninsula, have added to the difficulties in managing flows across this border. **In this context, maintaining a high exchange capacity at the Spanish border means accepting controlled excess flows.**

Excluding the Spanish border, and despite an increase in the power flows in installations, better **anticipation of constraints** and improved **coordination between control rooms have limited** the number of cases of flow limits in installations being exceeded, which remains within the average of the last five years.

15. Countertrading: a system for adjusting trading schedules in order to reverse the direction of flows and thus alleviate congestion.

Although not an issue directly related to safety, the increasing connection of RES installations to the distribution and HV(B1) networks (63 kV or 90 kV) may cause power flow constraints that must be managed jointly by RTE and the DSOs. It is therefore sometimes necessary to restrict the output of certain installations in order to comply with operating rules.

In a bid to regulate this phenomenon and thus establish an optimised electricity system, the 2019 national network plan (SDDR) anticipated that these curtailments would correspond on average to around 0.3% of onshore renewable energy output in a fully operational network (that is to say, an electricity system with no participation of renewable energy producers and no installations locked-out and tagged-out).

The volume of energy not dispatched (END) linked to curtailment measures in a fully operational network has been steadily increasing since 2021: according to estimates, this volume rose from ~230 GWh in 2023 to ~375 GWh in 2024 (in other words, to ~0.55% of output). This rise is tied to the pace of onshore RES connection (47 GW at the end of 2024 compared to 27 GW at the end of 2019) and to the fact that output limitation is still being implemented manually and preventively in certain areas. This increase in END was therefore expected, and is clearly taking shape. Since 2019, RTE has been introducing New Adaptive Zone Controllers (NAZA) that are designed to manage and rectify these constraints, thereby limiting the volume of END. By the end of 2024, 18 NAZA controllers had been installed and interfaced with the control systems used by the DSOs, with a firm commitment to continuing and accelerating the programme for roll-out.

In order to take into account uncertainties related to changes in consumption and RES generation over the coming years, and to factor in the pace of NAZA roll-out, a higher ceiling of 0.8% has been applied to the network access tariff TURPE 7 HV(B). This rate is calculated as the ratio of energy curtailed to total onshore photovoltaic solar and wind energy output. The French Energy Regulatory Commission may revise this rate during the tariff period, to take into account the results of the 2025 national network plan (SDDR).

Voltage control

5.1 Managing the risk of voltage collapse

The electricity system's voltage is controlled by multiple sources of reactive power (generating units, capacitors, shunt reactors, reactive power compensation devices based on power electronics – SVCs, etc.) distributed across the network.

In any given area, the sources of reactive power may no longer be adequate to meet requirements in the event, for example, of a loss of transmission installations or generating units, and all the more so if consumption is high.

Importing a supply of top-up power from a neighbouring area thus causes major voltage drops in the network. Automatic on-load tap changers, installed in the network transformers supplying customers, compensate for these voltage drops. However, this results in increasing the inrush current and therefore in lowering the area voltage a little further.

Below a certain level of low voltage, referred to as critical voltage, the limit of transmissible power is reached.

Under its System Defence Plan, RTE operates two automated schemes against voltage collapse in the West and North, ADO (since 2009) and ADN (since 2015). The technical renovation of these automatic schemes is currently underway. In the event of a network incident resulting in a significant voltage drop, these automated systems activate a volume of localised load-shedding, just enough to prevent an uncontrolled spread of voltage loss, thereby avoiding more extensive power outages. These two automated schemes supplement the TC-BS controller deployed nationwide following the incident on 12 January 1987. This system, which was renovated in 2023, controls automatically the transformer on-load tap changers installed in both the public electricity transmission system and the public electricity distribution system. This automated device operates only within a given geographical area, linked to the measured voltage at a specific terminal. Several areas may be impacted, depending on the severity of an incident.

Though it is still included in the Defence Plan, the risk of voltage collapse is less present today owing to structural changes in the electricity system (stagnating consumption, fewer extractions on the transmission system, the growth of distributed RES). In consequence, the operational challenges are shifting incrementally towards the issue of high voltages (see next section).

There were no major challenges in the management of low voltages during the winter of 2023/2024. No safeguard alert for low voltage has been sent since 2021.

The activation threshold for the Western and Northern Automatic Schemes Against Voltage Collapse (ADO and ADN) was never reached (they were last activated in March 2020).

The continued improvement seen in 2024 was largely due to the generating units in western and north-west France during the winter months, combined with moderate consumption levels.

Nevertheless, there were low voltage values in the transmission network (400 kV and 225 kV) during the first half of 2024, attributable to significant electricity flows (cross-zonal transit flows) linked to trading. Although there was no risk of voltage collapse, the transformer tap changer controller activation thresholds were exceeded on six occasions in the Lyon and Savoie region, and on one occasion in the Centre region. Over this period, calls for synchronous compensation measures were sometimes required to manage the voltage plan for Savoie. RTE will continue to monitor this phenomenon, particularly in areas where consumption is expected to increase.

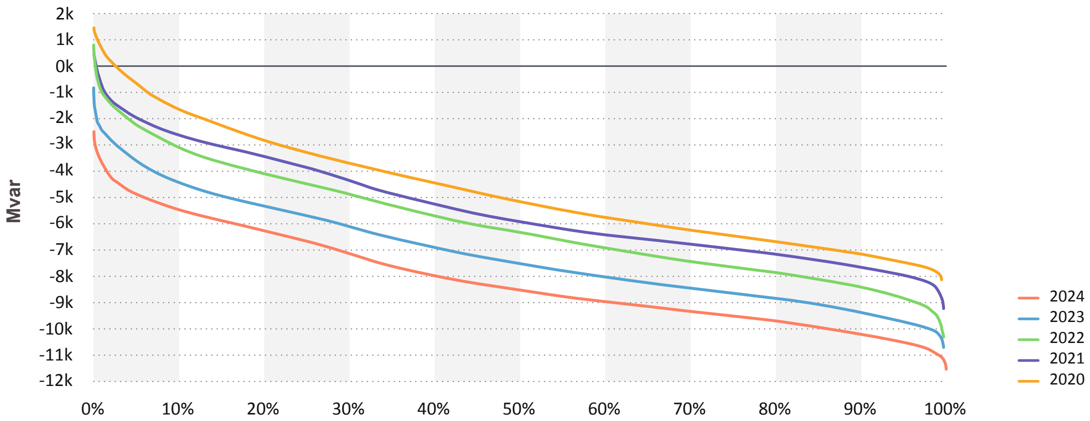
5.2 Control of high voltage

High voltages appear when the equipment controlling reactive power (generating units, SVCs, inductors) can no longer absorb the reactive power generated in the electricity system (capacitors, lightly loaded lines or cables, reactive power generated by customers, etc.). These phenomena, which in the past occurred during summer weekend dips in consumption, are now on the increase, throughout the year, including on weekday afternoons during periods of high distributed generation and low consumption. Extended high-voltage conditions can shorten the service life of equipment and also cause equipment degradation that impacts the quality of electricity. They can also have more serious consequences (overvoltage appears to have caused the Iberian blackout of 28 April 2025 – this issue will not be addressed in this safety report, which covers 2024).

Despite an improvement in 2024, breaches of high voltage limits remain a focus for RTE. The main reasons are the following:

- The changing nature of transmission and distribution systems, which are increasingly placed underground and therefore generate more reactive power;
- The increase in HV(A) electricity production, reducing the share carried by the public transmission system;
- Developments in the technical properties of energy uses, which consume less reactive power, and in some cases, even produce it;
- Although slightly increasing, electricity consumption in France remains at a level lower than those observed before 2020;
- And lastly, major works have an impact on voltage control. This was the case in particular in the West Region in 2024: the unavailability of several installations meant that it was not possible to use all the power compensation measures for downward control of voltage, and no other mechanisms were available (such as a synchronous compensation unit, for example).

FIGURE 14 – MONOTONIC CURVE FOR REACTIVE POWER EXCHANGES AT THE TRANSMISSION/DISTRIBUTION INTERFACE IN 2024



The first three points above are a particular focus, given the steady increase over several years in reactive power injection from the public distribution system (of the order of 800 MVAr/year since 2020). As a result, since 2023, and to an even greater degree in 2024, the distribution networks have been in a situation of continuous injection of reactive power into the transmission system throughout the year. The curves below show the reactive power exchanges at the distribution-to-transmission interface.

The number of limit breaches in the 400 kV system remained low and stable in relation to 2023.

On the 225 kV network, the number of breaches was lower than in 2023, owing to the improved availability of the nuclear fleet, high water stocks, significant electricity flows, the resumption of compensation measures, particularly in the Paris Region, and the commissioning of new inductors (four in the Paris Region).

…but remained high compared to the period 2018-2022, due in part to infrastructure maintenance operations in the West Region, spotlighting the challenges of voltage limit breaches linked to outages.

FIGURE 15 – VOLTAGE LIMIT BREACHES

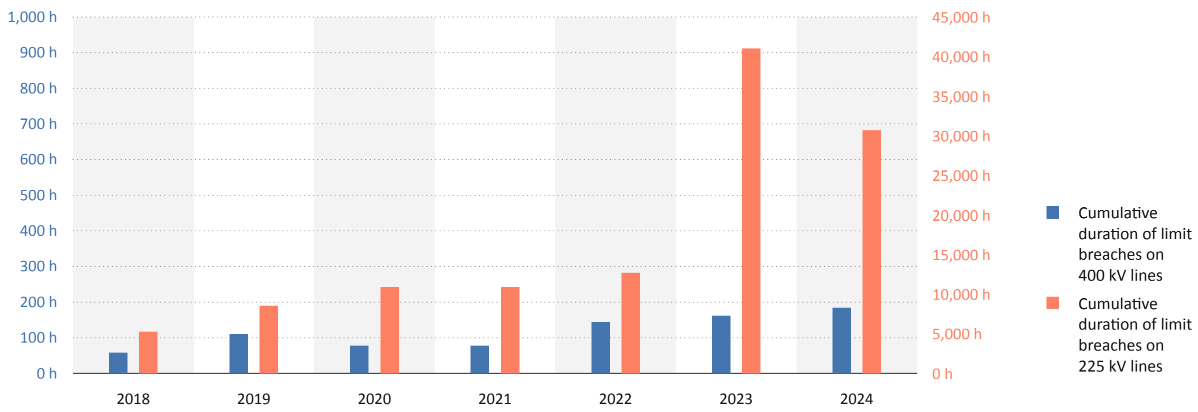
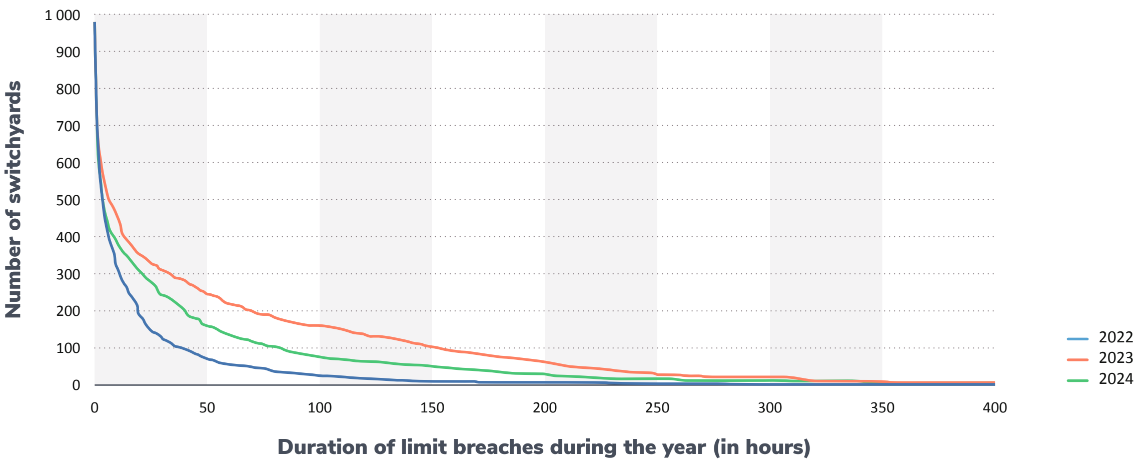


FIGURE 16 – NUMBER OF 225 KV SWITCHYARDS INVOLVED IN VOLTAGE LIMIT BREACHES



The graph 16 shows the distribution of these breaches on the 225 kV network for the last three years.

Maintaining voltage within safe ranges, particularly during spells of high voltage, relies on several mechanisms:

- The activation of reactive power compensation systems connected to the public electricity transmission network, and in particular of inductances (voltage-drop inductors) in the case of high voltages, which is increasing year on year;
- The contribution to voltage control of all the generating assets connected to the public electricity transmission network, as part of the voltage system services contract. This contribution is a requirement for all generating units connected to the public transmission network (primary voltage control for HV(B1), primary and secondary voltage control for HV(B2) and HV(B3)[16]);
- The contribution of RES generating units connected to the distribution networks with regulation for reactive power absorption once these units inject active power;
- The occasional withdrawal from operation of transmission system installations so as to reload the system and reduce the capacitive effect that raises voltage levels;
- The use of generating units connected to the public transmission network that have a "synchronous compensation" role that allows these units to absorb or supply reactive power without injecting active power into the electricity system;
- The option for RTE to set a contractual requirement for the targeted startup of generation units in order to enable their contribution to voltage control.

Aside from the contracts entered into beforehand with production assets to guarantee the availability of target units, the cost to RTE of calling in additional balancing means to maintain voltage was similar to 2022, following a sharp increase in 2023: around € 3M in 2024 for a volume de 11.3 GWh (compared to € 22M in 2023 for a volume of 112 GWh, and less than € 4M for 12 GWh in 2022). Using synchronous compensation units cost € 11.4M in 2024 (versus € 32.1M in 2023 and € 13.6M in 2022).

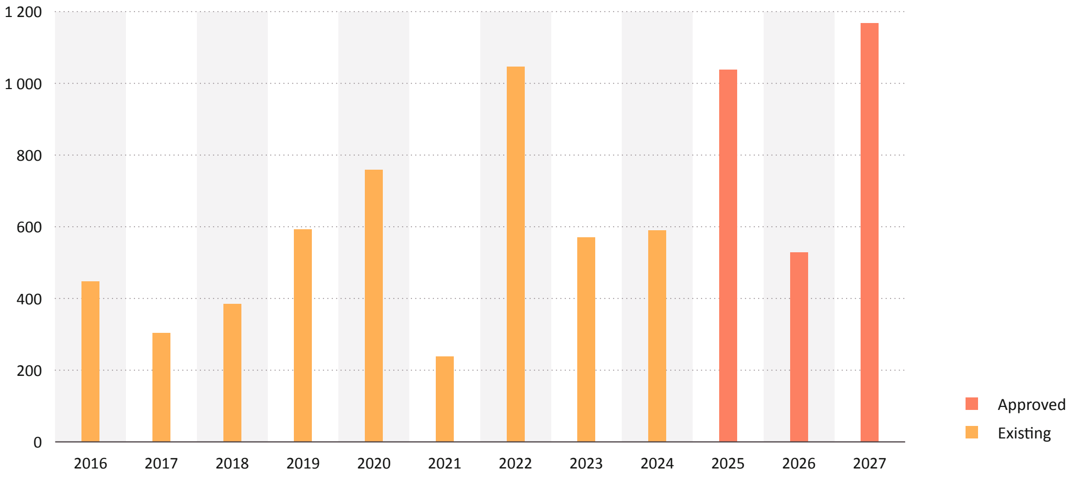
16. HV(B1) 90 kV - 63 kV; HV(B2) 225 kV - 150 kV; HV(B3) 400 kV.

Against this background, **RTE is proceeding with its power compensation installation programme** for better control of high voltage: 590 MVAR of inductors[17] were connected in 2024. In the West Region, which was severely affected by high voltages in 2024, the commissioning of the inductor in Niort, in November 2024, will support the management of the voltage plan. Seven of the 14 new inductors planned for 2025 are due to be installed in the West Region.

A new nationwide study was launched in 2024 to update voltage compensation requirements by 2030, following on from the last study in 2022 (assessing requirements for 2027). The study findings suggested a requirement for 34 additional items of equipment to manage constraints under normal conditions, in addition to other levers for action, such as the use of voltage control system services for installations connected to the public transmission system.

The 2023 joint initiative with ENEDIS to change the voltage setpoint value for RES connected to the distribution networks is ongoing and will be extended until the end of 2026. The expected gain from setting their tangent phi within the [-0.25; -0.35] range is key to compensating the delivery of reactive power from distribution to transmission systems that has been observed (an estimated annual growth of around 800 MVAR). Furthermore, the reinforcement of this initiative aimed at the other DSOs should drive its implementation in areas identified as risk-significant.

FIGURE 17 – INDUCTOR INSTALLATION PROJECTS BY COMMISSIONING YEAR



17. This volume corresponds to new equipment determined in voltage plan control studies. It does not include inductors associated with new connections (particularly offshore wind power), with studies conducted as part of the Regional Grid Connection Scheme for Renewable Energies (S3REnR) or the replacement of existing equipment. It should also be noted that the compensation measures for new connections and for S3REnR requirements are financed by stakeholders.

What is more, the trial launched in 2023 of a solar photovoltaic fleet connected to the south-western 225 kV network is ongoing. Given that the fleet was called into service for static compensation at nighttime to help control voltage, 2024 proved to be an opportunity to demonstrate the technical feasibility of the solution and to improve real-time voltage control. Preparations for similar wind farm trials were drawn up in 2024, for launch in 2025.

In consultation with the relevant stakeholders (trade unions, producers), the rules governing the contribution to voltage control were changed in April 2024. The new regulations put forward to the RES generating units paved the way for the entry of 6 new participants from the 3rd quarter and 15 additional participants from the 4th quarter of 2024. In 2024, RTE continuously monitored the performance of 470 voltage control entities (generating units, including RES assets, consumption units, storage units, HVDC). The results of this monitoring are similar to those of the previous year (the magnitude of the reactive power deviations remained constant overall compared with 2023). These performance deviations and the unavailability of production assets delivering system services led to reductions in contractual payments and to penalties, amounting to € 20.2M in 2024, up slightly on the last two years (€ 18.3M in 2023 and € 19.3 M in 2022).

6 Highlights of the year 2024

6.1 The management of network flows closer to real time is increasingly complex, as evidenced by events that may challenge the safety of the electricity system

Its position in Europe and in the European electricity system, connected to several areas on the periphery of the European power network (Spain, Great Britain, Italy) but also closely interconnected with the Benelux countries, Germany and Switzerland, makes France a key junction, or an "electricity interchange". Changes in the production mixes of European countries are now altering electricity flows across the Continental Europe Synchronous Area, leading in particular to increased power exchanges between Northern and Eastern European countries, and between Southern and Western European countries. As an 'electricity interchange' between Northern, Southern and Eastern Europe, France is acting increasingly as a hub for transit flows when such trading patterns are established. This is illustrated in practice, for example, by the electricity exchanges between the Iberian Peninsula and the Germany-Benelux region, which are areas that already have significant installed solar and wind capacity. These cross-zonal "transit flows"[18] are growing in terms of volume and frequency.

Between 2001 and 2020, cross-zonal transit flows were primarily loop flows from Germany to Italy and Switzerland, via France. Power exchanges became more diverse during the 2010s. And these new trading patterns developed in the 2020s, and in 2024 in particular, with the emergence of electricity flows passing through France from Spain to the rest of Europe.

The illustration above spotlights general trends in electricity trading patterns, as monthly averages. However, it does not capture the changeability of the interconnected European electricity system, in which power flows (along with other measured values) vary from second to second depending on the time of day, week, or year. This changeability calls for constant adjustments to manage the balance between supply and demand and the associated flows. To illustrate, in the first half of 2024, France was a significant net importer from the Iberian Peninsula during the first four months, and then became an exporter to the Peninsula from May onwards.

18. As the European electricity system is interconnected, it is reasonable to assume that France's power exchanges with immediate neighbours are made up of flows originating in, or routed to, countries that are "further away". To put it simply, if, over a given time interval, France imports electricity from Spain but at the same time also exports electricity to Italy, then it is logical to consider that, over the time interval in question, some of the electricity exchanged between France and Italy is drawn from generation in Spain. These power exchanges are referred to as cross-zonal transit flows.

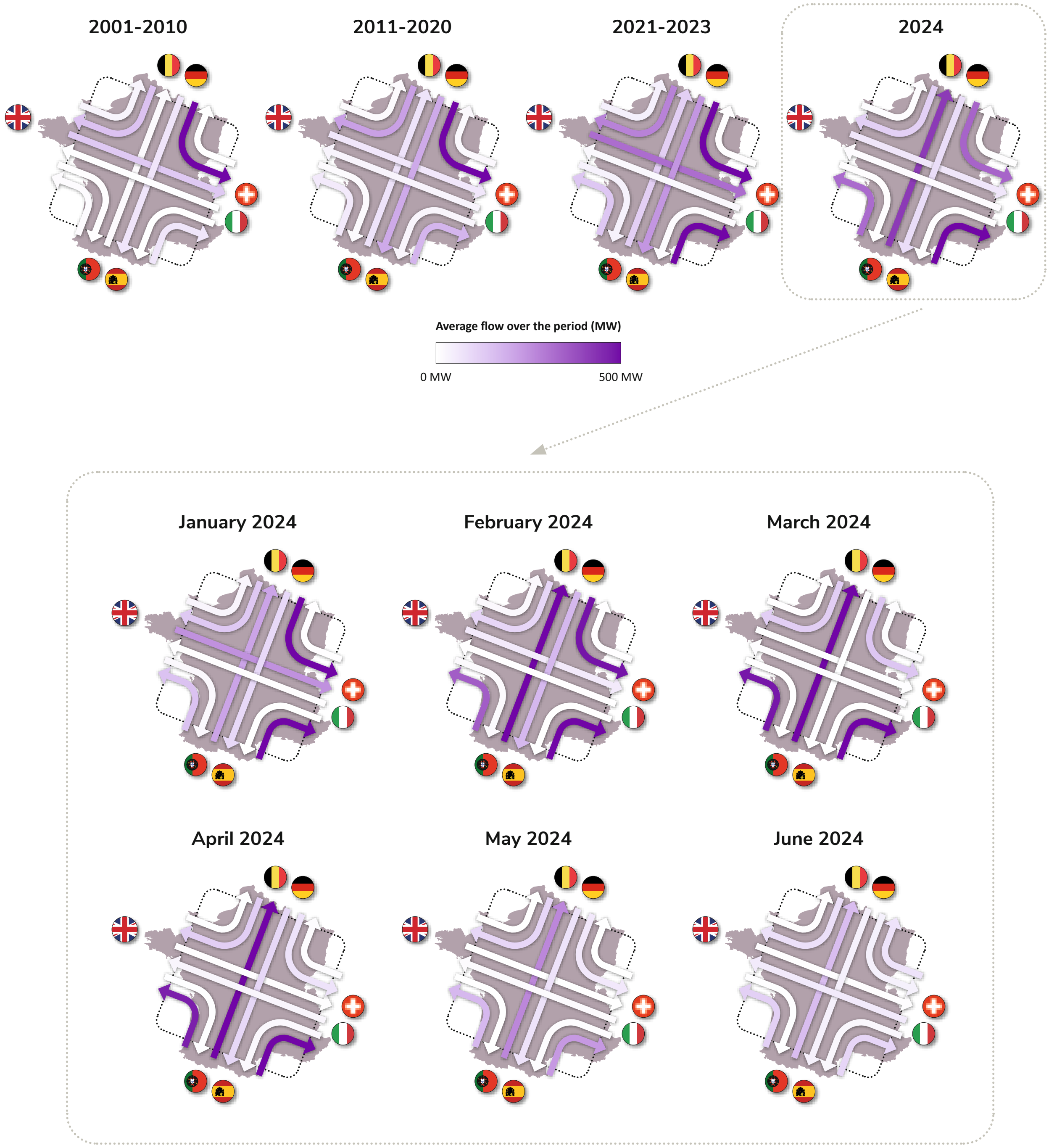
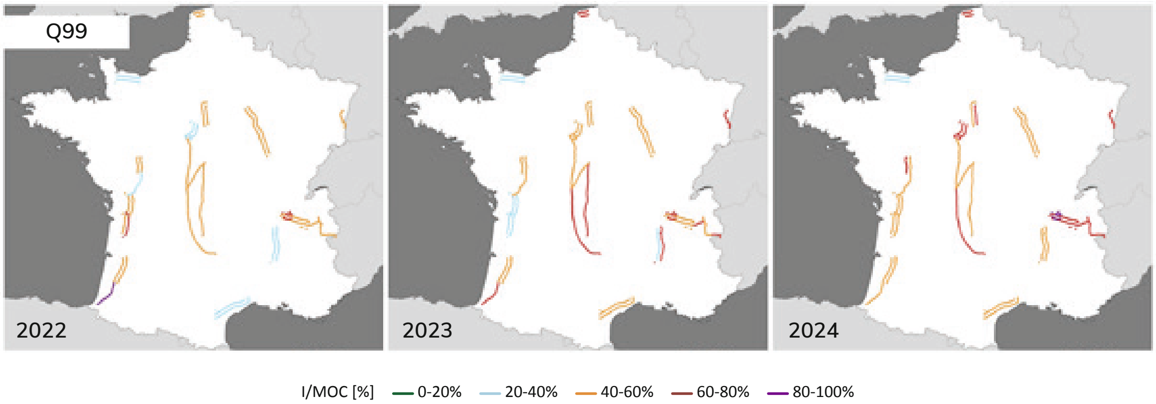


FIGURE 18 – CHANGES IN THE CROSS-ZONAL TRANSIT FLOWS INTERSECTING THE FRENCH ELECTRICITY SYSTEM

Above: Changes in the transit flows crossing the French electricity system during the last decades (averages for each period, and the first half of 2024).
Below: Changes in the transit flows crossing the French electricity system in the first half of 2024 (monthly averages).

In addition, based on a representative sample of around forty 400 kV lines, an analysis has provided a more accurate picture of the changing loads on installations in the national network, based on a review of the "transit flow/MOC" ratio[19]. The figure below illustrates the changes over the last three years for the 99th percentile, corresponding to the 80 hours per year (1% of the time) when the load factor is highest. This load factor is changing considerably: overall, it changed most significantly in the '20% to 60% of MOC' bracket in 2022, and in the '40% to 80% of MOC' bracket in 2024. These load factors take into account the measures implemented in real time to maintain energy flows within the framework of the power system's operating policy.

FIGURE 19 – 99TH PERCENTILE OF LOAD FACTORS FROM 2022 TO 2024, FROM A SAMPLE OF 400 KV LINES



19. MOC: A maximum operating current that is not time-limited but is only reached occasionally and for a limited time.

HIGH EXPORT LEVELS LED TO POWER FLOW CONSTRAINTS IN THE ELECTRICITY SYSTEM, JUST AS IT WAS ENTERING A PHASE OF MAJOR WORKS AIMED AT SECURING ITS RENEWAL AND DELIVERING DECARBONISATION AND REINDUSTRIALISATION TARGETS.

These cross-zonal "transit flows" are increasing in terms of volume and frequency, and they come in addition to the volumes of exports from French power generating assets. With this in mind, and in conjunction with the existing planned reduction in power exchanges linked to scheduled works and the longstanding damage to the Albertville-Rondissone interconnection between France and Italy, during April and May RTE implemented one-off reductions in export capacity to countries on France's eastern border. These measures were activated after all conventional procedures had been deployed and additional maintenance work had been cancelled[20]. However, even during this period, France continued to be a net exporter to Germany and Belgium, with an export balance that exceeded the maximum recorded values of the last ten years, while its export balance for the Italian and Swiss borders remained close to average values.

This need for additional capacity reductions is the result of the dual effect of:

- High levels of low-carbon generation in France and in the Iberian Peninsula;
- The reorganisation of power flows within France, against this background of significant low-carbon generation, particularly evident in the south-west of France;
- Primarily maintenance work but also very-high-voltage transmission infrastructure reinforcement work by RTE (the programme to renovate and reinforce the main lines of the French very-high-voltage transmission network was detailed by RTE in the 2025 national network plan – SDDR, the guidelines for which were made public on 13 February 2025). This work led to the unavailability of electrical installations, mainly in the spring and autumn, and therefore to increased flows in the remainder of the network.

From May onwards, constraints in the transmission system near these borders eased, though they remained significant. In the summer of 2024, RTE expected a repeat of such conditions between August and October, but outcomes were in fact better than anticipated and did not call for exceptional measures.

During this period, the management of electricity system operation was particularly difficult. Between March and June 2024, despite exceptional export reductions, 18 situations (later classified as level-B SSEs) during which a hazard condition in the network could have challenged system safety were detected in real time, representing a risk exposure time of approximately 40 hours. Fifteen out of these 18 situations were caused by operating constraints related to power flows at the Italian and Swiss borders. Resolving these adverse conditions required rapid action (adjusting the topology of the system, including in neighbouring systems, adjusting the national generation schedule, and further reducing real-time cross-border exchanges).

As mentioned above, despite a demanding work schedule between August and October, the electricity system had fewer operating constraints in the second half of the year. Five similar situations were identified, 4 of which applied to the border area with Switzerland and Italy.

20. In the period from March to June 2024, 16 planned lockout-tagouts of 400 kV installations were cancelled a few weeks or days before the scheduled start of works (or adjustments were made to the scope of works in order to minimise the duration of the lockout-tagouts).

6.2 Management of negative spot price episodes

WHY ARE PRICES NEGATIVE?

An increase in negative prices is to be expected in an electricity system in which the share of renewables is growing, particularly if electricity consumption remains low. Episodes of negative prices generally occur during periods of low demand combined with a high supply of renewable energy. When supply exceeds demand, generating units with a non-zero marginal production cost should shut down. However, they may prefer not to and, instead, fleetingly offer up their electricity at a negative price. In other words, they opt to pay buyers for a few hours, to use electricity. This is because the temporary shutdown of a thermal generating unit can be costly due to technical and economic constraints (start-up costs, minimum technical capacity, minimum shutdown time, etc.). Consumers are therefore paid to use abundant electricity during those specific windows of time.

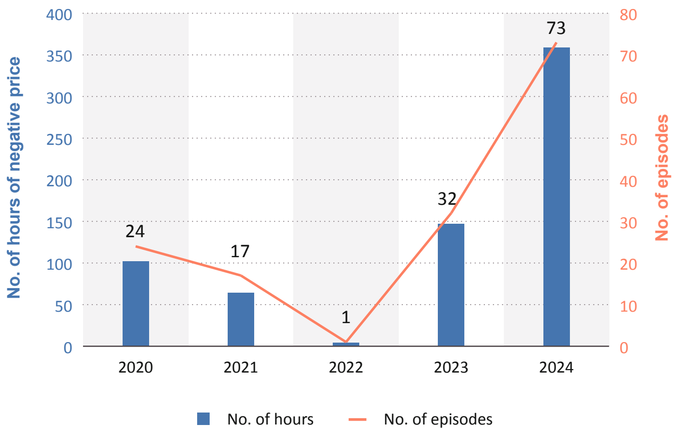
Negative prices are not inherently representative of a market malfunction. In theory, negative prices act as a useful economic signal, prompting consumers to consume during periods of high output, and urging producers to lower production when there is no market for their output. However, since in practice only a small part of electricity consumption at any given time is covered by volumes traded at spot prices (or volumes with prices indexed to the spot price), the incentive effect of this signal on the level of consumption is reduced. What is more, a large proportion of renewable generating assets are not exposed to market prices, as they have direct power purchase agreements under the purchase obligation mechanism. Consequently, negative prices are not an incentive for them to reduce their output. In contrast, installations operating under the premium tariff mechanism are encouraged not to produce electricity when prices are negative. The mechanism does not provide for any remuneration for production during these episodes, but it does provide for compensation if the installation's cumulative number of hours of downtime over the year exceeds a given threshold defined for each sector.

More specifically, wind and solar output during episodes of negative prices was generally lower than during episodes of zero prices. This difference clearly demonstrates the effect of generation curtailment by price-sensitive renewable energy fleets (operating under the premium tariff mechanism or exposed to market prices) during negative-price hours, the total volume of which was estimated at 1.8 TWh in 2024.

The number of hours of negative spot prices rose sharply in 2024, with a total of 359 hours of negative pricing during the year, or 4% of the time (compared to 147 hours in 2023). The increase in the number of negative price episodes has gained momentum in recent years, driven by the continued development of low-carbon generation and the ongoing efforts to keep consumption levels below those of the period 2014-2019.

The contractual framework governing the **generating units operating under the premium tariff mechanism** (an installed capacity of 11.5 GW in 2024, primarily RES, compared to 8.3 GW in 2023) prompts the generating units in question to shut down when the day-ahead market price is negative, indicating overproduction in the electricity system in relation to consumption and cross-border trade. In addition, some of the RES generating units operating outside the support mechanism (not subject, for example, to a purchase obligation) quite reasonably engage in the same behaviour by stopping production during these periods of negative prices. Thus, in 2024, **the synchronised shutdowns of significant volumes of renewable energy generation** occurred at much greater frequency and amplitude than in previous years, owing to the overall drop in market prices and the growing share of RES in the French energy mix. These episodes corresponded closely to periods of large volumes of solar photovoltaic generation. Although these periods are known a day ahead, special attention is still needed during these episodes to anticipate and assess as best as possible the volumes of RES shutdowns and, respectively, RES startups, at the beginning and at the end of these periods. These rapid changes in output can now reach production volumes of around 12 GW on the French side, which is considerable.

FIGURE 20 – EPISODES OF NEGATIVE SPOT PRICES



In order to understand the impact on system safety, beyond the number of hours it is also necessary to consider the number of episodes. Balancing the electricity system is undeniably more difficult at the beginning and end of each of these episodes.

Thanks to the reserves and margins provided for unforeseen events, it is possible to deal with these episodes through deliberate overproduction compared to balancing requirements in order to prepare for the drop in generation, while also securing additional production capacity to counteract lower output should the drop in generation prove to be more significant or more rapid than expected.

Similarly, at the end of the episode, in other words, shortly before production resumes (when prices are positive once more), the sharp rise in generation can be anticipated through deliberate underproduction, while securing a downward balancing capacity should the recovery in output be larger than expected.

Managing the complex dynamics of shutdown and startup

Predicting the precise dynamics of the shutdowns and startups of generating assets engaged in these episodes is now a real challenge, both in terms of volume and location. For example, wind conditions change between shutdown and resumed output, thus altering the geographical distribution of wind power generation. This uncertainty influences the optimisation of real-time balancing as well as the management of transit flows and voltages, which call for close coordination between network operation and supply-demand balancing activities.

These episodes therefore interweave national priorities, such as balancing supply and demand in the electricity system, with more localised operations, such as managing the voltage plan and power flows in electrical connections, particularly in areas with large numbers of shutdowns or startups. These phenomena occur most often in the 63 kV and 90 kV network, to which part of the RES generating assets are directly connected, but which also interfaces with the distribution system, to which many installations are connected.

Nevertheless, these production shutdowns and startups give rise to rapidly changing power flows in all the networks, which can also impact the 225 kV system, in terms of both flows (1 level-A SSE recorded in 2024 for a temporarily exceeded maximum current value at startup) and voltage (for example, a rapid increase of +9 kV at a 225 kV substation during a shutdown of RES output). Controllers and automated systems restore stable operating conditions, often bolstered by adjustments to the topology of the system near substations, so as to equalise the distribution of power flows across the network.

In order to gain a better understanding of which areas will be most affected, historical data is being used to proactively identify those generating units that are most likely to shut down in response to negative spot prices.

These phenomena underline the importance of the work initiated by RTE in partnership with the government's Energy and Climate Department (DGEC), the Energy Regulatory Commission (CRE) and the distribution system operators, in the 3 following areas:

- **Clarity:** ensuring that all parties provide reliable and detailed schedules that allow RTE to anticipate supply-demand balancing within operational windows.
- **Flexibility:** ensuring that the levels of electricity produced by part of the RES fleet can be adjusted by activating the downward and upward balancing offers made by participants (during negative spot price episodes, for example).
- **Phasing:** structuring the process for shutting down RES generation (steadily or in steps) during periods of negative prices so as to optimise control of the impacts on European electrical frequency.

7 Prevention of large-scale incidents

7.1 Network stability

LOSS OF SYNCHRONISM (LOCALISED FREQUENCY OSCILLATIONS)

In nominal operation, the generators of Europe's interconnected production assets all operate at the same frequency of around 50 Hz: this is referred to as synchronised system operation, with the system acting as the "synchronising link" between the power generators.

This balance can be disrupted by a short-circuit, which accelerates the rotation of a generator. If the short-circuit is not cleared sufficiently rapidly, or if the generating unit was not in a sufficiently stable condition from the onset, it may not be able to re-align with the frequency of the overall system: this results in loss of synchronism. If the phenomenon persists, it then spreads to the other generating units. In order to prevent this from happening, loss of synchronism protections are activated and split the network up into predefined areas so as to isolate the affected area.

In order to guarantee the stability of interconnected generating units, RTE carries out special tests at various time intervals, and implements the necessary preventive measures:

- Setting maximum short-circuit clearance times and complying with them;
- Restricting the operating range of generating units in terms of active and reactive power, to ensure greater initial stability;
- Adjusting operating schemes, and optimising the scheduling of withdrawals from service of installations;
- Checking the performance of generating unit controls and of protection systems.

The protection schemes that uncouple a section of the network in response to loss of synchronism were not activated in 2024. Nevertheless, six events (level-B SSEs) had a localised impact on the stability of the transmission system:

- On 24 May 2024, on 18 and 22 June 2024, and on 14 November 2024, voltage control operations during dips in consumption led to a brief excursion from reactive-power-absorption risk control criteria at Civaux power plant.
- On 17 March 2024, a similar situation arose at the Blayais power plant, with a brief excursion from reactive-power-absorption risk control criteria.
- On 18 November 2024, information on a fault in the busbar differential protection system at the Gatinais 400 kV substation was misinterpreted, thus preventing implementation of mitigation measures to prevent an excursion from risk control criteria.

At the end of 2024, an industrial version of the StabSys (system stability) application was rolled out: this is an automated cyclic model application that analyses transient stability in the RTE electricity system and the risk of loss of synchronism. This application provides enhanced monitoring of these phenomena, on an hourly basis, 24 hours a day.

INTER-AREA OSCILLATIONS

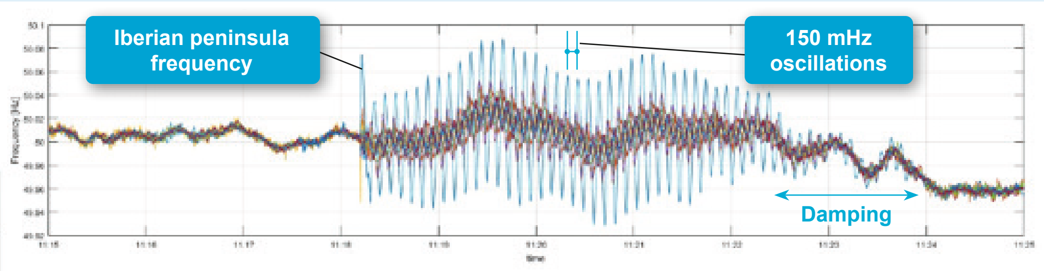
Inter-area oscillations (or inter-area modes) are complex electrotechnical phenomena that can arise between two or more parts of an extensive network. They appear when there are greater power exchanges or when borders are less well interconnected. In such configurations, an imbalance (a load variation or a disruption, for example) may cause synchronous generators in different geographical areas of the network to begin oscillating against each other, at a low frequency (between 100 mHz and 1 Hz), out of phase with each other. This gives rise to oscillations in all the electrical parameters, and particularly in the active power in the lines interconnecting the areas. The most poorly damped inter-area mode in Europe is currently the East-Centre-West inter-area mode, where oscillations in the Iberian Peninsula and Turkey are out of phase with central Europe, up to a frequency of around 200 mHz. As the Iberian Peninsula sits at the extremities of the European network, and the Franco-Spanish border is rather less well interconnected, the management of this border has a major impact on this mode.

To illustrate this phenomenon, the graph below shows the frequency variations that were recorded during the event that occurred on 1 December 2016.

The frequency value remained at around 50 Hz but varied significantly at different points in Europe's interconnected system.

This phenomenon destabilises the electricity system and if not damped can threaten safety, leading potentially to the tripping of production units and to the splitting up of the European network.

The deployment of equipment at numerous measuring points across the European system (Phasor Measurement Units, or PMUs), with data shared among Europe's network operators, means that the phenomenon is now monitored and its impacts are mitigated.



Monitoring of the damping of power oscillations across the European continent has revealed that this damping could be low over long periods. The connection of Ukraine and Moldova to the European Synchronous Area in March 2022 reinforced the need to monitor these oscillation phenomena.

Several oscillation events corresponding to the East-Centre-West inter-area mode were reported in 2024, including some that called for countertrading to cut back electricity exports from Spain to France. This was the case in particular on 10, 11 and 25 January, 21 February, 25 April, 30 September and 22 October 2024, amounting to 7 occurrences (compared to 8 in 2022 and 3 in 2023).

Forced oscillations caused by generating unit malfunctions

There were no events in 2024 involving forced oscillations.

An oscillation detection algorithm has been developed by RTE in partnership with Washington State University (OASIS Project), using the remote monitoring data of generating units. An initial version of an open-source system based on this algorithm has been tested on past events and will be made available to operational teams (excluding control rooms, for the time being) in 2025, in order to automate the process of pinpointing the location of generating units that may be causing forced oscillations.

System inertia

ENTSO-E is also working on the phenomenon of inertia and analysing the operating experience from events around Europe.

An electricity system's inertia reflects its capacity to limit rapid frequency variations during major imbalances in generation and consumption. Inertia is a key contributor to frequency stability in the system. The phenomena at play are major losses of generation, of consumption, or of exchange flows between areas (network separation).

An ENTSO-E-led study project launched in 2022 is modelling changes in system inertia, using the studies conducted in relation to the Ten-Year Network Development Plan (TYNDP). It aims to assess system inertia in the context of a changing European electricity system. Its simulations focus on scenarios with a break-up of the Continental Europe area into several separate sub-areas, as was the case in particular during the Franco-Spanish incident of 24 July 2021, or again on 4 November 2006 (which saw Continental Europe split into 3 areas). The results of these simulations are being used to draw up recommendations designed to ensure adequate inertia and thus guarantee system safety.

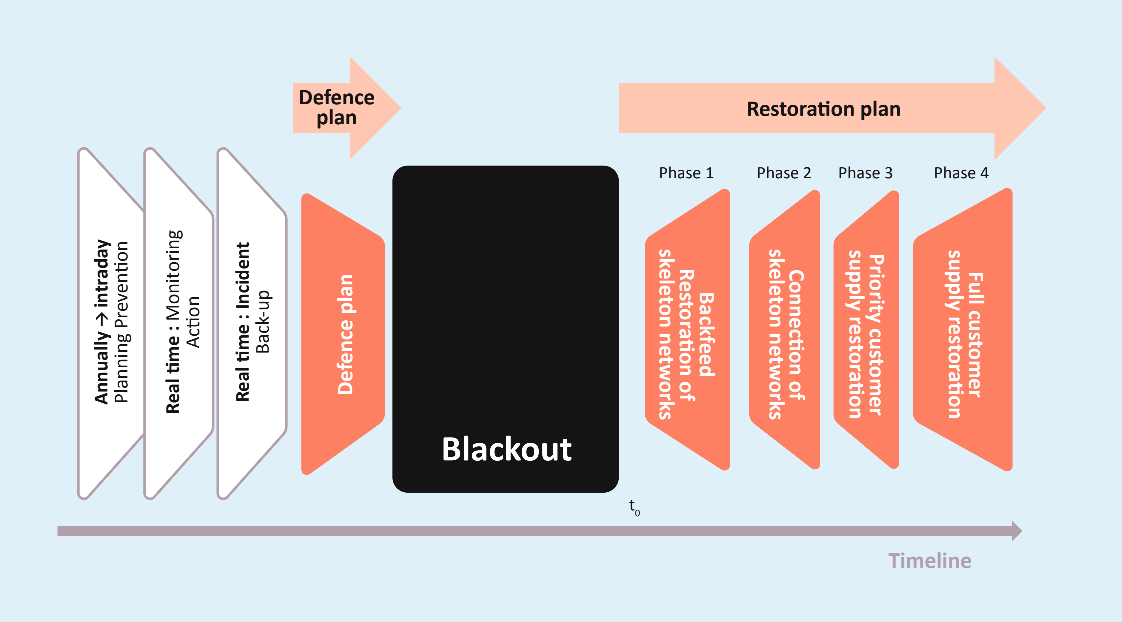
The 2022 and 2023 reports had highlighted reduced total system inertia in the future, the growing risk of a Europe-wide blackout in the event of a split from the continental network, and the vital delivery of instantaneous distributed inertia to limit any deterioration in the European system's resilience and ensure its robustness to such events. The 2024 study assessed several methodologies for sharing out inertia requirements, resulting in the selection of a methodology under which each country would ensure 2 sMW/MVA of inertia for 50% of the year, by 2035.

The proposed methodology would prevent any deterioration in inertia fulfilment, within this timeframe, compared with current levels. Applying this rule would not call for additional investment in the French electricity system before 2035, but would be more restrictive in the lead-up to 2040, when the same requirement of 2 sMW/MVA would have to be ensured 90% of the time. The selection of this second proposal would require specific investment in France. However, the requirements will be updated every two years based on TYNDP data, and the criterion for 2040 has not yet been finalised.

In 2025, the group will assist in defining a method for yearly monitoring of the inertia criterion (more than 2 sMW/MVA for 50% of the year), under Article 39 of the SOGL, which recommends monitoring inertia where necessary.

7.2 Prevention of large-scale incidents

THE ELECTRICITY SYSTEM'S DEFENCE-IN-DEPTH



THE DEFENCE PLAN

The Defence Plan brings together all the automatic mechanisms that deliver the corrective actions designed to counter the electrotechnical phenomena that can lead to network collapse, whose rapid onset and development precludes any human intervention. The Defence Plan covers the following actions, amongst others:

- The automatic separation of regions that have lost synchronism (loss of synchronism protection system);
- The automatic load-shedding of non-priority loads upon frequency drop (under-frequency load shedding);
- RTE's own automatic schemes under its Defence Plan (ADO/ADN, etc.);
- Automatic on-load tap-changer blocking.

Under-frequency load shedding

In France, since 2023, the management of under-frequency load shedding, shared between RTE and the DSOs, has been based on a standard 6-step load-shedding plan, ranging from 49 to 48 Hz, in keeping with the European Emergency and Restoration code.

The change in the energy mix on distribution networks has given rise to greater mingling of consumption and generation, with in particular the significant growth in solar power low-voltage connections in the midst of pockets of consumption. This mingling makes it more difficult to assess gross consumption since, depending on the level of power generated at a delivery point that is also a consumption point, this electrical entity can change from being a consumption point to a delivery point, depending on the day and time of year. This calls for a rethinking of the way in which under-frequency shedding is allocated and managed, as the current organisation could lead to the shedding of generation alongside load shedding, thus having the oppositive effect to the one intended. Discussions are underway, with ENEDIS in particular, to study the required changes to the existing under-frequency shedding arrangements.

THE SYSTEM RESTORATION PLAN (SRP)

Despite RTE's deployment of all the levers of action at its disposal, an abnormal combination of adverse events could lead to a total collapse of the power network (blackout) of a region, or of the whole country, or even beyond.

RTE must then restore normal system operation (the action of "system restoration") and must act rapidly to minimise the duration of the blackout's impact, in a controlled manner, keeping people and property safe, and in particular, avoiding any fresh collapse of the network.

RTE's strategy for restoring all or part of the system following a blackout, in the absence of any possible back-up from a grid that has remained energised (in France or abroad), relies on nuclear units in islanding operation. Gradual network restoration would be carried out using predefined skeleton networks, thus ensuring progressive re-energisation of priority customers, followed by the remaining loads.

The sequencing of this strategy depends on the availability of a blackout-resilient telecontrol system throughout the first three network-restoration phases of the SRP.

The 2019 implementation of the Emergency and Restoration code in France has meant the designation of nuclear power plants as the sole restoration service providers for France. However, in the event of insufficient availability of nuclear units in islanded mode, the generating assets that are available for backfeed scenarios and have black-start capacity could be called upon as appropriate (this represents 14 hydropower plants and 3 combustion turbines).

SRP blackout resilience projects

In accordance with regulations[21], RTE must have a System Restoration Plan that guarantees minimal impact on network users through rapid restoration to normal operating conditions, and can deliver backup power to essential substations for 24 hours.

In order to comply with these regulatory requirements, the SRP must be executed remotely from control rooms, throughout the period of substation auxiliary services autonomy. This requires telecommunications networks that are blackout-resilient, as well as power supply units with the expected autonomy (8 hours/10 hours/24 hours). Given the large number of circuit breakers that need to be operated, substation battery autonomy does not allow for the entire network to be re-energised by means of local operations.

Several large-scale projects have therefore been launched, some focusing on the telecontrol of RTE sites, and some on the wider involvement of all stakeholders contributing to the SRP (generating units and distribution system operators), with the object of ensuring the resilience of telecommunications systems (telephony, telecontrol and power supplies to telecommunications equipment), for both RTE's own systems and those that are shared.

21. The European code specifying emergency procedures for electricity system restoration (Emergency and Restoration Network code) and the public transmission system grid-concession specifications.

Cooperation with EDF for the joint management of safety in nuclear power plants and in the electricity system

NUCLEAR ISLANDING OPERATIONS, SKELETON NETWORKS AND VOLTAGE BACKFEED

For a nuclear reactor, an islanding operation represents a transition from a state of nominal operation (transmission of full power to the electricity system) to one of separation from the network, with the unit producing only the power needed for its own operation.

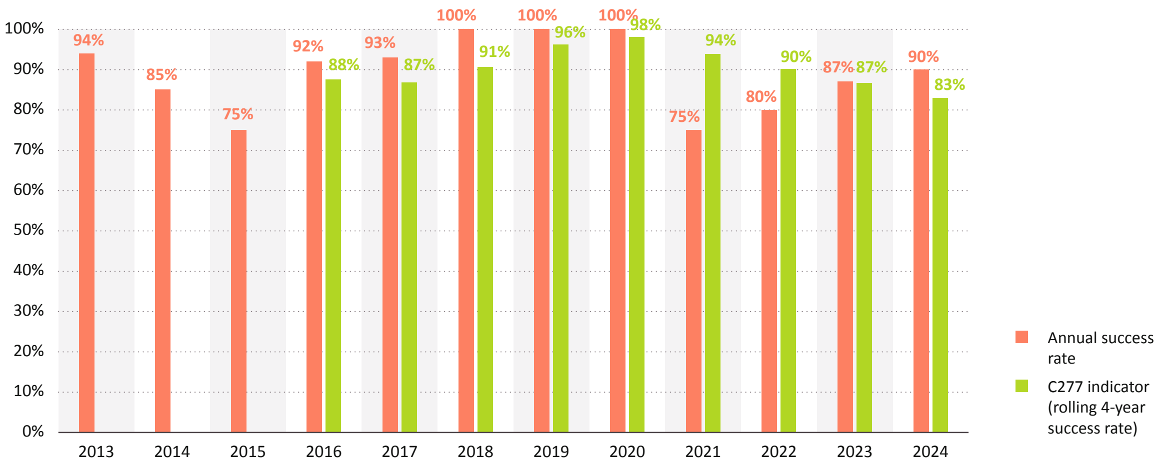
In the event of a blackout, the successful islanding operation of nuclear units is essential for nuclear safety, and is key to restoring the electricity system. Reactors that have completed successful islanding operation then enable the resumption of supplies to the auxiliary systems of nuclear power plants that were not able to carry out their islanding operation and thus require fast voltage feedback (a scenario of backfeed from one nuclear unit to another, or involving assets with blackstart capacity), but also to resupplying customers as rapidly as possible.

System restoration is dependent on the step-by-step re-energisation of 400 kV lines and lower-voltage substations (so as to achieve the necessary load restoration to minimise transient overvoltage phenomena), referred to as regional skeleton networks, which connect nuclear sites to each other so as to restore power to the substations of high-consumption areas.

Excluding blackouts, an unsuccessful islanding operation does not have an impact on the safety of the electricity system.

In 2024, the nuclear power plants performed **9 successful islanding operations** (both planned and unplanned), with a success rate for the year of 90% (and a rolling four-year success rate of 83%), a satisfactory result given the multiyear target of 60%.

FIGURE 21 – ISLANDING SUCCESS RATE



A responsibility shared by EDF and RTE

In the event of a blackout, the System Restoration Plan is essential in ensuring both nuclear safety and the ability to rapidly restore normal system operation.

The “C277” contract sets out the commitments of each party in the event of a blackout: RTE provides the public transmission networks, with the object of running the backfeed scenarios and delivering backup power to the auxiliary supplies of plants (evaluated at 3, nationwide, within 2 hours), while EDF provides the nuclear units that have successfully completed their islanding operation (60%, with 24 hours of operation) to set in motion the network restoration.

Moreover, the nuclear power plants (NPP) have also been designated as the only high-priority significant network users, for which supply must be restored first, at the start of the system restoration operations, for reasons of nuclear safety and because of their capacity to rapidly re-supply consumption. The establishment of the 7 regional skeleton networks meets this regulatory requirement.

This contractual framework implies a commitment from both RTE and EDF to carry out field and simulator tests to ensure that, should the need arise, the equipment, incident management procedures, organisation and operators will meet the expectations of both companies. In 2024, all these tests were carried out (a total of 36).

The aim of the field tests is to assess the ability of the nuclear units, after a successful islanding operation, to re-energise, at a set voltage and frequency, a test-network that may either be limited to the switchyard of the islanded nuclear unit (busbar voltage feedback), or may consist of a series of installations, or even another nuclear unit (external voltage feedback), until the test-network is reconnected to the main network.

As a result of these tests, 92% of the scenarios for re-supplying power to the auxiliary systems of nuclear units are now considered to be operational (tested in the last 6 years), and 8% of these scenarios are considered usable (tested in the last 6 to 12 years).

8 Information and telecommunications systems

8.1 Control room systems

In 2024, the availability of critical applications stood at over 99.5%, while the availability of the systems supporting the safe operation of the electricity network remained stable, in line with previous years.

The number of significant events rose in 2024, particularly for level-A SSEs (21 in 2024 compared to around ten per year since 2021).

Two level-B SSEs were recorded in 2024 (1 in 2023), on 18 January 2024 and 10 December 2024. They brought about the loss of the signal sent to the contributors to secondary frequency control, following a hardware failure, in the first event, and following maintenance on a database, in the second.

Each of these events was subject to an in-depth investigation, and the resulting actions were aimed primarily at facilitating the detection of a malfunction, so as to speed up the elimination of the malfunction.

RTE's new SCADA is now fully operational

A trial run of RTE's new SCADA began on 20 July 2023, covering network operation and supply-demand balancing activities. The trial was extended on 14 May 2024 to include the functions supporting the input to network studies tools. Adjustments made in response to the findings and observations raised during this trial run translated into a decision to move to the operational phase: StanWay has been the sole network operation system since 1 October 2024.

The Alert and Safeguard System (SAS)

SAS ensures the secure transmission of RTE's alerts and notices of required actions by the contributors to safety, thereby guaranteeing control of degraded or risk-significant situations.

The safeguard of the system calls for rapid action and coordination between RTE control rooms and:

- the control rooms of distribution and generation companies.
- RTE's operational teams.

With SAS, the operators transmit safely, accurately and rapidly pre-drafted notices and messages, including:

- System safeguard notices, for faster implementation of actions by participants in situations with supply-demand pressures, when the safety of the electricity system may be compromised.
- Alert notices, which are used for disturbed conditions.

In 2024, the availability rate for RTE's Alert and Safeguard System (SAS) equipment was entirely satisfactory: no level-A SSE was recorded (versus 1 level-A SSE in 2023, and 2 level-A SSEs in 2022).

The number of SSEs resulting from failure to acknowledge system notices or inappropriate actions by generating companies, distribution companies or RTE operators, in cases of actual "critical status, inadequate reserve margins" alert notices (severity level A), stood at 2 (compared with 36 in 2023, 50 in 2022 and 31 in 2021).

This significant improvement reflects the reduced number of calls for action made to participants in 2024, compared to previous years, as well as the implementation of targeted action plans (procedures and organisation, skills development, resilience of systems, software and configuration updates).

Among the installations connected to the public electricity transmission network, the high-power sites are equipped with an Alert and Safeguard System, but this is not the case for lower-power installations. And in view of the large overall number of these facilities (RES, aggregators, etc.), notices issued by RTE may be required in some degraded situations, in order to manage the operating modes of these installations. The means of communication with the main control rooms or management centres of these installations should be considered, to ensure appropriate operation, particularly at times of significant deterioration in operating conditions or, where applicable, of network restoration.

The process of network studies against a background of variable power generation and exchange

In order to make the right decisions, ranging from network investment to the real-time management of operations, network studies are carried out for different timelines. The way these studies are conducted is changing in response to the energy transition and to European market integration.

For longer-term studies, the process can be based on “multi-situational” analyses, simulating several annual scenarios at the European level, with hourly granularity, and down to the level of the output of local renewable energy fleets.

The scheduling process with the DSOs is also evolving, with the alignment of processes for advance notification of works, an earlier notice period for limitations due to constraints, so that they can be managed with minimum curtailment of production from RES (this must be underpinned by consistency in contracting), and the deployment of automated control systems.

For shorter-term studies, the process for the studies encompasses renewable generation predictions based on weather forecasts, the generation schedules of contributors, and expected energy exchanges. This forecast data with half-hour or even quarter-hour granularity is updated at least every hour, from two days ahead up to real time.

The continuous sharing of this data with neighbouring TSOs and Regional Coordination Centres (RCC), and the coordination it allows, ensures that joint power network operation strategies are consolidated and updated.

R&D studies support these changes and explore uncertainty management methods in particular.

The “Convergence” platform is used for network studies, ranging from system development studies to real-time, and is therefore important for the system’s safety. Convergence is supported by the SEA (Sûreté en Anticipation”, or advanced safety monitoring) system, which allows the teams working in real time to prepare for network operability closer to real time.

9 level-A SSEs linked to these network studies systems were nonetheless reported in 2024:

- 3 level-A SSEs resulting from a malfunction in the SEA application;
- 6 level-A SSEs linked to configuration issues or resulting from the introduction of a new database.

These events are connected to changes made during 2024: firstly, the input from StanWay into the research application chain since 14 May 2024, and secondly, updates to the SEA system at the end of the year.

The IPESN system (Integration of Renewable Energy in the National System) is used for short-term studies and during system operation. It provides estimates, for a selectable time period ranging from 4 days ahead to 2 days after, of the power already generated by wind and solar photovoltaic energy sources, as well as forecasts of the power they will generate at local, regional, and national level.

No level-A SSE linked to the availability of the systems used for analysing supply-demand balance, balancing, or markets was reported.

8.2 The telecommunications network and information system

The operational safety of the electricity system is closely tied to the efficient operation of the secure telecommunications network, to the information system (IS), and to their ability to counter cyber-threats.

Past telecommunications systems

The Secure Fibreoptic Network (ROSE), an infrastructure owned and operated by RTE, is made up of about 22,000 km of fibreoptic cables, and delivers the secure telecommunications services contributing to the safety of the electricity system: "high-level" telecontrol, the exchange of information between electrical fault protections, and secure telephony.

In 2024, out of a total of 23 SSEs, there was 1 level-A SSE attributable to the ROSE infrastructure (the failure of a card).

No level-A SSE was reported in relation to the operation of the Secure Telephony System (STS) (compared to 2 level-A SSEs in 2023).

RTE's new telecommunications systems

In order to renew these telecommunications networks, RTE has commissioned the deployment of the INUIT (Integrated Telecommunications Network Infrastructure) network and the SUR-T high-speed and very-high-speed network across all its tertiary and industrial sites. Services are gradually migrating to these fibreoptic networks, and the dismantling of older telecommunications networks will follow.

SUR-T is an IP network that is independent of INUIT and dedicated to applications for electricity system operation. It is designed to address the risk of systemic failure of one of the telecommunications networks, and to guarantee a minimum level of observability and controllability in the electricity system.

By the end of 2024, INUIT hardware had been deployed across the majority of relevant sites, while the SUR-T hardware had been rolled out across more than half the relevant sites.

In 2024, out of a total of 23 SSEs, 1 level-A SSE was attributable to the INUIT infrastructure (a defective card).

Cybersecurity

The security of RTE's information system (IS) is an essential part of the operational safety of the electricity system, particularly for the industrial IS, but also for the IS for information exchange with customers, market players and partners.

In 2024, aside from its operations in the run-up to the Olympic Games and the surveillance system put in place during the Olympic events, RTE also implemented various other measures focused on enhancing the cyberattack-resilience of its systems and organisation.

The European Cybersecurity Code

Commission Delegated Regulation (EU) 2024/1366 of 11 March 2024 supplementing Regulation (EU) 2019/943 of the European Parliament and of the Council, establishing a network code on sector-specific rules for cybersecurity aspects of cross-border electricity flows (Network Code on Cybersecurity, NCCS) entered into force on 11 June 2024.

This regulation follows on from the EU's 2022 action plan for the digitalisation of the energy system. This plan stipulates that the cyber-resilience of the electricity system must be strengthened by way of new legislation covering sector-specific rules for cybersecurity aspects of cross-border electricity flows.

The NCCS sets out security requirements and standards for operators whose activities have an impact on cross-border electricity flows within the EU. It establishes common rules for assessing cybersecurity risks, reporting cyberattacks, threats and vulnerabilities, and implementing a cybersecurity risk management system. It also includes recommendations on energy supply-chain security.

Pursuant to Article 48 of 11 March 2024, the Energy Regulatory Commission (CRE) designated RTE as a critical-impact entity. On a voluntary basis, this designation requires the entity to provisionally establish its high-impact and critical-impact cybersecurity perimeters, and then ascertain which assets should be included in the initial cybersecurity risk assessment.

This proposed risk assessment methodology was approved by all transmission system operators on 7 March 2025, with EU-DSO Entity approval confirmed on 5 March 2025.

9

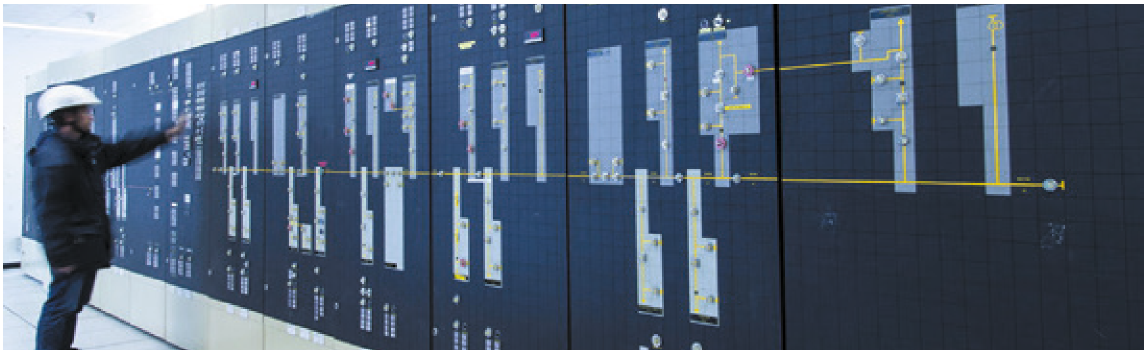
Organisation

9.1 The ORTEC emergency response organisation

In 2024, there were no emergencies that called for the activation of the emergency response organisation (except for the information system emergency response organisation, and the national and Paris Region emergency response organisations, which were pre-emptively activated for the opening ceremonies of the 2024 Paris Olympic and Paralympic Games).

The year was marked by 3 main areas of focus :

- The continued preparations for **the 2024 Olympic and Paralympic Games,** and the deployment of the emergency response organisation during the Games. The two priority areas of preparation involved strengthening the emergency organisation to adapt it to the scale of the event, and forming a team of RTE liaison officers whose remit was to serve as interfaces between RTE and the Paris 2024 organisation.
- The continued **implementation of changes to the emergency response system, in line with the organisational changes.**
  - The establishment of the Electricity System Operation Centres in Paris and in Nantes (COSE-Paris and COSE-Nantes) allowed the H24-room managers to resume a 24/7 on-call role in the control room, and resulted in improvements to ORTEC's coordination in the Ile-de-France Region.
  - The creation of "pools" (operational leaders and for logbooks) under the responsibility of each ORTEC representative, and operating on the principle of a statistical on-call duty.
- The significant involvement of the ORTEC community in the RésilienSE Project (system cyber-attack-resilience) and the deployment of a corresponding emergency exercise.



9.2 System safety audits and internal audits

In the context of its internal audit process, RTE assesses yearly its management of operational activities (and therefore of system safety) in light of the risks it has identified and prioritised, and of the measures it has taken and their effectiveness.

In 2024, three safety-related topics were audited internally:

- The ‘Operational risk control’ policy – in relation to short-circuit current;
- The ‘Operational risk control’ policy – in relation to post-operation analysis;
- Design, development and implementation of market mechanisms.

These audits concluded that control of electricity system operation was entirely satisfactory.

9.3 European coordination

The electricity transmission system is a European network. Today, the 43 TSOs in 36 countries are linked by around 420 interconnections, including around 30 on French borders. The safety of the French network therefore relies in part on the efficient operation of the European electricity system.

Since the emergency synchronisation of the Ukrainian TSO’s (Ukrenergo) power network to the synchronous area on 16 March 2022, the Regional Group Continental Europe (RGCE), which oversees within ENTSO-E the operational and frequency-related matters in the Continental Europe (CE) Synchronous Area, has led the studies and analyses needed to understand the potential impacts of this synchronisation on the European network, and gradually increase the exchange capacities at the borders with Ukraine and Moldova.

At the end of 2023, the Ukrainian electricity system was pronounced compliant with all measures and regulations (defined in the catalogue of measures), paving the way for its TSO to become a Member of ENTSO-E. And in January 2024, the Ukrainian TSO became a Member of ENTSO-E.

At the end of 2023, the Moldovan TSO (Moldelectrica) also joined ENTSO-E as an Observer Member. As for Ukrenergo, assessment of Moldelectrica’s compliance with European rules continued throughout 2024.

2024 was also marked by preparations for **the connection of the Baltic States to the Continental Europe Synchronous Area in February 2025.** These preparations included an analysis of compliance with European codes, led by ENTSO-E, as well as significant investments in network equipment and SCADA systems to support system balancing and voltage control operations.

Coordination in response to the incident in the Balkans on 21 June 2024

Another noteworthy event for Europe in 2024 was the major incident that occurred in the Balkans. This was an event classified as a scale-3 incident (under the incident classification scale methodology defined in Regulation (EU) 2019/943) on the European severity scale used to classify incidents in the European electricity system, that is to say, the highest level of severity.

On Friday 21 June 2024, the loss of several transmission network installations within a short period of time led to a major disruption of the Continental Europe power system, with a partial blackout in the western Balkans. The incident affected Albania (OST), Bosnia and Herzegovina (NOSBiH), Montenegro (CGES) and Croatia (HOPS). The restoration process, initiated immediately after the incident, allowed for a rapid return to normal operation, approximately 3.5 hours after the first installation tripped.

Given the scale of the incident, ENTSO-E established an Expert Panel tasked with investigating the causes of the incident and providing the necessary recommendations to enhance network robustness and Europe-wide coordination.

The interim report published at the end of 2024 details the system conditions before the incident, charts the changes in these conditions during the event, and outlines the measures taken immediately after the incident occurred, prior to the initiation of system restoration. It also describes the communication between regional coordination centres (RCCs) and transmission system operators (TSOs).

This interim (fact-driven) report is the end product of a process of event-related data collection and preparation, which began immediately after the incident had been resolved. It provides the basis for in-depth analyses led by a team of experts (made up of representatives from ENTSO-E, ACER and national regulatory authorities), which will be included in the final report.

Network codes, derived from the European Union's Third Energy Package, set out the main rules that must be followed by all parties for any interconnected network operation. The set of codes has been published and is now in force.

Covering different fields (operation, markets, connection), the codes, within their scope, support the safety of Europe's interconnected electricity system:

- The Emergency and Restoration code sets common standards for the management of network emergencies and for system restoration. The System Operation Guideline code provides a set of common principles for electricity system operation;
- In regard to markets, safety is a cornerstone of the codes on balancing (Electricity Balancing), which deal with supply-demand balancing, the Guidelines on Forward Capacity Allocation, which deal with rules for long-term markets, and the Capacity Calculation and Congestion Management code, which aims to structure short-term and long-term electricity exchanges, respectively.
- The Requirements for Generators code specifies requirements for the connection of generating facilities and, more specifically, technical requirements designed to increase the resilience of the electricity system;
- The Fourth Energy Package, titled 'Clean Energy Package', came into effect on 5 July 2019 and sets out new rules, in particular a minimum 70% interconnection capacity that must be made available for cross-border trading, as well as regulations on risk-preparedness in the electricity sector.

Work has continued on implementing the network codes specified in the European regulatory framework, and has been marked by several Europe-wide milestones and projects.

Continued roll-out of RCC roles

European regulations require that every European TSO should receive the services of a RCC (Regional Coordination Centre). As one of the founding members, RTE uses the services of CORESO, as well as those of TCNET, for some services.

The following key services are now provided by the RCCs:

- Pan-European Common Grid Model (CGM);
- Coordinated Capacity Calculation (CCC);
- Coordinated Security Analysis (CSA);
- Pan-European Short-Term Adequacy (STA) assessment of supply and demand;
- Outage Planning Coordination (OPC).

In addition to these key services, the RCCs work closely with the European TSOs to carry out the tasks set out in European regulations.

Over the next few years, CORESO will have to deploy all 16 services, 10 of which are set out in the Clean Energy Package, which have been or will be mandated to it by the TSOs of the two operation regions (or SORs – System Operation Region), Central Europe and SWE.

The following two services have already been in place since 2023:

- Event analysis and operating experience feedback (post-operation analysis): this service carries out detailed analyses of major incidents involving multiple TSOs. The aim is to issue recommendations and best practices for implementation;
- Training and certification: this service covers training for operators, as well as a certification programme for continued proficiency.

The remaining services required by the Clean Energy Package are currently being incorporated into operational processes, or are being elaborated, in accordance with a specific methodology, for deployment in the coming years. In 2024, the RCCs and transmission system operators continued to work closely to drive forward the implementation of the remaining services. This concerns in particular:

- Sizing and mutual agreement on sharing secondary reserves to ensure supply-demand balancing (Regional Sizing of Reserve Capacity);
- An assessment of the volume of available balancing offers (Regional Procurement of Balancing Capacity);
- Coordination for post-blackout network restoration (Regional Restoration at Request of TSOs).

European Risk Preparedness Plan

In 2023, work led by ENTSO-E with input from the various TSOs and member states yielded a new methodology for defining electricity crisis scenarios, which was approved by ACER.

This new methodology was applied to reassess the 31 regional crisis scenarios that had been established in 2020. The new cycle of updates focused on a smaller number of scenarios that were relevant for each region, and generated simulations based on statistical models. The aim was to simulate these scenarios and develop corresponding risk management action plans. The TSOs and government departments are responsible for providing the inputs needed to assess the likelihood of each scenario occurring, as well as their potential impacts (including inter-regional impacts).

This approach relies on the involvement of several stakeholders in order to ensure alignment with the national risk preparedness plans, and on regional coordination where necessary. The Member States contribute to this process through a number of competent authorities that work closely with the Regional Coordination Centres (the RCCs like CORESO), the regulatory authorities, and the Electricity Coordination Group (ECG).

APPENDIX 1: Glossary of terms

Term	Description
Balancing mechanism (BM)	French law lays down that generation companies must provide RTE with the power that is technically available, for purposes of supply-demand balance. This is achieved by means of the balancing mechanism, which enables RTE to pool the resources of contributors through a permanent open mechanism, and allows the contributors to benefit from their shedding capacity or generation flexibility. Drawing on the price-volume offers, RTE performs its balancing operations by selecting and combining offers on the basis of price until volume requirements are met. Arrangements are in place to deal with shortfalls: ▶ for deadlines of more than 8 hours, RTE sends an alert notice requesting additional offers; ▶ for deadlines of less than 8 hours, a "degraded mode" notification allows RTE to mobilise, beyond any potential additional offers, one-off offers and other resources that have not been submitted for balancing.
Primary and secondary frequency control	In the event of any unforeseen issue adversely affecting the balance between generation and consumption, primary frequency control automatically provides almost immediate restoration of balance, through the group participation of all the partners in the synchronous network. Rules are set by the ENTSO-E Continental Europe Regional Group to ensure that measures are taken to maintain frequency within predefined limits. Subsequently, secondary frequency control by the partner responsible for the disruption automatically cancels out any residual deviation from the reference frequency, along with any deviations from scheduled electricity exchanges between the different control areas.

<table>
<tr><th>Term</th><th>Description</th></tr>
<tr><td>ENTSO-E</td><td>Established at the end of 2008, the European Network of Transmission System Operators for Electricity has been the sole association of European TSOs since 1 July 2009.

ENTSO-E's remit is to strengthen cooperation between the TSOs in key areas such as the development of network codes regulating technical aspects and market mechanisms, coordinate the European transmission network's operation and development, and conduct research.

Under its charter, the association's main decisions are taken by its General Assembly. An Executive Board is responsible for general oversight and strategic planning. Operational matters are dealt with by four committees and their subdivisions: the Market Committee (MC), the System Development Committee (SDC), the System Operations Committee (SOC), the Research and Development Committee (RDC), and a Legal and Regulatory Group. RTE is represented on all these bodies.

In order to ensure the technical coordination of synchronous interconnected TSOs in the Continental Europe zone, and the evaluation of commitments to safety, as set out in its 8 Policies, and endorsed in the Multilateral Agreement signed by members of the former association (Union for the Coordination of the Transmission of Electricity), SOC has set up an ad hoc sub-regional body, the Regional Group Continental Europe (RGCE).</td></tr>
<tr><td>Secure telecommunications network</td><td>This secure network consists of a dedicated telecommunications infrastructure, mainly owned and operated by RTE, and tasked with conveying all the information (voice, data) required for telecontrol.

These systems fulfil the following functions:
▶ the ("low-level") transmission of the telecontrol data for all substations – and of a limited number of telephone conversations between very-high-voltage substations – and for all substation group management centres;
▶ the ("high-level") transmission of telecontrol data and of telephone conversations between control rooms and substation group management centres;
▶ the transmission of telecontrol data and of telephone conversations between generating units and control rooms;
▶ the transmission of telecontrol data and telephone conversations between control rooms and the distribution network operation centres.</td></tr>
</table>

Term	Description
Performance controls of generating units	Given the critical nature of the services provided by generating facilities, once they are connected to the French public electricity transmission network, they may be subject to performance controls. These controls check the behaviour of the generating units in relation to primary and secondary frequency control and power control (static gain, or “statism”, planned reserves, response times, etc.), and also in relation to primary and secondary voltage control (provision of the contractual framework in the U/Q diagram, response dynamics).

APPENDIX 2: Glossary of abbreviations

ACER	Agency for the Cooperation of Energy Regulators
ADN	Northern Automatic Scheme against Voltage Collapse
ADO	Western Automatic Scheme against Voltage Collapse
aFRR	Automatic Frequency Restoration Reserve (secondary reserve)
ANSSI	National Information Technology Services Security Agency
BCP	Business Continuity Plan
BM	Balancing Mechanism
BRP	Business Recovery Plan
CACM	Capacity Allocation & Congestion Management
CCC	Coordinated Capacity Calculation
CCR	Capacity Calculation Region
CGM	Common Grid Model
CGS	Critical Grid Situation
CONSOL	Application for the calculation and display of real-time estimation curves, and multiregional results
CORE	Capacity Calculation Region covering Central Western Europe and Central Eastern Europe
CORESO	Coordination of Electricity System Operators (Brussels-based RCC)

CORSN	Operational Centre for Digital Networks and Systems
COSE	Electricity System Operation Centre
CRE	Energy Regulatory Commission
CSA	Coordinated Security Analysis
CURTE	Power Transmission System Users' Committee
DACC	Day-Ahead Capacity Calculation
DGEC	General Directorate for Climate and Energy
DSO	Distribution System Operator
EBGL	Electricity Balancing Guidelines
ECG	Electricity Coordination Group
END	Energy not dispatched
ENTSO-E	European Network of Transmission System Operators for Electricity
EU-DSO Entity	Association of Distribution System Operators (DSOs) in Europe
FCAGL	Forward Capacity Allocation Guidelines
FCR	Frequency Containment Reserve (primary reserves)
FW	Firewall – key component of internet access architecture
HLM	High Level Meeting
HTA	HV (A) High Voltage A, managed by the DSOs
HTB	HV (B) High Voltage B
HVDC	High Voltage Direct Current
ICS	Incident Classification Scale
IDCC	Intraday Capacity Calculation
INUIT	Integrated Telecommunications Network Infrastructure
IPES	Insertion of RES in the Electricity System

ISP	Imbalance Settlement Price
LPM	Military Programming Act
MARI	Manually Activated Reserves Initiative (management of fast reserves with a 15-minute activation time)
mFRR	Manual Frequency Restoration Reserve (tertiary reserves)
MOC	Maximum Operating Current
NCCS	Network Code on Cybersecurity (common European framework for the cybersecurity of cross-border electricity flows)
NCER	Network Code Emergency and Restoration
NPP	Nuclear Power Plant
OPC	Outage Planning Coordination
ORTEC	RTE emergency response organisation
PER	Regional Exchange Gateway
PICASSO	Platform for the International Coordination of the Automatic frequency restoration process and Stable System Operation
PLASMA	Equipment Monitoring Software Platform
PMU	Phasor Measurement Unit
RCC	Regional Coordination Centre
RES	Renewable Energy Sources
RfG	Requirements for Generators
RGCE	Regional Group Continental Europe (ENTSO-E)
ROSE	Secure Fibreoptic Network
RR	Replacement Reserve (BM)

S3REnR	Regional Grid Connection Scheme for Renewable Energies
SAS	Alert and Safeguard System
SCC	Stress Corrosion Cracking
SCADA	Supervisory Control and Data Acquisition
SDB	Supply Demand Balance
SDDR	RTE Ten-Year Network Development Plan for France
SLFC	Secondary Load Frequency Control
SOGL	System Operation Guidelines
SOR	System Operation Region
SRP	System Restoration Plan
SSE	Significant System Event
STA	Short Term Adequacy (pan-European supply-demand balance assessment)
STANWAY	Network operation and SDB management system
STS	Secure Telephony System
SVC	Secondary Voltage Control
SVC	Static Var Compensator
SWE	South-West Europe (Capacity Calculation Region)
TC-BS	Automatic on-load tap changer blocking scheme
TERRE	Trans-European Replacement Reserve Exchange (management of tertiary reserves, traded in 30-minute blocks)
TOC	Transient Overcurrent
TSCNET	RCC covering Central and Eastern Europe, based in Munich
TYNDP	ENTSO-E Ten-Year Network Development Plan for Europe
UFE	French Electricity Union (professional association of the electricity sector in France)

Le réseau
de transport
d'électricité

Immeuble Window
7C Place du Dôme
92073 PARIS - LA DÉFENSE CEDEX
www.rte-france.com

RTE Réseau de transport d'électricité, Société anonyme à Directoire et Conseil de surveillance au capital de 2 132 285 690 € - RCS Nanterre 444 616 258 - © RTE - Document non contractuel - Mise en page : Good Eye'D - Visuels © Médiathèque RTE et © Interstellar - Adobestock - Impression sur papiers issus de forêts gérées durablement.