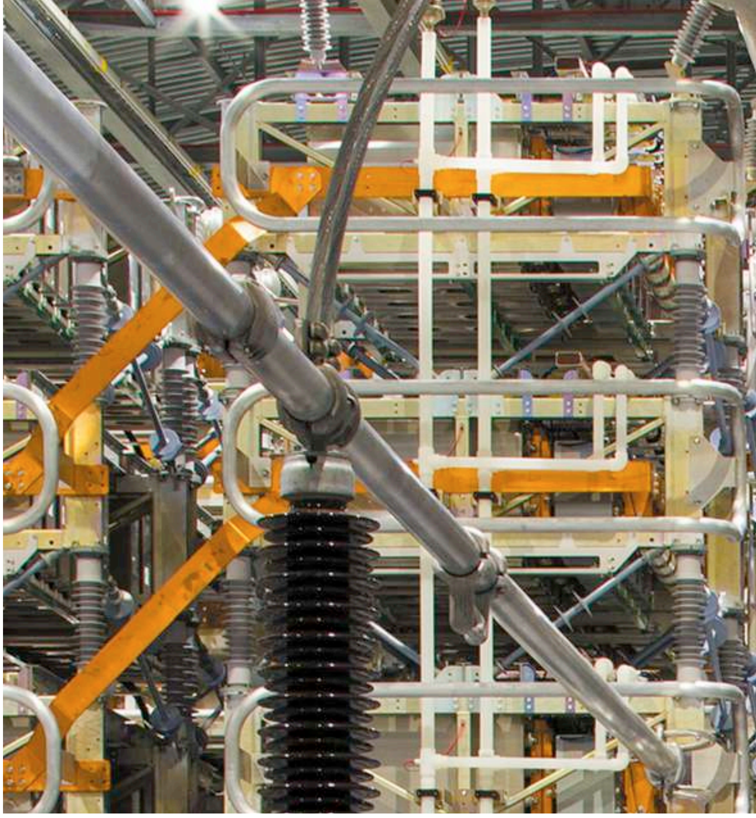
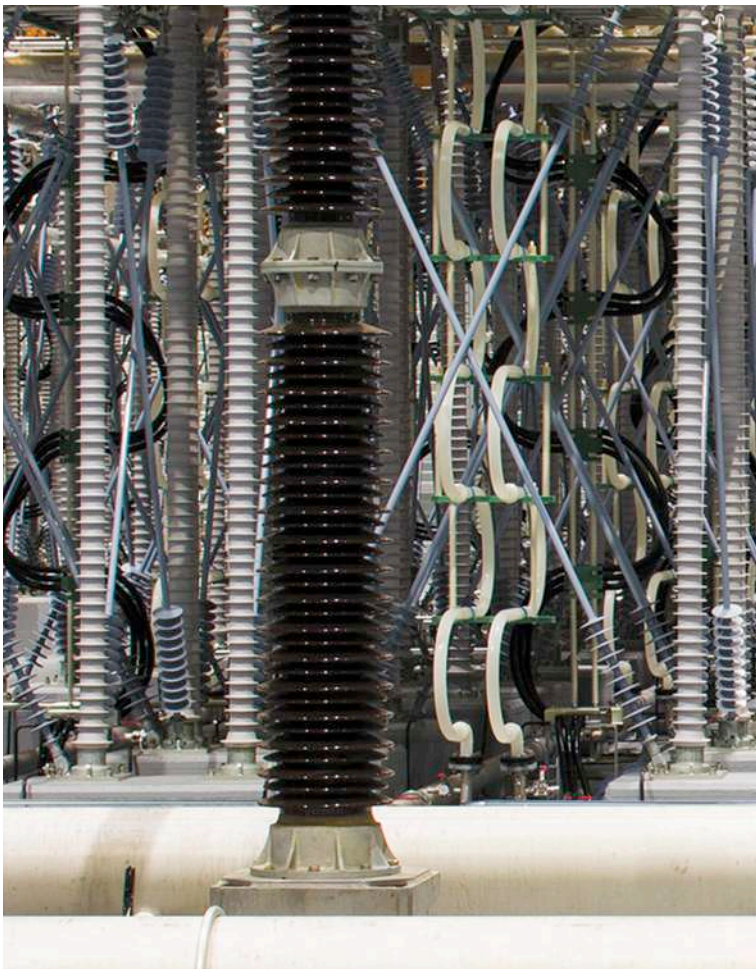
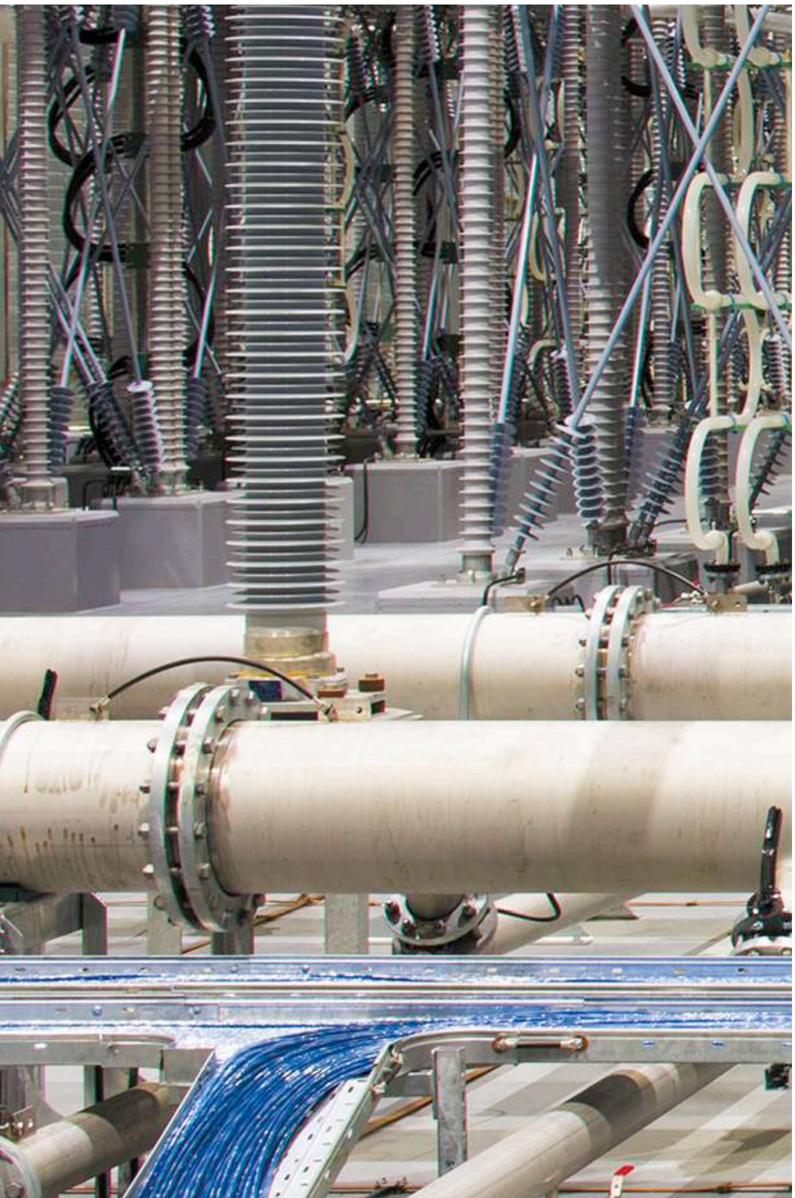
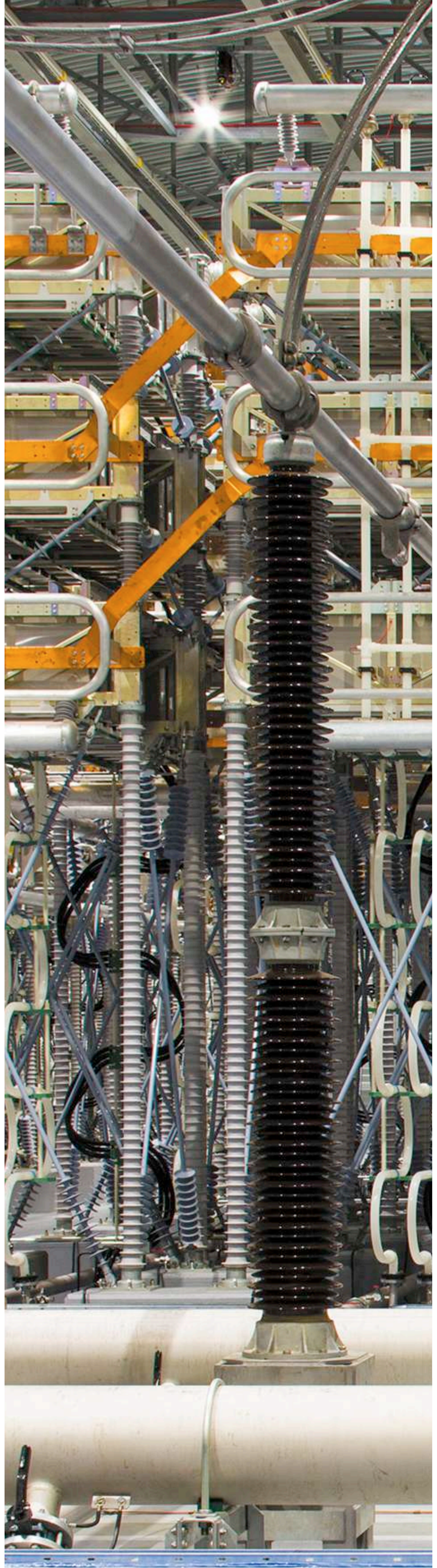
Le réseau
de transport
d'électricité

RELIABILITY REPORT
2022









Summary

01. Overview

1.1 The analysis of the key indicators for 2022 demonstrates a satisfactory level of operational reliability

2022 was marked by two main events, namely the end of the health crisis and the Ukraine war. As in 2021, the underlying trend remains that of **an electricity system undergoing more and more balancing, with a growing share of renewable energy that does not yet contribute to flexibility or system services,** and **significant flow variability** linked to changes in the energy mix; this is all taking place **at a time** when **the availability of the nuclear fleet is at a historic low.** All contributors to reliability in France and Europe must remain vigilant in this rapidly changing environment.

The following points should be highlighted for 2022:

- **A slight increase in the number of Significant System Events (SSEs) compared to 2021, and a continuing overall upward trend in the number of SSEs since 2017;**
- **A further rise in the number of breaches of high voltage limits.** These breaches can be explained by several factors:
  - **a drop in electricity consumption.** The geopolitical context and the structural limitations on access to resources have led to a rise in the cost of energy, which has had a considerable impact on electricity consumption. Particularly mild temperatures have also contributed to reduced consumption.
  - **the historically low availability of the nuclear fleet,** which has significantly restricted the available means of managing voltage;
  - **HV(A) networks increasingly placed underground;**
  - **the rise in HV(A) electricity production,** reducing the share carried by the public transmission system.

This trend is a reminder of the **importance of the availability and continued performance of the fleet of dispatchable energy resources,** until the new renewable generation technologies are able to provide equivalent system services.

Given these risks, RTE and relevant stakeholders in France (CURTE, DGEC, CRE, distribution system operators) and in Europe within the framework of ENTSO-E, have taken numerous actions to guarantee the highest level of reliability:

- Assistance with the development of **flexibility and modulation in renewable power generation,** to support supply-demand balance management and ensure the reliable operation of the network (management of 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 service offers** of the different contributors, in coordination with the distribution system operators.
  Some of the issues related to high voltage electricity may be addressed by changing the setpoint values (tangent phi) of the HV(A) production facilities, and wind power installations in particular. These modifications, made as and when needed, require further development.
- Continued implementation of measures to **guarantee adequate supply-demand margins** and to deliver a lasting improvement in the quality of frequency (mobilising new flexible products as part of RTE's call for tenders, certification of new reserve capacities such as storage systems and distributed energy aggregators, the establishment of the European exchange platforms, etc.).
- **Enhanced cooperation between the transmission system operators and the European coordination centres,** building on the roll-out of services planned under the European network codes.
- **Increased cross-border flow capacity.**
- **Expansion of the programme to install voltage compensation systems,** and the introduction of measures to develop the contribution of distributed generation to voltage control.

Also worth noting for 2022 is the **implementation of the contingency plan for winter security of supply,** in conjunction with the public authorities, which paved the way for **additional mechanisms for supply and demand balance,** including in particular:

- an information campaign inviting consumers of all types to moderate or shift their electricity use,
- an updated and streamlined EcoWatt scheme,
- strengthened measures to protect the power system,
- a shift in the off-peak midday hours during the winter period,
- an adjustment to the framework for calls for electricity supply from co-generation units subject to a purchase obligation, to ensure their participation during EcoWatt orange and red alert days.

The electricity system was placed under enhanced monitoring from the autumn of 2022 onwards. In light of the drop in consumption seen between October and December 2022, combined with mild temperatures and an efficient European daily market enabling electricity imports, **RTE did not issue any EcoWatt alert.**

Lastly, 2022 saw the permanent connection to the network of **Eleclink**, the **private HVDC interconnector between France and England,** and of the CCGT plant at Ponant-Landivisiau, and **the first MW to be produced by off-shore wind (St-Nazaire).**

02. Significant System Events (SSEs)

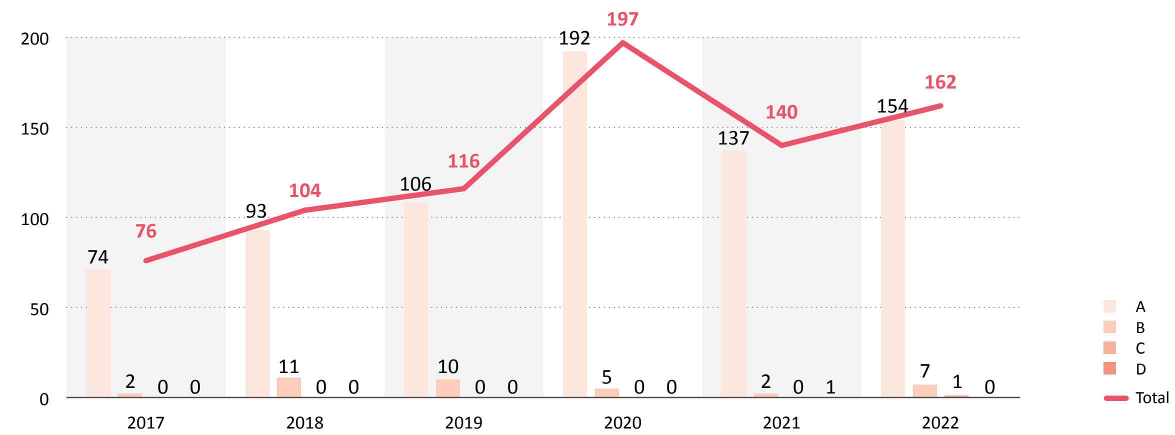
SIGNIFICANT SYSTEM EVENTS – THE SSE CLASSIFICATION SCALE

Every year, RTE evaluates the system's operational reliability by recording Significant System Events (SSE). They are classified on a scale of severity from 0 and A to F. These events constitute incidents which may result from diverse causes. Though it has more gradations, RTE's classification is consistent with the Incident Classification Scale (ICS) put forward by ENTSO-E, with its four levels of severity. Monitoring SSEs over several years brings to light low-level trends, and measures over time the effectiveness of the actions taken to improve operational reliability.
Events classified from A to F are considered as having a proven impact on reliability: the magnitude of this impact increases from A (localised, single and controlled incident) to F (widespread incident). Level-0 events are considered as having no proven direct impact on reliability (low-level events) and are used for trend analysis.
In the case of an **A or B rated SSE, the reliability of the electricity system is not put significantly at risk and remains under control** (the SSE scale goes from A to F in ascending order of severity as it affects reliability).

The SSE classification scale has 5 headings: Operation, Network, Control Systems, Generation, and Distribution.

With 154 events classified as A, 7 classified as B, and 1 classified as D, **2022 saw a slight increase in the number of Significant System Events (SSEs) compared to 2021, and a continuing overall upward trend in the number of SSEs since 2017.**

TREND IN SSES WITH A SEVERITY CLASSIFICATION ≥ A



This general trend since 2017 stems from the fact that **the electricity system is adapting to the change in the energy mix, with an ever-growing need for balancing, a context that was exacerbated by the health crisis in 2021 and by significant geopolitical tensions in 2022,** as characterised by:

- A generating fleet that is offering **fewer opportunities in terms of flexibility and system services** than it has in the past. This fleet comprises a growing proportion of renewables, which do not yet contribute to flexibility and system services. In addition, there has been a reduction since 2020 in the availability of the fleet's nuclear units, linked in particular to the discovery in 2021 of a stress corrosion issue affecting part of the fleet;
- **The variability of flows in terms of direction and intensity.** The number of SSEs related to flows temporarily exceeding permissible levels in RTE installations rose from 0 in 2015 to 52 in 2022 (42 in 2021). The vast majority of these excess flows occurred on the Franco-Spanish border and were caused by imbalances in East-to-West energy flows against a background of maximising exchange capacity along this border.

More specifically, the following points are worth noting for 2022, in comparison to 2021:

- **A slight increase in the number of level-A SSEs,** mostly linked to industrial action causing 9 instances of shortfalls in reserve margins, and to the isolation of the Argia-Cantegrit line near the Spanish border, giving rise to several N-criterion events where the current rating was exceeded.
- **A few level-B SSEs associated with particular events** that generated a temporary departure from the "Risk control" policy.
- **The occurrence of one level-C SSE** following the simultaneous loss of several pieces of regional telecontrol equipment (Regional Control System, SRC) and of the national control system (National Control System, SNC), leading to loss of observability and remote controllability for all the substations operated from the operating centres in Nantes and Saint-Quentin-en-Yvelines.
- **In parallel, there was an increase in the number of SSEs linked to control systems.** There were a total of 12 events involving the loss of remote control and/or assessment systems, the highest figure to date.
- A return to normal figures for the number of SSEs associated with frequency deviations, which had risen from 2 to 7 in 2021 and dropped back to 2 in 2022.
- A rise in the number of SSEs related to **supply-demand balance management,** driven in particular by **the historically low availability of the nuclear generation fleet.** The discovery of the stress corrosion phenomenon led to the shutdown of several power plants, resulting in the lowest annual output (279 TWh) since 1988. Thus, the number of situations where the supply-demand balancing mechanism was under strain gave rise to 32 level-A SSEs in 2022 (19 in 2021).
- **Occasional and minor overloads** in the domestic network and on the Franco-Spanish border; these events were partly linked to rapid substantial variations in flows during changes to cross-border trading schedules and in power generation schedules. Each situation was promptly resolved (lasting less than a minute).

THE RELIABLE OPERATION OF THE ELECTRICITY SYSTEM

Electrical energy cannot currently be stored on a large scale, and electrical installations do not have limitless transmission capabilities.
Guaranteeing system reliability means ensuring a 24/7 balance between electricity production and use, and transporting electricity from centres of production to centres of consumption. This entails controlling the changes and reactions of the electricity system in response to various unforeseen issues (short-circuits, unplanned changes in consumption or generation, unforeseen unavailability of production or transmission units, etc.). It also involves minimising the risk of country-wide or widespread blackouts.
The origin of a large-scale incident is always characterised by four main phenomena, which, irrespective of their initial causes, either occur one after the other or are combined throughout the incident.

These phenomena are the following:

Cascading overloads

- If the flows in one or more lines exceed capacity following a combination of incidents or a beyond design basis incident:
  - the lines are automatically de-energised
  - electricity flows are switched to other lines
  - there is a risk of further overloads, etc. (cascade overloads).
- RTE at all times implements a flow risk control policy, thereby ensuring that such a cascade event cannot occur as a result of a single unforeseen issue.

Voltage collapse

- In the event of multiple failures, particularly in generation or in voltage regulation systems, voltage can drop and may produce knock-on voltage drops.
- RTE at all times implements a voltage risk control policy, thus ensuring that such a collapse cannot arise due to a single unforeseen issue.
- Furthermore, RTE has equipped the network with automatic schemes delivering targeted load shedding to mitigate any voltage drops, should the production and consumption plan prove inadequate in the event of an unforeseen issue affecting several generating units.

Significant frequency variation

- In the event of multiple unforeseen issues affecting generation, beyond the margins for frequency control, there is a risk that overall frequency may drop or increase. With large-scale unforeseen issues, these drops can lead to load shedding.
- The use of primary and secondary reserves for frequency control and then restoration in the event of a risk condition in Europe's largest connected generating unit ensures that RTE and other TSOs in Europe's synchronous area can prevent this type of situation.
- In the event of beyond design basis incidents, the defence plan (with under-frequency load shedding) averts any significant drop in frequency.

Loss of synchronism

- A short-circuit close to a generating unit may result in generator acceleration.
- The stability studies undertaken by RTE for various operating configurations ensure that these localised changes in frequency are averted.
- For loss of synchronism potentially resulting from beyond design basis incidents, possibly compounded by technical issues with generating units, RTE operates at all times protection schemes that uncouple a section of the network in response to loss of synchronism. These schemes minimise the spread of a loss of synchronism to the rest of the network.

System reliability is defined as the ability to:
- Ensure normal system operation (normal frequency range, voltage, current, short-circuit power) in both nominal conditions and in the event of unforeseen issues, in accordance with risk management rules;
- Minimise the number of incidents and prevent major incidents;
- Mitigate the consequences of major incidents when they occur.

03. Supply-demand balance and frequency control

3.1 Supply-demand balance management impacted by the nuclear fleet's stress corrosion issues

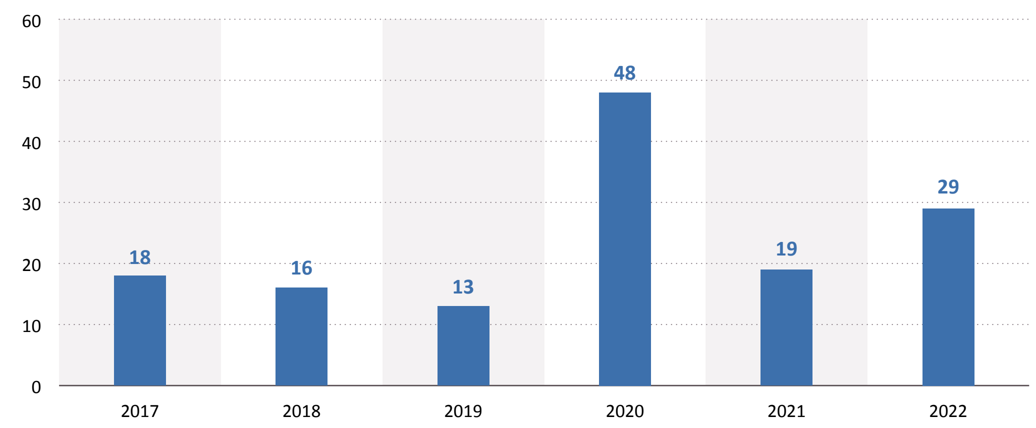
In 2022, **29 situations gave rise to alert notices** being sent to inform stakeholders of **an anticipated shortfall in upward margin that could not be restored in real time.**

This was an increase compared to 2021, but can partly be explained by industrial action, which generated 9 shortfalls in margin.
Pressures on the supply-demand balancing mechanism arose primarily in the summer and autumn of 2022.

Total electricity production (445 TWh) was at its lowest level since 1992, owing to the low output from nuclear and hydropower.

The nuclear generation fleet experienced historically low availability throughout 2022, reaching its lowest level since 1988 (279 TWh). This was due to several factors:
- the Grand Carénage plant refurbishment programme, whose operations were expected to peak between 2020 and 2025;
- the impact of the first Covid-19 lockdown on the 2-3-year maintenance schedule;
- the discovery of stress corrosion cracking (SCC) anomalies in the N4 series plants (Chooz and Civaux) in December 2021, which were later found in other plant series, leading to the preventive shutdown in the spring of many reactors to allow for inspections.

LEVEL-A SSES LINKED TO SHORTFALLS IN SDB UPWARD MARGIN



THE FIRST ECOWATT ORANGE ALERT WAS ISSUED ON 4 APRIL 2022:

This was the product of an uncommon combination of various events: the night of 4 April had been the coldest for the month of April since 1947; import capacity was low prior to the daily auction, and was exceptionally low from Germany and Belgium; EDF had announced the unplanned unavailability of the Dampierre 1 nuclear unit, at a time when nuclear power availability was already uniquely low; wind power during the critical 7am to 9am hours had been underestimated, along with the output of the co-generation units; the mechanisms used to manage peak consumption in France had ended on 31 March and were therefore not available on 4 April (capacity mechanism, TEMPO tariffs, call for tenders for demand response, etc.).

In addition, several production facilities had started maintenance operations at the end of March and were no longer available, and the RTE alerts most likely led the market players to seek a long position, which may have increased the daily auction price.

The combination of these factors led to RTE triggering an EcoWatt orange alert.

(Source: June 2022 CRE Report)

The hydropower fleet was impacted by particularly hot and dry weather conditions, causing a 20% drop in production compared to the 2014-2019 average.

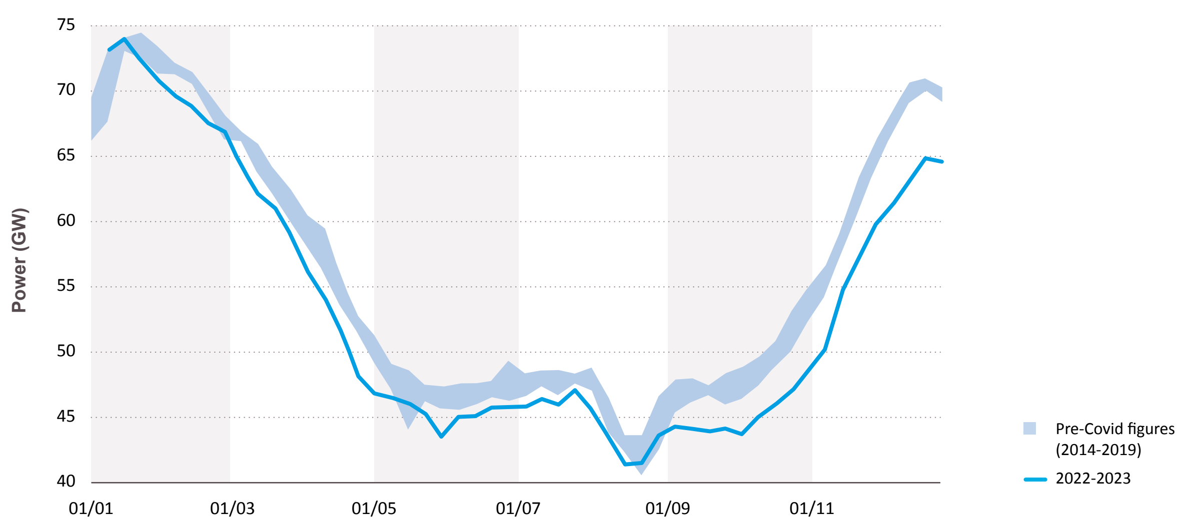
In contrast, the first offshore wind farm (St-Nazaire, 480 MW) was gradually commissioned between July and September 2022.

These unforeseen issues with generating potential were compounded by geopolitical factors, with high gas prices resulting from the war in Ukraine and the ending of Russian gas imports. These high prices affected all European countries, highlighting their heavy dependence on gas, and in turn affected the cost of electricity.

In anticipation of a winter period with expected supply-demand pressures, the St-Avold coal-fired power plant, which was to close down permanently on 31 March 2022, was started up again in the autumn.

Public awareness campaigns were launched in the summer of 2022, calling in particular for reduced power consumption by businesses, the authorities and individuals. The price effect, combined with the appeal for energy efficiency, led to a significant drop in consumption by the end of the summer and throughout the winter of 2022-23.

AVERAGE WEEKLY ELECTRICITY CONSUMPTION, ADJUSTED FOR NORMAL TEMPERATURES



France recorded high imports from its neighbours to offset this production shortfall, posting a net import balance for the year (16.5 TWh), for the first time since 1980.

Around 18 GWh of demand response capacity was activated in 2022, a figure that remained stable in comparison to 2021. Furthermore, the demand response sector continued to expand in 2022, reaching a capacity of 3.98 GW, including 0.66 GW of implicit demand response by the end of the year. Out of the 3.3 GW of certified implicit demand response, an average 1.8 GW was offered through the Capacity Mechanism on PP2 days, in order to meet the requirements of the Capacity Mechanism and the Call for Tenders for Capacity.

However, the real-time recourse to demand response mechanisms remained limited, owing to the players' pricing policies, and the terms and conditions of offers, which, in 70% of cases, were not aligned with RTE's reduced operating window for the implementation of the European framework.

Regarding **shortfalls in downward margin,** the deployment of a **new automatic margin calculation tool** in the summer of 2021 allowed for more accurate calculations of available margins. Instances when the requirement for a 15-minute downward margin was not achieved were frequent.

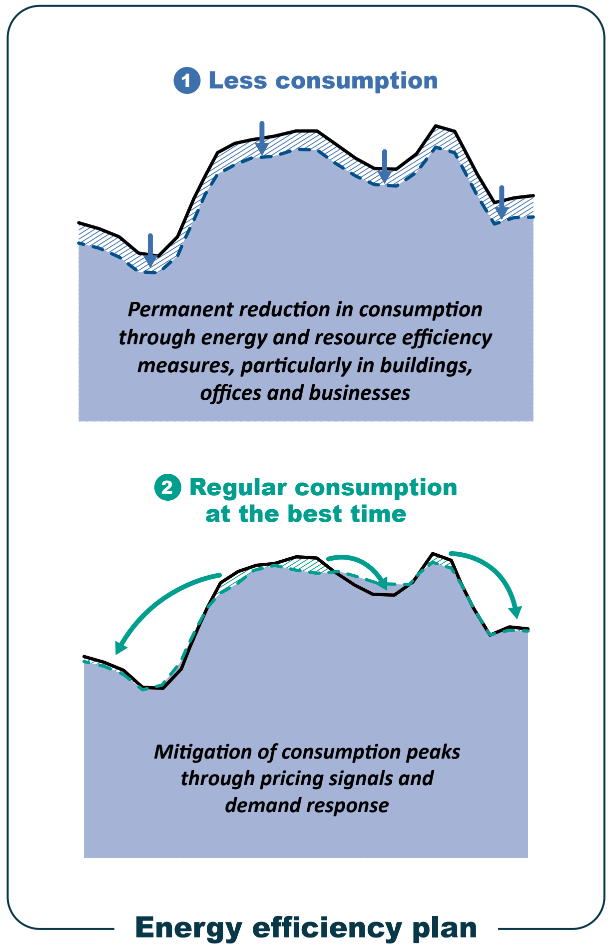
Compared to 2021, when these shortfalls mostly arose in the spring and summer, in 2022 they were more significant in winter, and mainly in December. They **can be explained by the increasing lack of dispatchable and flexible sources with, in particular, a growing share of renewables that do not yet contribute significantly to the balancing mechanism.**

A contingency plan for winter security of supply

Owing to the **limited availability of the nuclear fleet and the risk of pressures** in European electricity trading, RTE made preparations throughout 2022 for the management of a winter with a security of supply under strain.

A number of measures were thus implemented, in conjunction with the authorities, to optimise the levers for action available to RTE to balance supply and demand. The 5 measures are as follows:

I. AN INFORMATION CAMPAIGN INVITING CONSUMERS OF ALL TYPES TO MODERATE OR SHIFT THEIR ELECTRICITY CONSUMPTION



II. AN UPDATED AND STREAMLINED ECOWATT SCHEME

Based on feedback on the EcoWatt mechanism collected in April 2022, RTE worked to **provide better visibility of the EcoWatt scheme and increase its effectiveness** by way of three major innovations:

- **An initial announcement of the expected colour code is made 3 days** ahead instead of 2, thereby allowing businesses to better prepare, between Friday and Monday, for the coming week;
- **A simplification of the colour code,** with 3 colours instead of 4, reflecting the degree to which the supply-demand balance is under strain, and the likelihood of power disconnection if the public does nothing:
  - Green: no alert;
  - Orange: supply-demand balance under pressure. Eco-friendly actions are welcome;
  - Red: electricity system supply-demand balance under significant pressure. Disconnections are unavoidable if we do not cut back consumption;

  The same code applies to the country as a whole (the yellow regional alert has been scrapped) to make it clearer;
- **The announcement is now made at hourly intervals,** to make it possible to take action when the system needs it most, and thus be most efficient.

III. STRENGTHENED MEASURES TO PROTECT THE POWER SYSTEM

The "standard" means of protecting the system include several technical procedures that can be called upon in ascending order:

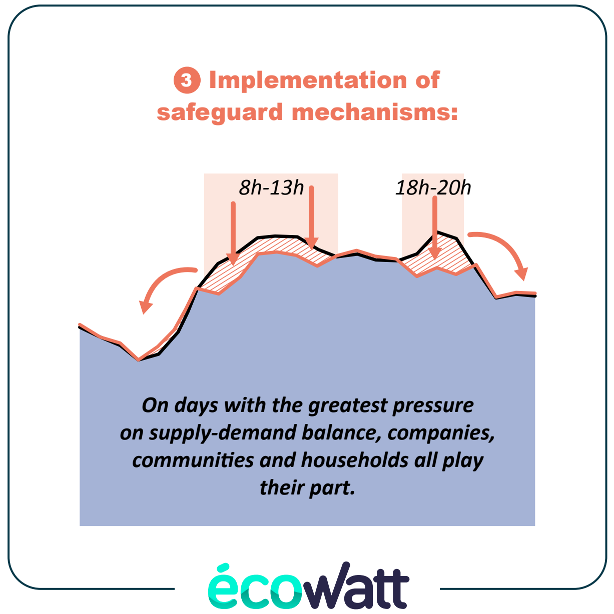
- As a first step, a given **demand response capacity** of last resort, provided by large industrial sites, through the **interruptibility mechanism.** This contract-based mechanism can be activated without notice, and applies to consumption sites that are connected to the public electricity transmission network and compensated for it;
- A 5% **voltage drop in the public transmission networks** (a value referred to as "- 5% Un"). This reduces the power used by electrical equipment connected to the HV(A) and LV networks (heaters, lights, hotplates, etc.).
- As a last resort, the **implementation of a load shedding plan,** which entails organising rotating power cuts in France. This load shedding plan, deployed in successive steps, is activated according to the extent of the power imbalance. Preparations are made the day before, with real-time adjustments for the amount of shedding needed. This is a last-resort procedure that is deployed to prevent grid collapse (blackout). Consumers are only disconnected for a time limited to two consecutive hours.

In order to reduce the risk of resorting to load shedding, and in addition to these "standard" mechanisms, the updated EcoWatt alert and its widespread coverage in national and regional media (television, radio, press) was designed to drive further action by businesses, communities and households, in addition to the above protection schemes. RTE's estimated potential of 4 to 5 GW was not tested this winter as no alert was issued.

Furthermore, other protection mechanisms were added through the "purchasing power"[1] law, and are designed to maximise the capacities offered both through the markets and the balancing mechanism, for all capacities (generation, demand response, storage, backup generators for consumption sites), by means of:

- **An obligation to offer available power,** applicable to all the capacities already participating in the balancing mechanism, whatever their connection voltage level, during EcoWatt red alert phases;
- **An obligation for the demand response capacities** that are active in the energy wholesale markets to submit an offer during EcoWatt red alert phases;
- The requisition of some emergency generators belonging to consumers, under an obligation to offer available power through the balancing mechanism during EcoWatt red alert phases.

These levers for action can be activated before or at the same time as the interruptibility mechanism, prior to resorting to a voltage drop. These arrangements have freed up an estimated 500 MW of additional power.



1. Law No. 2022-1158 dated 16 August 2022 on emergency measures for the protection of purchasing power.

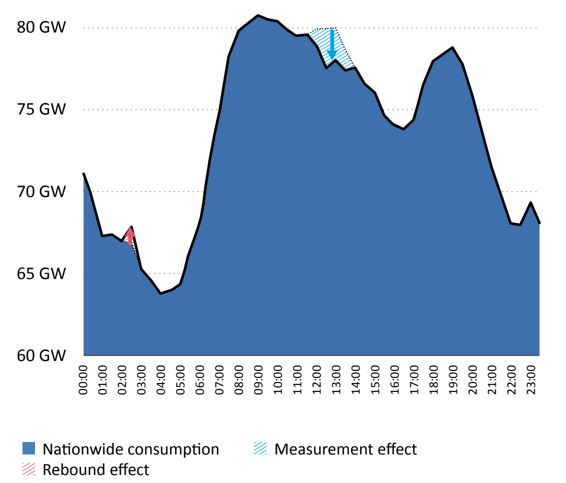
IV. A SHIFT IN THE OFF-PEAK MIDDAY HOURS DURING THE WINTER PERIOD

Consumers who have signed up to a peak/ off-peak tariff have the use of 8 off-peak hours a day. They are therefore charged a preferential rate if they use power at those times.
Every day, these customers' hot water tanks automatically start heating up during off-peak times. **For 4.3 million customers, some of these off-peak times were set in the 12pm to 2pm window, in other words, during the morning peak load.**

At the request of the Ministry for Energy Transition, **to avoid midday consumption peaks and limit the risk of winter power cuts,** from 15 October 2022 to 15 April 2023, **the off-peak midday hours were rescheduled to the afternoon dip,** at around 3pm.

This measure reduced the midday consumption peak by 2.5 GW.

IMPACT OF HOT WATER TANK OPERATION ON THE NATIONAL LOAD CURVE



V. AN ADJUSTMENT TO THE FRAMEWORK FOR CALLS FOR ELECTRICITY SUPPLY FROM CO-GENERATION UNITS SUBJECT TO A PURCHASE OBLIGATION, TO ENSURE THEIR PARTICIPATION DURING ECOWATT ORANGE AND RED ALERT DAYS

In order to maximise the availability of the co-generation units subject to a purchase obligation in the 2022-2023 winter, the regulatory framework for mobilisation was slightly adjusted so as to require the *obligated party*[2] to ensure the selection of cogeneration units that have opted for the "available to the electricity system" mode on days when the demand-supply balance of the power network is under strain (namely, on EcoWatt orange and red alert days between November 2022 and March 2023). This guarantees the availability of around 600 MW.

The impact of the winter contingency plan on supply-demand balance

RTE placed the electricity system under enhanced monitoring from autumn 2022.

The period from October 2022 to December 2022 saw a drop in gross consumption, three-quarters of which was caused by the energy crisis (price signal effect and energy efficiency drive), and to a lesser extent by the weather conditions in France.

The industrial sector recorded a steady reduction in consumption from the beginning of winter onwards, independently of weather patterns. Changes in consumption in the tertiary sector (offices, shops, etc.), and particularly in the residential sector (housing), were much more visible during the weeks with cold weather. Heating clearly remains the main driver of a decrease in consumption.

Thanks to this drop in consumption and the relatively mild weather, RTE did not issue any EcoWatt alerts between October 2022 and December 2022.

2. Businesses designated to purchase the energy produced by the facilities subject to a purchase obligation.

3.2 European electricity system frequency control under continued scrutiny

The **monitoring measures taken by all the TSOs across Europe, in which RTE was actively involved,** had a positive impact on the number of deviations recorded from 2019 onwards. Following a worsening in 2021, there was an improvement once again in 2022, a clear indicator that continued vigilance is needed and that the European TSOs must not relax their efforts.

With 31 significant and sustained frequency deviations in 2022, **European frequency control has improved compared to 2021** (78 frequency deviations). Most of these were downward deviations (that is to say, when generation is lower than consumption, and frequency drops below 50 Hz). To varying degrees, France was involved in 26 of the 31 deviations recorded in 2022.

In a similar vein, there was a drop in the number of significant frequency deviations in 2022 compared to previous years: **2 level-A SSEs were reported in 2022, versus 7 in 2021.**

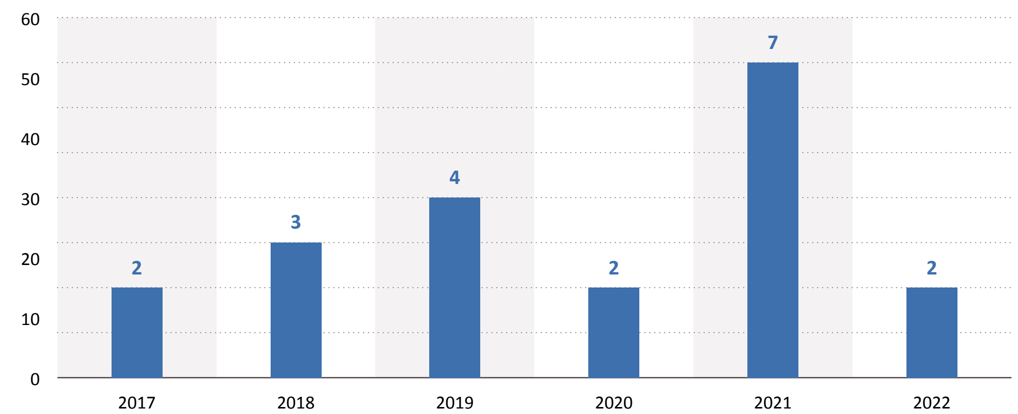
French frequency control was the main contributor to one of these two events. This was partly linked to significant deviations from consumption and generation forecasts, as well as to the limited capacity to adjust the French electricity system's generating output.

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 – still occurs, although there has been a marked improvement since May 2022 (129 deviations of more than 100 mHz at the end of November 2022, on a 12-month sliding scale, compared to 185 in 2021 and 174 in 2020).

Following a proactive joint decision by the European TSOs, 1 January 2021 marked the implementation of enhanced monitoring of each TSO's contribution to frequency control during changes in cross-border trading on the hour; RTE must remain vigilant. Although it met its target in 2022, certain quarters were close to the 30% threshold.

Year	2021				2022			
Quarter	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
RTE threshold (<30%)	23%	24%	29%	21%	22%	26%	18%	29%

NO. OF LEVEL-A SSES – FREQUENCY DEVIATIONS



In 2022 (as in previous years), France met the two criteria stipulated by European network codes for quality of control in each of the load-frequency control blocks of the synchronous area. Based on a frequency control deviation 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	2019	2020	2021	2022
Level 1 threshold (< 30%)	11%	9%	9.2%	7.4%
Level 2 threshold (< 5%)	3.6%	3.0%	3.4%	2.3%

These indicators improved in 2022, reflecting the improved quality of French frequency control. This can be explained by several factors. A new method for setting the size of aFRR (Automatic Frequency Restoration Reserve, or secondary reserves) was introduced in November 2021. This has resulted in an improved distribution of reserves throughout the day, by boosting volumes in periods of time that have historically been shown to experience significant variations, and reducing them when the system's parameters are more stable. The restriction on offsetting imbalances between TSOs was terminated mid-2021, within the limits of the capacity available in the interconnectors. Lastly, in a context of particularly high imports, often reaching the system's maximum capacity, energy exchanges were less volatile, thereby reducing the large hourly variations in flows that are often a source of frequency control deviations.

The contractual framework governing **generating units operating under the premium tariff mechanism** (8.3 GW of installed capacity as of end 2022, primarily renewables) prompts the generating units in question to shut down when the day-ahead market price is negative, indicating overproduction in the electricity system. **The synchronised shutdowns of these volumes of energy generation** in response to the same signal continued to occur in 2022, but significantly less often than in the previous year, owing to the rise in electricity prices caused by the energy crisis. Special attention is now needed whenever there are negative market prices: the volumes involved are above 1,500 MW, the same order of magnitude as the French nuclear unit with the highest output. **Work has begun to ensure that by 2023 this phenomenon is reflected more accurately in the models for forecasting renewable generation.**

These events have highlighted once more the importance of the scheduling, predictability, observability and, last but not least, dispatchability of renewable energy and its contribution to the supply-demand balance. The emergence of offers with short deadlines and activation times would indeed be an effective way of mitigating and limiting deterministic frequency deviations. What is more, should there be a reversal in this trend, the absence of an intervening technical stage in this 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.**

Although **the scheduling of secondary reserves by those responsible is above contracted volumes on average, there were deficit conditions for 19% of the time in 2022,** *versus* 21% in 2021 and 19% in 2020.

However, **the total annual duration of shortfalls in primary reserves has markedly improved** (a total time of 2.8 days of failure versus 7 days in 2021 and 6 days in 2020).
In regard to these reserves, 2022 saw a further increase in the contribution of storage units (batteries) and load sites, resulting by the end of 2022 in 355 MW of batteries and 122 MW of certified load for primary frequency control, against a French requirement of around 500 MW.
In respect of electricity system reliability, it has been noted that these shortfalls in scheduling diminish closer to real time owing to the frequency restoration measures taken by RTE, though these shortfalls must continue to be a focus of attention in frequency control.

It is still generally difficult to restore the required reserves for the balancing mechanism in real time due to a fall in spare capacity. This problem is made worse when the generating units providing system services are shut down to reduce output for downward supply-demand balancing. This is the case of hydropower in particular, which mostly impacts secondary reserves. Since primary reserves are increasingly covered by means of production that are not offered via the balancing mechanism (batteries and loads), these reserves are less affected by RTE's system balancing measures.

The implementation of the European Electricity Balancing code has also offered RTE 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 their automatic activation and for the real-time balancing of supply and demand.

In particular, RTE is taking part in the three projects to set up European platforms, namely, TERRE (Trans-European Replacement Reserves Exchange) for managing tertiary reserves (traded in 30-minute blocks), MARI (Manually Activated Reserves Initiative) for managing fast reserve products (with an activation time of 15 minutes), and PICASSO (Platform for the International Coordination of the Automatic frequency restoration process and Stable System Operation) for managing secondary reserves. **RTE was connected to the TERRE platform in December 2020, the trialling of which was completed by April 2022.**

The balancing volumes activated on the TERRE platform remained stable compared to 2021, and on average accounted for around 17% of the total balancing volume for 2022. The activation of reserves abroad represented 81% of the reserve requirements formulated by RTE that were met by the TERRE platform. The remaining balancing operations are carried out by drawing on offers in the French balancing mechanism. This low volume is partly explained by the limited pool of standard offers, whose format is not well suited to the characteristics of the French fleet.

RESERVE MARGINS AND MARGIN RESTORATION

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, mostly provided by dispatchable generation** (also known as frequency restoration system services), as a first response to an unforeseen generation or consumption issue in the network.
- **tertiary reserves,** intended to complete the full restoration of the supply-demand balance, and to rebuild any system services that were used up during the emergent issue.

Operating margins are calculated for these various reserves, for both upward and downward margin provision.

Their levels (and thus the **offers available in the balancing market to attain them)** must meet minimum requirements, which are time-dependent:

- **fast reserves,** which are designed to deal at any time, 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,** which aim to address unforeseen issues that may arise in the hours ahead: a deviation from the consumption forecast, an unforeseen technical event, a wind or solar power generation forecasting error, etc.

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

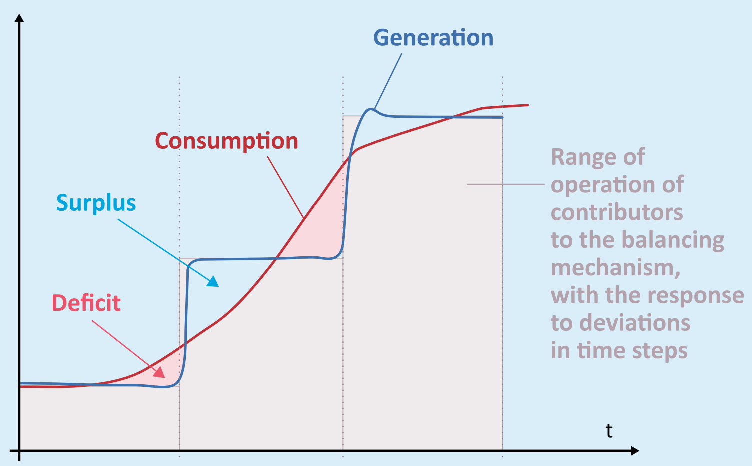
Just as the activation of upward reserve provision may increase available system service levels (by starting up generating units), in the same way, the activation of downward reserve provision may lower those levels by causing the shutdown of generating units that were contributing to system services.

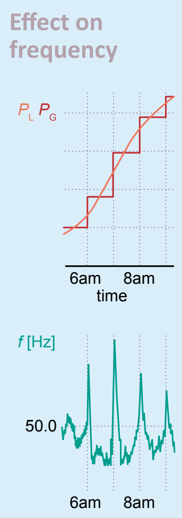
On-the-hour frequency deviations

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 changes rapidly and is (fleetingly) out of synch with demand (consumption + trading), which for its part is continuous. The supply-demand balance is therefore impacted for a few seconds or minutes: 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). Should an event affecting the supply-demand balance (such as the loss of a generating unit) occur at the same time, frequency variations may be intensified and may in some cases lead to activation of the French interruptibility mechanism, or even in the most serious situations to under-frequency load shedding.

Illustration of the phenomenon:

When consumption rises, frequency drops slowly immediately before the hour, reflecting the shortfall in power, and increases rapidly immediately afterwards, following the start-up of quick-response generating units such as hydropower plants.





Source: University of Stuttgart

04. Risk control underpinning system reliability

4.1 Network stability

Losses of system stability due to loss of synchronism

In 2022, no protection scheme was activated to uncouple a section of the network in response to loss of synchronism.

However, a few events were recorded in 2022:

- On 6 April 2022 in Warande, following storm Diego and the increased vulnerability of the fibreoptic network, many teleprotection systems became unavailable, requiring costly power reduction measures to avoid the loss of network stability. This event gave rise to a level-A SSE.
- On 21 April 2022 in Cubnezais, following damage to a teleprotection system, one of the units at Blayais NPP was downpowered to prevent loss of system stability. This event gave rise to a level-B SSE.
- On 24 October 2022 in Braud, the teleprotection system was no longer functional following the implementation of a particular operating scheme, which, in the case of a busbar fault, would have led to a loss of system stability. This event gave rise to a level-B SSE.

Performance of the protection plan

The speed with which faults in installations are resolved is a contributing factor to the stability of the electricity system.

In 2022, 95% of the 304 faults on 400 kV lines were addressed in keeping with expectations. 84% of these were single-phase faults.

Good results for the 225 kV lines flagged up as central to the network's stability also contributed to this high level of reliability: 100% of faults were resolved within 200 milliseconds.

Differential busbar protections are key to the rapid and targeted clearance of faults occurring in substations (which are infrequent but present a high risk to reliability). **The availability rate this year stood at 99.94%** (this rate has remained above 99.2% since 2015).

Inter-area frequency oscillations

Monitoring of the damping of power oscillations across the European continent revealed that this damping could be inadequate over long periods. The connection of Ukraine and Moldova to the European synchronous area reinforced the need to monitor these oscillation phenomena. This is why a system for detecting inter-area oscillations was made available from summer 2022. It is able to identify these oscillations in real time, and inform dispatch centres of the most effective damping measures to apply: a preventative change in the method of controlling the direct-current link between France and Spain, or even a drop in imports from the Iberian Peninsula.

There were many inter-area frequency oscillations in the European power network:

- The North-South mode: recorded on 5 January in Italy, with 50 mHz oscillations;
- A new East-Centre-West mode frequency since the synchronisation of Ukraine with the continental power network: recorded on 30 March, with 40 mHz oscillations, then again between 5 and 10 May, on 6 August, on 14 August, and between 26 November and 8 December.

In order to better observe the phenomenon and mitigate its impact, the European transmission system operators are sharing many additional measuring points (phasor measurement units), and are also jointly carrying out ex-post studies for a detailed analysis of the causes.

LOSS OF SYNCHRONISM (LOCAL FREQUENCY OSCILLATIONS)

In nominal operation, the generators of Europe's interconnected generating units all operate at the same frequency of around 50 Hz: this is referred to as synchronised system operation, with the system creating 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 the withdrawal from service of installations.
- Checking the performance of generating unit controls and of protection systems.

INTER-AREA FREQUENCY OSCILLATIONS

Inter-area oscillations are complex electromechanical phenomena that occur between several parts of the European electricity system, which oscillate out of phase in low-frequency mode at around 200 mHz and give rise to active power oscillations, particularly in interconnectors. They involve real risks for the reliability of Europe's electricity network if they come close to frequencies of resonant modes in the European system.

4.2 The risk of voltage collapse

No major challenges with low-voltage management in the 2021/2022 winter

No safeguard alert for low voltage was sent out in 2022 (versus 0 in 2021 and 17 in 2020).

The activation threshold for the Western and Northern Automatic Schemes against Voltage Collapse (ADO and ADN) was never reached.

Despite reduced availability owing to maintenance operations and the stress corrosion phenomenon, the continued improvement seen in 2022 was largely due to the generating units in Western and North-West France during the winter months, combined with moderate consumption levels.

THE RISK OF VOLTAGE COLLAPSE

The electricity system's voltage is controlled by multiple sources of reactive power (generating units, capacitors, reactances, SVCs, etc.) distributed across the network.

In any given area, the sources of reactive power may no longer be adequate to meet requirements following the loss, for example, of transmission installations or generating units.

Importing a supply of top-up power from a neighbouring area 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. If no action is taken, this leads to network voltage collapse.

Under its System Defence Plan, RTE operates two automated schemes against voltage collapse in the West and North, ADO and ADN. 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.

4.3 The management of network flows

Excluding incident conditions, 2022 saw an increase in the overall number of one-off cases of 225 and 400 kV overload. These overcurrent conditions were always rectified within the permitted timeframes, and did not jeopardise the reliability of the electricity system.

Even more than in 2021, the **Spanish border (interconnection and upstream network) accounted for a significant portion of the cases of exceeded line flow limits.**
As exchanges between France and Spain have more than doubled since 2015, the loads of installations in the area have come close to operating limits, and the number of overload protection activations has increased.

Despite efforts in pre-empting changes to cross-border trading schedules and the ability to predict the East-West distribution of these exchanges, as well as high levels of intraday countertrading based on intraday capacity calculation, **great uncertainty remains over real-time line flows in interconnection systems. The ramping up of mechanisms for shared European balancing reserves, and potential deviations in supply-demand control in the Iberian Peninsula, have contributed to the difficulties in managing flows across this border.**

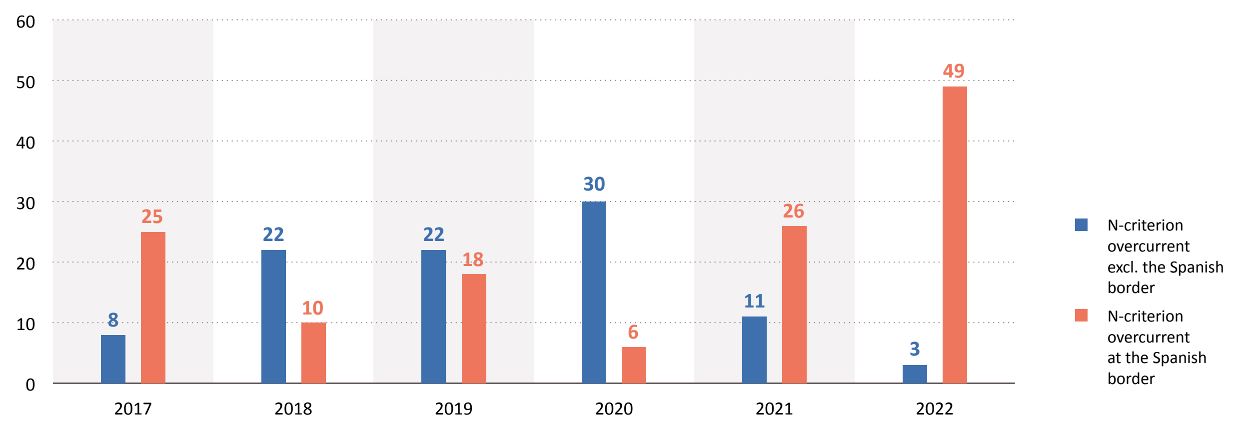
In this context, maintaining a high exchange capacity at the Spanish border means accepting controlled excess flows.

In 2022, one main factor led to a **further increase in cases of flow limits being exceeded at the Spanish border:** the withdrawal from service of the Argia Cantegrit 400 kV line in May and June, for works. This resulted in more frequent overloads on the 225 kV Canegrit Mouguerre line, a lower-capacity line that is therefore more vulnerable to events that may affect cross-border flows.

A conductor replacement project is underway at the Franco-Spanish border. In the short term, the operation of this area will remain challenging, as new works will involve the unavailability of some installations, which will increase the loads on others and the load transfer coefficient on available lines.

Leaving out the Spanish border, the cases of flow limits being exceeded is decreasing. A **new system for monitoring and predicting constraints** was rolled out in 2021. Measures were taken in 2022 to strengthen **coordination between operating centres.**

OVERCURRENT EVENTS EXCLUDING INCIDENT CONDITIONS



CASCADE CURRENT OVERLOADS

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 distance between the line and its environment.

Maximum values are therefore set for each installation:
- A current rating (CR), with no time limit, but which is only reached occasionally and for a limited time.
- Temporary current limits, above those of the CR but for much shorter time periods (less than 20 minutes).

In order to avoid the risk of exceeding these current values, the 225 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 more disconnections. Successive load transfers can 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.

THE PROCESS OF POWER NETWORK STUDIES AGAINST A BACKGROUND OF VARIABLE 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 process for conducting these studies is changing in response to the energy transition and to European market integration.

For longer-term studies, the process can rest on "multi-situational" analyses, simulating several annual scenarios at the European level, with hourly granularity, even honing in on the local output of renewable generating fleets.

The scheduling process with the TSOs 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 renewable sources (this must be combined with contractual alignment), and the deployment of automated control systems.

For shorter-term studies, the process 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 data with neighbouring TSOs and CORESO, and the resulting joint coordination, ensures that common power network operation strategies are consolidated and updated.

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

4.4 Post-blackout power restoration

In 2022, the nuclear power plants performed **4 successful islanding operations (out of a total of 5),** with a rolling four-year success rate of 90%, a highly satisfactory result given the multiyear target of 60%.

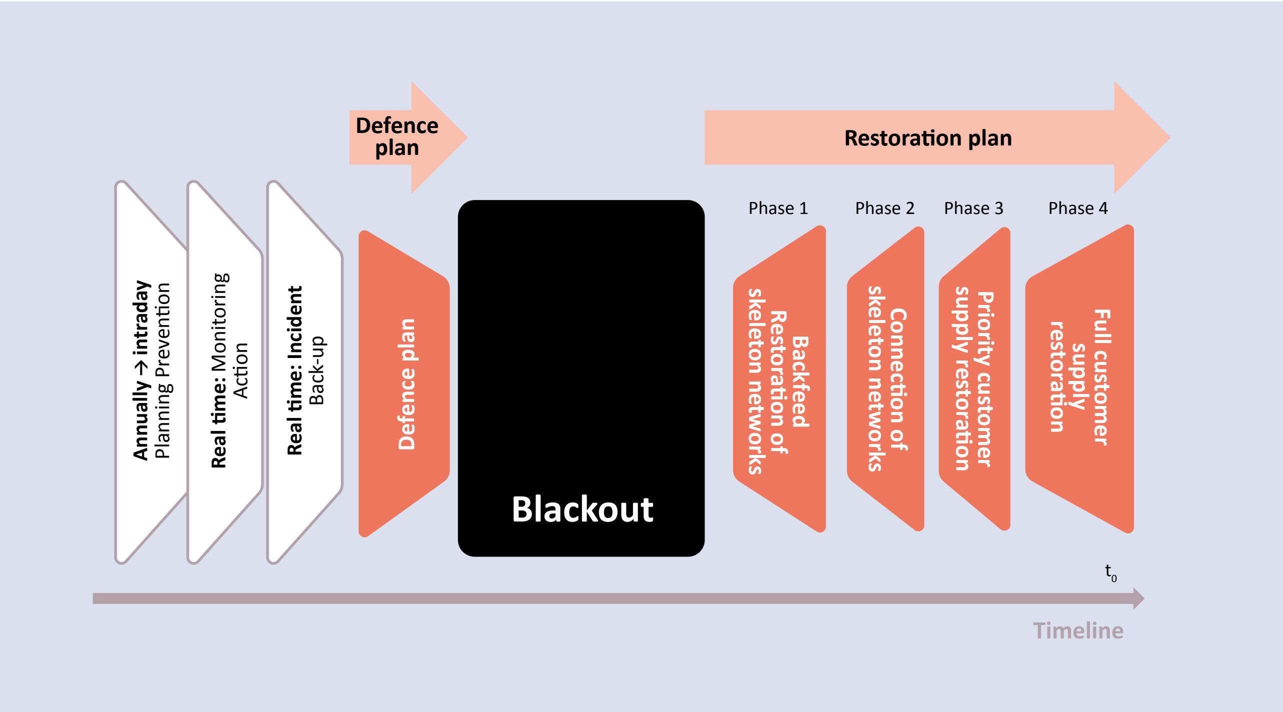
NUCLEAR ISLAND HOUSELOAD OPERATION AND SKELETON NETWORKS

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

In the event of a blackout, the successful houseload operation of nuclear units is essential for nuclear safety, and is key to restoring the network and resuming supplies to customers as rapidly as possible.

Network restoration is dependent on the step-by-step re-energisation of 400 kV lines, referred to as regional skeleton networks, which connect house-loaded units to the substations of high-consumption areas.

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:

- the automatic separation of regions that have lost synchronism (loss of synchronism protection system DRS);
- the automatic load-shedding of non-priority loads upon frequency drop;
- the tailored automatic schemes under RTE's Defence Plan (ADO/ADN, etc.);
- the automatic locking of transformer on-load tap changers.

THE RESTORATION PLAN

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

RTE must then restore normal system operation (the action of "network 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 to restore all or part of the network following a blackout, in the absence of any possible back-up from a grid that has remained energised (in France or abroad), relies on the nuclear units in houseload operation. Gradual network restoration is carried out using predefined skeleton networks, thus ensuring progressive re-energisation.

05. Breaches of high-voltage limits

5.1 Breaches of high-voltage limits once more on the increase

In 2022, eleven situations highlighted difficulties in complying with RTE's reference standards:

- Seven in relation to compliance with maximum voltage ranges in the event of installation trips: five instances where the N-1 criterion was not met (400 kV substation in Clérac), and two instances linked to the tripping of a SVC (static var compensator) in the Merlatière and Plaine Haute 225 kV substations.
- Four in relation to compliance with maximum voltage ranges, with no installation trip.

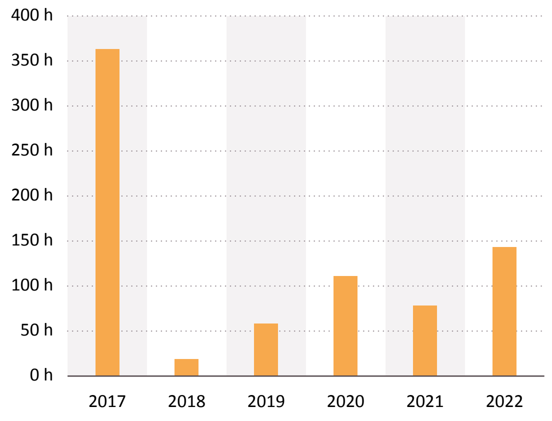
These situations led to the reporting of 11 level-A SSEs (compared to two in 2021 and none the previous year).

Breaches of limits in the 400 kV system were up from 2021.

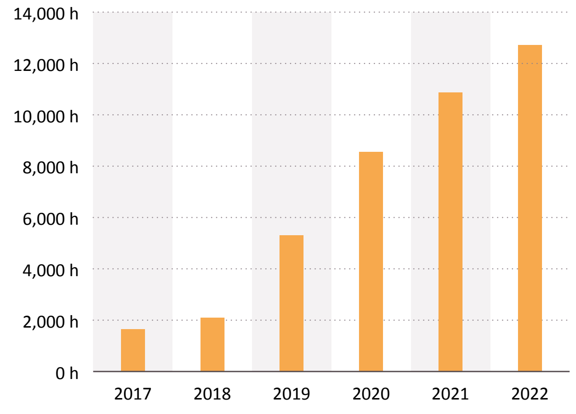
On the 225 kV network, the number of breaches increased once more; however, individual breaches were still small and brief.

RTE is proceeding with its power compensation installation programme for better control of high voltage: 1,046 Mvar of inductors (voltage-drop inductors) were connected in 2022, not counting those installed for reactive power compensation of offshore connections.

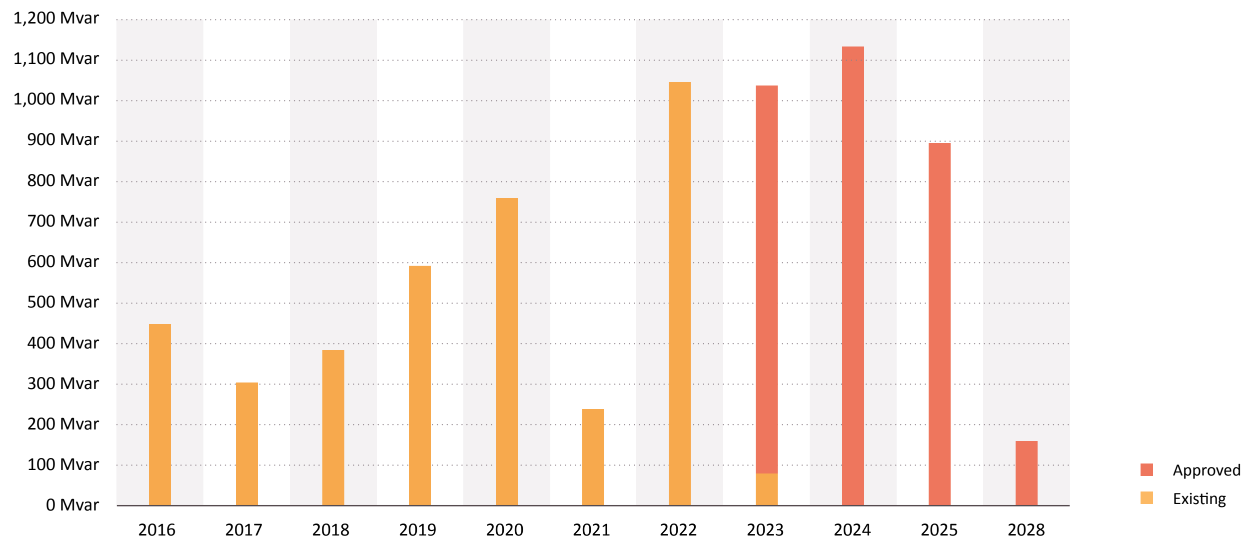
CUMULATIVE ANNUAL DURATION OF LIMIT BREACHES (VOLTAGE: 400 KV)



CUMULATIVE ANNUAL DURATION OF LIMIT BREACHES (VOLTAGE: 225 KV)



INSTALLED INDUCTORS (EXCL. OFFSHORE CONNECTIONS) BY COMMISSIONING YEAR



A new nationwide study is underway in France to revise the requirements for inductors in the 225 kV network by 2027, as the previous study dates back to 2020. This study will be updated every 2 years, on a rolling 5-year study plan. One-off regional studies may be carried out as needed to identify requirements for the 90 and 63 kV networks, as well as any requirements for the 225 kV network that may not have been identified in the national study.

Consultations are ongoing on the **voltage-control participation of new sources (wind and solar power installations connected to the distribution system, batteries, HVDC lines),** and trials will take place in the TURPE 2021-2025 tariff period. Regarding these new sources connected to a distribution system, work is underway with distribution companies and relevant stakeholders to include them in the current technical and contractual framework, and to establish a roadmap for updating this framework.

THE ISSUE OF VOLTAGE RANGE LIMIT BREACHES

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, now appear throughout the year, during periods of very low energy consumption.

Three main factors explain this shift:

- The significant development of renewable energy in distribution networks, reducing active power extraction from the transmission system, and thus increasing the production of reactive energy in the network.
- The changing nature of transmission and distribution networks, which are increasingly placed underground and therefore generate more reactive power.
- Lastly, developments in the technical properties of energy uses, which consume less reactive power, and in some cases, even produce it.

From a reliability perspective, high voltages have less short-term impact than low voltages, but can shorten the service life of equipment and cause degradation that impacts the quality of electricity supply.

06. Dependable and accessible reliability systems

6.1 Control room systems

As in recent years, **the availability of the systems supporting the reliable operation of the electricity network** was high in 2022.

Control systems

In 2022, several significant events affected **control systems:**

- **On 29 June, the loss for over 2 hours** of the Nantes Regional Control System (and of its support system in Saint-Quentin), of the Saint-Quentin Regional Control System, of the 2 National Control Systems (Main and Fallback), of the National Centre for System Operation (CNES) and then of the Toulouse Regional Control System (and support system in Marseille) following an incident with the fibre optic network *(severity level C SSE).*
- **9 incidents involving malfunctions (5) or work execution (4)** linked to control systems in substation group management centres, and in regional or national dispatch centres *(severity level A SSE).*

These events led to the implementation of targeted action plans (resilience, software updates and configuration, skills enhancement).

In order to address the obsolescence of existing control systems – the Regional (SRC) and National (SNC) Control Systems – and in order to use a single network control system, **RTE launched the STANWAY Project for their replacement. The new system is due to be commissioned in 2023 across RTE's eight control rooms.**

Since 2015, **the Support Mechanism for Regional Dispatch Centres (SIDRE)** has made it possible to take over the operations of several operations centres. It is operational in all three inter-regional zones. Skill levels are maintained through surveillance tests with (partial or total) switchovers, and in-service training for operators. In 2022, SIDRE was used on 13 occasions, 12 of which ensured that grid observability and operation were maintained throughout the incidents.

Other electricity network control room systems

In 2022, the availability rate of RTE's Alert and Safeguard System (SAS) equipment was satisfactory. Only 2 level-A SSEs and 6 level-0 SSEs were reported (versus 1 level-A SSE and 5 level-0 SSEs in 2021).

The number of SSEs resulting from failure to acknowledge system notices or inappropriate actions by generation companies, distribution companies or RTE operators, in cases of actual "critical status, inadequate reserve margins" alert notices (severity level A), rose from **31 in 2021 to 50 in 2022.** In 2022, owing to supply-demand balance constraints, the number of SAS notices increased, which automatically increased the number of failures to acknowledge system notices. This was compounded by the large number of generating units (NPPs) undergoing maintenance operations, when operators are less systematic in their acknowledgement of the notices they receive.

An e-learning package on how to use the SAS system, aimed at the contributors to network reliability, was posted online in 2022 and was shared in particular with new contributors connected to the French public electricity transmission network (EDF Renewables for the offshore fleet at Saint-Nazaire, for example).

THE ALERT AND SAFEGUARD SYSTEM (SAS)

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

The safeguard of the system calls for rapid action and coordination between dispatch centres and:

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

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

- system safeguard notices, for faster implementation of actions by stakeholders in situations with supply-demand pressures, when the reliability of the electricity system may be compromised ;
- alert notices, which are used for disturbed conditions.

The **"Convergence" network studies platform** is used for both system development and real-time research, and is therefore important for the system's reliability. In 2022, the overall availability rate of the datacentre hosting it was over 99%, with 2 significant unavailabilities reported on 22/05/22 and 26/12/22. The availability of this platform improved in response to the measures adopted after several incidents in 2018: enhanced reliability of the application's redundancy, adjustments to the recovery and business continuity plans, and improved impact analysis for work execution.

However, 5 level-0 SSEs in 2022 were linked to Convergence. Three of these events involved respectively a loss of observability of REE; works for a customer; and the removal of a phase-shifting transformer. The remaining 2 events related to the unavailability of the datacentre hosting Convergence.

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 energy sources, as well as forecasts of the power they will generate at local, regional, and national level.
A new version of the system was launched in 2022, thereby enhancing the reliability of the acquisition of this data that is currently of strategic importance for the reliability of the electricity system.

As in 2021, there were 10 level-0 SSEs and no level-A SSEs linked to the availability of the systems used for analysing the supply-demand balance, and balancing and markets; these malfunctions are mostly due to the complexity of the functional chains and to recent developments in supply-demand balance management platforms.

6.2 The telecommunications network and information system

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

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 reliability of the electricity system: “high-level” telecontrol, the exchange of information between electrical fault protections, and secure telephony.

In 2022, 1 level-C SSE linked to damaged optical storage, 1 level-A SSE linked to work execution and no level-0 SSEs were attributable to the ROSE infrastructure (compared to 1 level-B and 1 level-0 SSE in 2021).

In order to deal with obsolescence in these telecommunications networks, RTE has commissioned the deployment of the INUIT (Integrated Telecommunications Network Infrastructure) and the SUR-T high-speed and very-high-speed networks across all its tertiary and industrial sites. Services are gradually being switched to these fibreoptic networks, and operations to dismantle obsolete telecommunications networks are ongoing. SUR-T, a fibreoptic IP network, will carry essential services and align RTE’s fibreoptic networks.

One level-A SSE and 12 level-0 SSEs were reported in relation to the operation of the Secure Telephony System (STS), compared to 4 level-A and 13 level-0 SEEs in 2021. The level-A SSE involved an accidental blackout during work at the Nantes dispatching centre. The level-0 SSEs were caused by failures, or by work carried out by generation or distribution companies.

RTE’s new datacentre and telecommunications network infrastructure “HORUS” was commissioned in 2020. Work continued in 2022 to develop further industrial applications for this datacentre.

AN OPERATIONAL CENTRE FOR DIGITAL NETWORKS AND SYSTEMS (CORS-N)

In 2021, RTE established a national centre for the oversight, operation and management of its telecommunications network, its information system, and its cybersecurity: the Operational Centre for Digital Networks and Systems (CORS-N). The Centre will focus on:

- enhancing the reliability and high availability of digital systems;
- strengthening robustness to cyberattack;
- streamlining operations by consolidating reporting lines;
- improving efficiency and response times through end-to-end oversight of information system and telecommunications links so as to safeguard the reliability of the electricity system and customer services;
- fostering in-house skills for RTE’s core activities.

In 2022, CORS-N extended its scope of responsibility to include INUIT (Integrated Telecommunications Network Infrastructure) and the tertiary datacentre SNP (National Production System), until then operated by an external provider.

Cybersecurity

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

In 2022, risk assessments, external audits, and intrusion tests of RTE’s information system were carried out to establish the company’s level of resilience to cyberattack, and to ensure the continuity of its essential activities. The majority of the key information systems were the subject of detailed studies and now carry internal certification.

The measures to physically protect the rooms housing these systems have been defined and deployed in electrical sites subject to risk:

- in 2021, for the new HORUS datacentres and for the national centre tasked with the supervision of the information and telecommunications systems (CORSN),
- in 2022 and in coming years, for the new control rooms, the new equipment monitoring rooms, the new supply-demand balance management rooms, and the new centre in charge of managing operating experience.

6.3 The emergency response organisation (ORTEC)

In 2022, 6 separate events called for the activation of the emergency response organisation. There were different causes for these emergency responses (the supply-demand balance, the electricity network, fire, a storm, the information system, and telecontrol).

The year was marked by the enhanced preparedness of all contributors to the supply-demand balance (SDB) emergency response process. With regard to expected pressures on the supply-and-demand balance in the winter of 2022-2023, significant work was carried out to improve the robustness of the emergency response process, which to date has not yet been activated. This work focused on three areas:

- An **overhaul of the tools** used to create load-shedding plans: rework of the Macro-Délestage tool to produce a more robust, sustainable and automated tool through the development of the PENCROFF system, and an **update of associated documentation** (operating procedures, ORTEC factsheets) reflecting the changes made to the SDB emergency response process and the EcoWatt process.
- The drafting of recommendations that would enable stakeholders to organise the **management of a SDB emergency that may last several days, or even several weeks.**

- The provision of **training and refresher training for stakeholders** who may take part in the SDB emergency response.

07. European coordination

EUROPEAN INTEGRATION

The electricity transmission system is a Europe-wide network. The 43 TSOs across 36 countries are now linked together by approximately 420 interconnections, around 50 of which are sited at French borders. The reliability of the French electricity system is therefore partly dependent on the operation of the European power network.

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 reliability of Europe's interconnected electricity system:

- The Emergency and Restoration code defines common standards for the management of network emergencies and for system restoration. The System Operation Guideline provides a set of common principles for electricity system operation.
- In regard to markets, reliability is a cornerstone of the Electricity Balancing codes, which cover the supply-demand balance, and Capacity Calculation and Congestion Management, which aim to structure short-term electricity exchanges.
- In its requirements for the connection of generating facilities, the Requirements for Generators code includes technical requirements designed to increase the resilience of the electricity system.
- The Fourth Energy Package, titled Clean Energy for all Europeans, came into effect on 5 July 2019. Its objectives of enhanced European integration and renewable energy development open up new challenges and opportunities for the reliability of the electricity system.

7.1 Continued implementation of the european regulatory framework: network codes and the clean energy package

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

A change to RCC status for RSCS like coreso

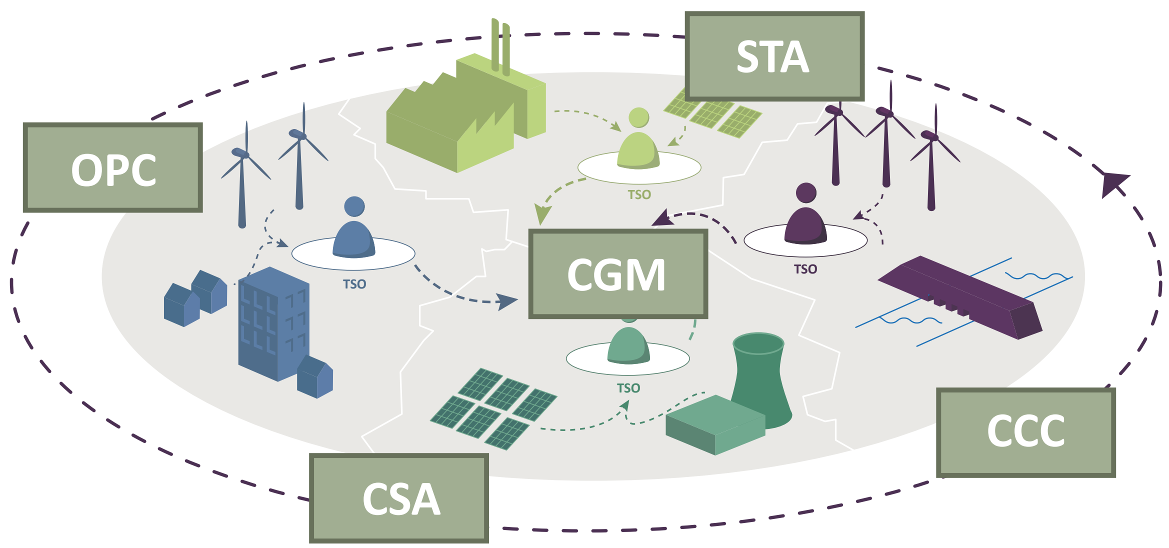
On 1 July 2022, the old Regional Service Centres (RSCs), the main examples being CORESO and TSCNET, became Regional Coordination Centres (RCCs), as defined in article 34 of the Clean Energy Package. This modified the status of Coreso and TESCNET, and led to changes to the decision-making rules followed by the two companies' decision-making bodies. In the next few years, Coreso will have to roll out all 13 services which have been or will be delegated to it by the TSOs in the two System Operating Regions (SOR). The development and deployment of these services had already been initiated prior to the change in status.

The main services include Coordinated Capacity Calculation (CCC), Coordinated Security Analysis (CSA), pan-European Short-Term Adequacy (STA), and Outage Planning Coordination (OPC). These 4 services rely on an initial service, namely, the provision of a Common Grid Model (CGM).

Risk Preparedness Plan

Member states continued their work on the risk preparedness of the electricity sector. In France, the Risk Preparedness Plan based on regional emergency scenarios provided by the TSOs has been put together by the government's Energy and Climate Department (DGEC), in conjunction with the network operators. It was approved by Parliament in 2022.

Work has been ongoing for the ENTSOE member states' working group, against the background of gas supplies impacted by the Ukraine war, and the low availability of nuclear energy in France and Finland, confirming the need to assess risk levels for several simultaneous scenarios.



7.2 New european codes for enhanced cooperation on electricity networks

The cybersecurity code

Through ENTSO-E, and in support of the French authorities, RTE contributes to the European initiatives for the protection of critical infrastructures and cybersecurity. These initiatives aim to raise the minimum requirements for all the stakeholders connected to the transmission or distribution network, and who may prove to be weak links in system reliability. **Among other things, this contribution involves the drafting of a new network code addressing cybersecurity, co-written with the EU-DSO Entity (association of European DSOs).** ACER, the Agency for the Cooperation of European Energy Regulators, submitted the revised text to the European Commission after consultation with ENTSOE and EU-DSO, for planned entry into force at the end of the second quarter of 2023.

The demand response code

The 4th Clean Energy Package, published in July 2019, stated that the European Commission should establish network codes for electricity system and market operation, including a code for "active participation of demand, including the rules on aggregation, energy storage and demand curtailment".

2022 was marked by RTE's work with ACER for the drafting of ACER's Framework Guideline: answers to ACER's questions submitted to TSOs and DSOs, a response to the public consultation on the draft framework guideline, and the preparation of communication material to set out its position.

The work on this code was carried out in partnership with the European TSOs within ENTSO-E, at a national level among system operators, and with our regulator.

The purpose of this future code is to harness flexibilities in the various market mechanisms, and to foster their use, particularly of those that are connected to the distribution network, by means of a harmonised European framework.

The main challenges facing RTE in regard to this work are to put forward rules that maintain effective operation of the electricity system, and to ensure access to the data stream needed for the successful fulfilment of our mission of transmission system operator.

The drafting of this code will begin in May 2023, for planned delivery to ACER in March 2024. The code may come into force in 2025 (depending on the duration of the consultation process by European bodies).

7.3 New milestones reached for capacity calculation

The period from 2020 to 2025 sees an acceleration in the implementation of the European requirements impacting interconnectors (the CACM, SOGL, FCA and EBGL network codes and the Clean Energy Package directive).

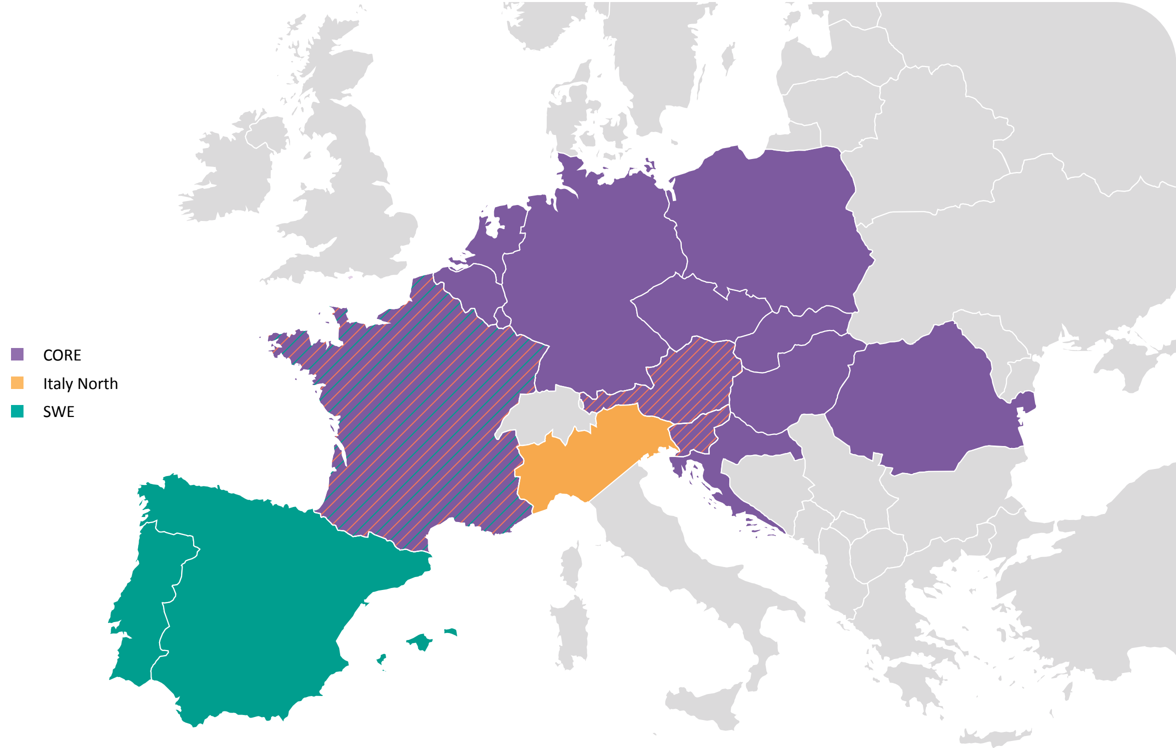
The text of the Clean Energy Package sets a minimum target of 70% of their capacity to be made available by interconnection installations for cross-border trading, a target that must be reached by 2025. The expected increase in cross-border exchanges requires ever-greater coordination between the European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

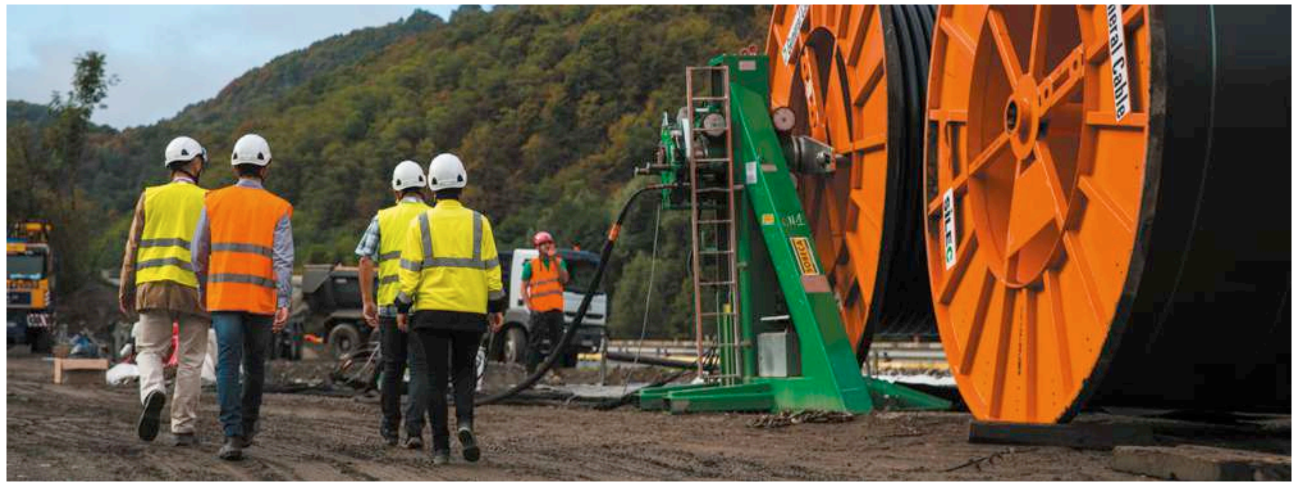
This has given rise to the launch of several projects under the aegis of the TSOs of the capacity calculation regions, as defined by the CACM code, for the calculation timeframes defined in the FCA (long-term timeline), CACM (day ahead and intraday timeline) and EBGL (balancing timeline).

RTE is involved in 3 different capacity calculation regions (Core, Italy North and SWE).

These capacity calculations use methods defined in the capacity calculation regions. The application of the content of these methods is driven by projects that focus on the coordinated calculation of optimised cross-border capacity for the market, in compliance with the operational safety rules stipulated by the TSOs.

Several new milestones were reached in 2022, making it possible to optimise cross-border capacity. In winter 2022, improvements in these calculations contributed to the management of supply-demand balance, against the background of a European energy crisis which resulted in particular in pressures on supply-demand balancing in France.





Deployment of the day-ahead capacity calculation in the Core region

2022 was marked in particular by the extension of the CWE flow-based[3] capacity calculation method (operational since 2015) to the Core region, thus expanding the flow-based zone eastwards, with different capacity calculation methods. This is the largest capacity calculation region in Europe. The implementation and integration of this new capacity calculation method for markets required close in-house cooperation between several RTE departments, including the teams working with the market projects and the national dispatch centre, and collaboration with the European coordination centres (CORESO and TSCNET) that now provide this service for all the TSOs in the zone.

Implementation of the CEP70 in the SWE region

Following on from Core and Italy North in 2021, the deployment of the Clean Energy Package capacity objectives was rolled out to the SWE region in early 2022.
The minimum 70% target rule for interconnection system capacity made available for cross-border electricity trade has been applied to the daily capacity calculation for the SWE region since the beginning of February 2022.

This has resulted in requests for capacity increases when the part of the network limiting the capacity calculation does not follow this rule. The TSOs respond, positively or negatively, to this request by analysing the network's operational limits.
At each of its mainland borders, RTE now offers up 70% of the capacity of installations for international trade on the daily calculation timeline.

Deployment of IDCC Run 1 in the SWE region

The first intraday capacity calculation was rolled out in 2022 in the SWE region. It regularly updates capacity available for next-day cross-border exchanges, once contributors have completed the schedules of generating units, which was never the case with the day-ahead calculation. As a result, the intraday calculation draws on more complete information, and is used to prepare for costly remedial actions (countertrading) that may be needed to secure scheduled trading between market players.

IDCC Run 2 in the Italy North region

Intraday capacity calculation in the Italy North region was partially implemented with Run 2, which gives results only for the last 12 one-hour intervals of the current day. The full intraday calculation is due by the end of 2024.
This calculation is used to prepare for costly remedial actions (countertrading) that may be needed to secure scheduled trading between market players.

3. Flow-based: a method for calculating capacities which optimises trade by factoring in the interactions between different borders.

7.4 MAJOR EVENTS IN EUROPE IN 2022

26 February 2022: emergency synchronisation of the Ukrainian power system with the synchronous area

On 26 February, in response to the war in Ukraine, the Ukrainian TSO requested the emergency synchronisation of the Ukrainian and Moldovan electricity systems to the synchronous area. A substantial amount of work was carried out in a short period of time to ensure technical readiness:

- The installation of telecommunication links for the exchange of a minimum of data between Ukrenergo and its neighbours (with appropriate architecture and protocols to prevent any risk of cyber-attack);
- The drafting of 4 operating procedures:
  - For the synchronisation operations themselves;
  - For the monitoring of oscillation phenomena that may arise;
  - For the coordination of the countermeasures to mitigate these oscillations, should they occur;
  - For emergency de-synchronisation, in the event of a serious threat to the synchronous area.
- A legal and contractual review, in particular of SAFA (the Synchronous Area Framework Agreement).

This successful synchronisation on 16 March 2022 has been succeeded by regular monitoring by RGCE (the Regional Group Continental Europe), which is in charge of operational matters within ENTSOE, for the CE synchronous area, so as to keep a close watch on any potential impact on the European network and gradually increase cross-border exchange capacity. As of 2 December 2022, in response to the Ukrainian TSO's request, the exchange capacity has been expanded to 700 MW between 10pm and 5am, and maintained at 600 MW the rest of the time. This increase was approved by RGCE.

7.5 Inter-area frequency oscillation studies

Inter-area oscillations are a resonance phenomenon between different generating units in Europe, which appears when there are substantial exchanges or when borders are less well interconnected. This phenomenon destabilises the electricity system and can threaten reliability, leading potentially to the tripping of production units and to the splitting up of the European network.

As the Iberian Peninsula sits at the extremities of the European network and the Franco-Spanish border is only moderately interconnected, the management of this border has a major impact on the oscillations experienced in Europe.

Therefore, REE and RTE have been working together since 2016 to draft and apply a border management procedure for the coordinated oversight of Franco-Spanish HVDC lines, in an effort to address these challenges and to reduce the exchanges to be made when conditions become potentially dangerous (which happened on 12 occasions in 2022). RTE and REE also initiate costly remedial actions to protect the European network from potential oscillations, particularly since the connection to Ukraine.

These risk conditions are identified through measurements provided by PMU (phasor measurement unit) equipment and via real-time analysis by signal processing software.

Another REE-RTE collaboration involves the statistical analysis of the causes of this phenomenon and parameter setting for the Franco-Spanish HVDC connection in order to reduce these oscillations (power oscillation damping).

At the European level, a subgroup within RGCE, the Subgroup System Protection and Dynamics (SP&D) Group, is monitoring this phenomenon and the OPEX from certain events.

7.6 Coordination for the winter period

Several measures were taken at the European level to secure electricity supplies for the winter of 2022-2023, in light of unprecedented pressures on the supply and demand balance in France and other European countries. These measures included:

- Weekly synchronisation meetings between the TSOs as well as the RCCs under the aegis of a working group within ENTSOE. These meetings were held every Friday and made use of data collected the evening before by the different TSOs – STA results (European process for SDB management), forecast of reserves, emergency arrangements, temperature alerts, etc.
- Several high-level meetings (HLM) with neighbouring TSOs (ELIA, REE, the German TSOs, Terna, NGSO, SwissGrid) to establish further support measures in the event of pressures on the French SDB: one of the main levers of action was to identify actions to maximise cross-border exchange capacity, particularly in the direction of imports to France, and to secure operational data exchange.
- Coordination with CORESO for the conduct of *ad hoc* studies, as needed, to validate key reliability aspects prior to activating the levers for action designed to increase imports. CORESO continued its work on a preemptive reliability assessment process that could be activated by one or several TSOs in a declared emergency situation: a Critical Grid Situation (CGS).

This coordination gave rise to concrete measures that can be activated as required, such as the possibility of waiving the CEP70 rule (200 MW of capacity offered beyond the calculation result) at the Franco-Spanish border after validation by the respective regulators, near-real-time updates of capacity, an alternative capacity calculation procedure in case of failure of the general algorithm, mobilisation of Spanish internal redispatching to safeguard Spain-to-France capacity, and optimisation of German imports through extended MEAS measures (Mutual Emergency Assistance System: exceptional emergency measure that is activated in the event of a SDB crisis).

7.7 Delivery of the report on the major event that occurred in 2022

The final report on the incident of 24 July 2021 was published on 25 March 2022.

This incident, which led to the separation of the Iberian Peninsula, was the subject of a detailed analysis that examined the causes and the actions taken. The expert panel, made up of representatives of the regulators and the TSOs, also put forward a series of recommendations for implementation by the TSO and/or DSOs.

These recommendations relate to:

- Securing the behaviours of renewable energy sources during disruptions;
- Improved consideration of the growing risk factors linked to weather hazards;
- The coordination of protection systems;
- The recovery of information if the underfrequency load shedding relays are activated;
- The synchronisation mechanisms in the event of grid disconnections.

Given that these recommendations are valid across Europe, their operational implementation is monitored within ENTSO-E.

08. Reliability audits and internal inspections

In accordance with its internal inspection process, RTE carries out a yearly assessment of its control of operating activities (and therefore of system reliability), in light of the risks that have been identified and prioritised, and of control measures implemented and their effectiveness. The internal inspections carried out in 2022 showed effective control in respect to reliability.

An internal audit was carried out in 2022, centred on reliability:

- safeguard plan operation.

The conclusions of the audit indicated effective control of reliable electricity system operation.

INTERNAL AUDITS

Internal audits focusing specifically on reliability are performed every year on behalf of the company senior management. The audit areas of focus are selected in such a way as to ensure that the full range of reliability-related issues are scrutinised over a three-to-four-year period, depending on the assessed risk level. The conclusions of these audits are submitted to RTE's Executive Committee. Recommendations are made to improve risk management. The actions initiated in response to the recommendations are implemented through action plans, reports on which are submitted to the Executive Committee.

APPENDIX 1: Glossary of terms

TERM	DESCRIPTION
BALANCING MECHANISM (BM)	French law stipulates 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.

TERM	DESCRIPTION
ENTSO-E	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, the coordination of European transmission network’s operation and development, and research activities. 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 sub-committees: 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 reliability, as defined 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), the SOC has set up an ad-hoc sub-regional body, the Regional Group Continental Europe (RGCE). *See: www.entsoe.eu*
SECURE TELECOMMUNICATIONS NETWORK	This secure telecommunications network is based on 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 telecontrol data for all substations, and the transmission of a limited number of telephone conversations between very-high-voltage substations and the substation group management centres; - the (“high-level”) transmission of telecontrol data, and the transmission of telephone conversations between dispatch centres and the substation group management centres; - the transmission of telecontrol data, and the transmission of telephone conversations between generating units and dispatch centres; - the transmission of telecontrol data, and the transmission of telephone conversations between dispatch centres and the distribution network operation centres.
PERFORMANCE AUDITS OF GENERATING UNITS	Given the critical nature of the services provided by generating facilities, they may be subject to performance audits once they are connected to the French public electricity transmission network. These audits 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

ADN	Northern Automatic Scheme against Voltage Collapse
ADO	Western Automatic Scheme against Voltage Collapse
aFRR	Automatic Frequency Restoration Reserve
ANSSI	National IT Services Security Agency
BCP	Business Continuity Plan
BM	Balancing Mechanism
BRP	Business Recovery Plan
CACM	Capacity Allocation and Congestion Management
CCC	Coordinated Capacity Calculation
CGS	Critical Grid Situation
CNES	National Centre for System Operation
CORESO	Coordination of Electricity System Operators
CORSN	Operational Centre for Digital Networks and Systems
CR	Current Rating
CSA	Coordinated Security Analysis
CSEA	Economic Oversight and Audit Committee
CURTE	Power Transmission System Users' Committee
DACC	Day-Ahead Contingency Contract
DSO	Distribution System Operator
EGBL	Electricity Balancing Guideline
ENTSO-E	European Network of Transmission System Operators for Electricity
FCA	Forward Capacity Allocation
FR	Fast Reserves (BM)
FW	Firewall – key component of internet access architecture
HLM	High Level Meeting
HVDC	High Voltage Direct Current
ICS	Incident Classification Scale
INUIT	Integrated Telecommunications Network Infrastructure
LPM	Defence Programme Law
MARI	Manually Activated Reserves Initiative (management of fast reserves with a 15-minute activation time)
NPP	Nuclear Power Plant
OC	Operation Centre
OPC	Outage Planning Coordination
ORTEC	RTE emergency response organisation
PER	Regional Exchange Gateway - dispatch centre remote control system
PICASSO	Platform for the International Coordination of the Automatic frequency restoration process and Stable System Operation
PMU	Phasor Measurement Unit
PUSH	Contingency Plan for Winter Security of Supply
RCC	Regional Cooperation Centre
RFG	Requirements for Generators
ROSE	Secure Fibreoptic Network
RPD	Public electricity distribution network
RPT	Public electricity transmission network

RSC	Regional Services Centre
SAS	Alert and Safeguard System
SCC	Stress Corrosion Cracking
SDB	Supply-Demand Balance
SIDRE	Regional Dispatch Centre Support Group
SLFC	Secondary Load-Frequency Control
SNC	National Control System
SOGL	System Operation Guidelines
SPD	Subgroup System Protection and Dynamics
SRC	Regional Control System
SSE	Significant System Event
STA	Short Term Adequacy - pan-European supply-demand balance assessment
STS	Secure Telephony System
SVC	Static Var Compensator
TERRE	Trans-European Replacement Reserve Exchange (management of tertiary reserves, traded in 30-minute blocks)
TSO	Transmission System Operator
STA	Short Term Adequacy : étude d'équilibre offre demande à la maille européenne
STS	Système de Téléphonie de Sécurité
TERRE	Trans European Replacement Reserve Exchange (pour gérer la réserve tertiaire (30'))

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 - Visuel de couverture : © Seignette-Lafontan - Visuels intérieurs : © Médiathèque RTE - Impression sur papiers issus de forêts gérées durablement.