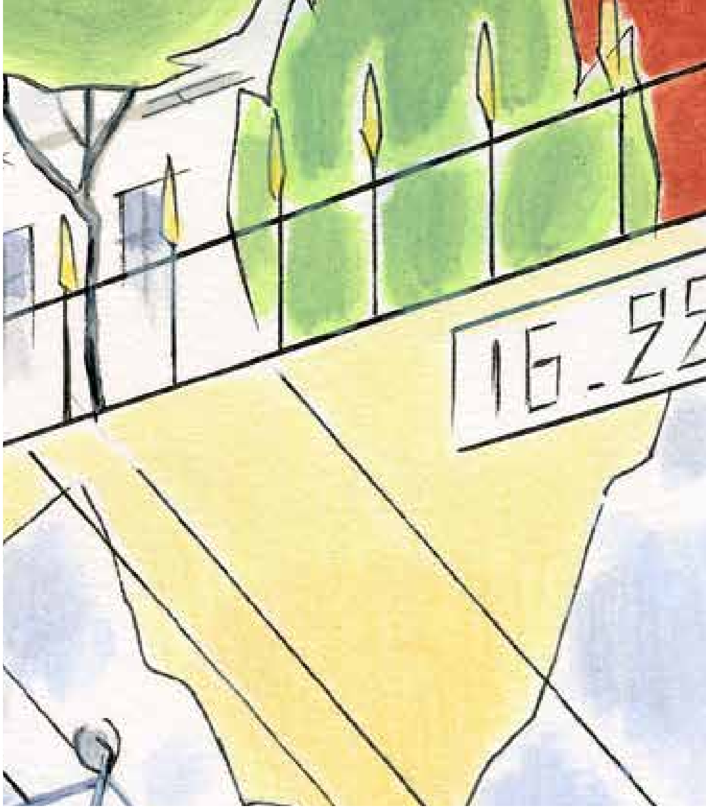
Le réseau
de transport
d'électricité

RELIABILITY REPORT

2021



OVERVIEW

01. Summary

1.1 ANALYSIS OF THE 2021 KEY INDICATORS DEMONSTRATES A SATISFACTORY LEVEL OF OPERATIONAL RELIABILITY

2021 saw a gradual return to pre-health-crisis conditions. **The key indicators for operational reliability have undoubtedly improved as a whole compared to 2020 (an untypical year owing to Covid),** but all contributors to reliability in France and in Europe must remain vigilant in the context of a system requiring more and more balancing, and with a growing share of renewable energy.

The following points should be flagged up for 2021:

- **a drop compared to 2020 in the number of Significant System Events (SSE), an indicator of the operational reliability of the electricity system,** but not yet however a return to pre-crisis levels, with continuing large numbers of instances of flows exceeding capacity at the Spanish border, and pressures on the supply-demand balance;

- **an ongoing rise in the number of threshold overruns of high-voltage limits in 2021,** despite the recovery noted in electricity consumption.

The underlying trend remains that of an **electricity system calling for more and more balancing, characterised by a growing share of renewables that does not yet contribute to flexibility or system services,** and **flow variability** that once again this year is notable for its **direction and intensity.**

The availability of the nuclear fleet, though up slightly from 2020, is nevertheless subject to monitoring and red flags for availability in 2022 and subsequent years.

In 2021, the availability of the nuclear fleet was marked by the impact of the public health crisis on maintenance programmes, and by the identification of a generic issue affecting some plant series.

As in 2020, this situation 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 measures to guarantee the highest levels 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, frequency and voltage 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;

- RTE's involvement in **three projects setting up European platforms** for the management of operating reserves. **RTE connected to the tertiary reserve platform (Trans-European Replacement Reserves Exchange – TERRE)** in early December 2020;

- **enhanced cooperation between transmission system operators and the European coordination centres,** building on the roll-out of services under the European network codes and the Clean Energy for All Europeans Package;

- **increased cross-border flow capacity;**

- **continued deployment of the programme to install voltage compensation systems,** and the introduction of measures to develop the contribution of distributed generation to voltage control;

- **preparations for the 2022/23 winter given the limited nuclear fleet availability, low hydropower capacity output in Southern Europe, and uncertainty over the impact of Russian gas supplies on the European supply-demand balance.**

1.2 THE IMPACT ON RELIABILITY OF THE PUBLIC HEALTH CRISIS

2021 continued to be affected by the Covid-19 related health crisis: the national lockdown imposed in late 2020 was gradually tightened in several administrative regions, and followed by reinforced health measures over all of mainland France between 3 April and 2 May 2021.

Faced with the continuation of the Covid-19 pandemic in 2021, and as an essential infrastructure operator, RTE extended the implementation of its **Business Continuity Plan (BCP),** originally designed to deal with flu pandemics. A country-wide unit, purposely distinct from the main emergency preparedness organisation ORTEC, continued to operate in 2021, overseeing the correct execution of the BCP. **The BCP has been continuously adjusted to changes in the epidemic, so as to protect the health of RTE's employees and contractors, while ensuring the continuity of its public service mission.** Along with the standard measures applicable to all employees (option of remote working, infection prevention measures, changes to operating practices), **additional measures were taken for key roles:** physical separation of dispatch centre staff, creation of employee bubbles for essential operations, sharing of good practices in ENTSO-E. One of the steps in the BCP involved the on-site lockdown of employees needed for network operation, but this mechanism was never activated.

The pandemic continued to have **an effect on the supply-demand balance,** as the generating fleet remained impacted by the consequences of the health crisis. Although there was no return to pre-crisis levels, there was a rebound in consumption, with some sectors more dynamic than others (a 1.7% increase on 2020, allowing for the climate hazards and seasonal effects that must be viewed against a 3.5% decrease in 2020 compared to 2019).

In these conditions, **the difficulties in forecasting changes in consumption** persisted in 2021, with 22 significant forecast deficiencies versus 25 in 2020, and an average of 10 from 2016 to 2019.

02. Significant System Events (SSE)

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 reflect the occurrence of 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 by the company to improve operational reliability.

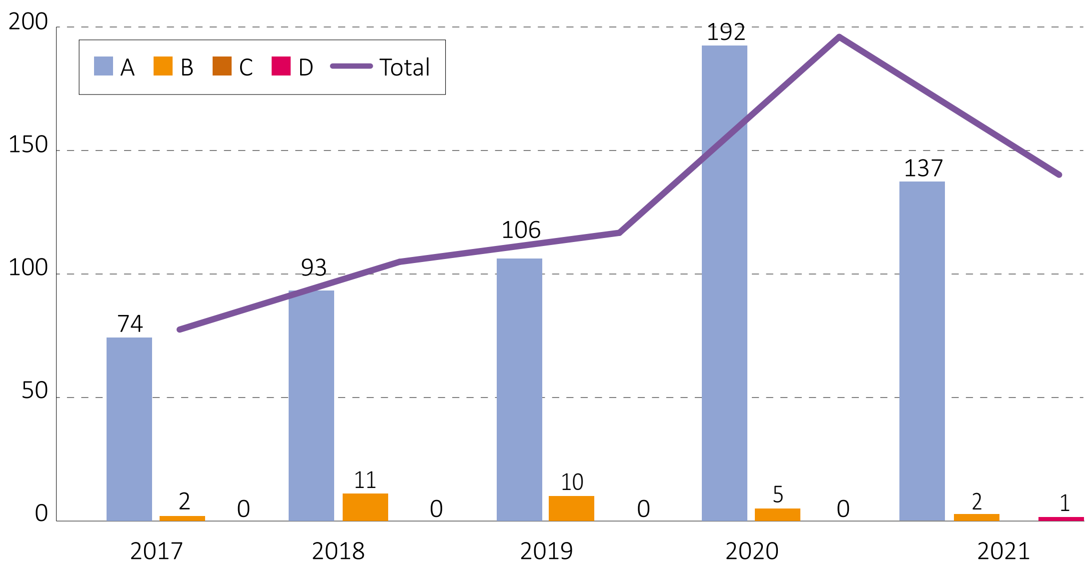
Events classified from A to F are considered as having a proven impact on reliability: the degree of impact increases from A (localised, single and controlled incident) to F (widespread incident). Level-0 events are considered as having no proven impact on reliability (low-level events) and are used 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 in terms of reliability).

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

With 137 events classified as A, 2 classified as B, and 1 classified as D, **2021 saw a drop in the number of Significant System Events (SSE) compared to 2020.**

Trend in SSEs with a severity classification ≥ A



The number of SSEs remains above the 2017-2019 average for level-A SSEs, but has dropped significantly for higher-level SSEs, which have a greater impact on the reliability of the electricity system (decreasing from 11 in 2018 to 3 in 2021), notwithstanding one level-D SSE related to the incident on 24 July 2021 (separation of the Iberian Peninsula from the rest of continental Europe).

The upward trend in level-A SSEs since 2017 stems from the fact that **the electricity system, with an ever-growing need for balancing, is adapting to the change in the energy mix, a context that was exacerbated last year and this year by the health crisis:**

• a generating fleet that is offering fewer opportunities in terms of flexibility and system services that it has in the past. This fleet comprises a growing proportion of renewables, for which RTE does not have adequately reliable production forecasts for balancing, on the one hand, and which, on the other hand, do not yet contribute to flexibility and system services. In addition, there has been a marked reduction since 2020 in the availability of the fleet's nuclear power plants, linked to the health crisis and its effects, as well as the identification in 2021 of a generic issue affecting some plant series;

• **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 42 in 2021 (33 in 2020). This year also saw 3 SSEs linked to difficulties in controlling the reference framework for power flows in cases of line trips in RTE's domestic network during extensive international energy exchanges.

More specifically, 2021 differed from 2020 as follows:

• **a significant reduction in the number of level-B SSEs** (with a greater impact on reliability than the level-A SSEs), dropping from 5 to 2;

• **the occurrence of one level-D SSE** following the trip of two 400 kV lines close to the Spanish border resulting from a fire beneath these lines. As there was no notification of this fire, preventive protection measures were not implemented. These trips led to the loss of all the interconnectors between France and Spain owing to cascading overloads and loss of synchronism. This beyond design basis event, which gave rise to an in-depth European OPEX report, demonstrated the effectiveness of the defence plan and of the coordinated actions of the French and Spanish TSOs, which enabled a rapid resynchronisation of the two networks within thirty minutes;

• a fall in the number of SSEs related to **supply-demand-balance management,** resulting partly from a slightly higher level of **nuclear generation fleet availability** than in 2020, though from the autumn onwards, the identification of an anomaly, believed to be generic across the 1500 MW plant series, led to the shutdown of several power plants.

Thus, the number of situations where the supply-demand balancing mechanism was under strain fell from 48 level-A SSEs in 2020 to 19 level-A SSEs in 2021:

• the improved **availability of generating plants in Western France in the winter months, which meant that no SSEs were reported for a deterioration in the voltage map (compared to 17 in 2020);**

• **occasional and always controlled overload protection start-ups** in the domestic network and on the Franco-Spanish border; these events were partly linked to rapid and extensive variations in flows during changes to the cross-border trading schedules and power generation schedules.

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 involves ensuring a 24/7 balance between electricity production and use, and carrying electricity flows from centres of production to centres of consumption. This means 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 extensive or country-wide blackouts.

The origin of a large-scale incident is always defined according to 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 several 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 continuously 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 constantly 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 an unforeseen issue affect several generating units, and the production and consumption plan prove inadequate.

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 a synchronously connected Europe can prevent this type of situation.
- In the event of beyond design basis incidents, the defence plan (with under-frequency load shedding) averts a potentially significant drop in frequency.

Loss of synchronism
- A short-circuit close to a generating unit may result in generator acceleration.
- The stability studies performed 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 continuously operates 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.

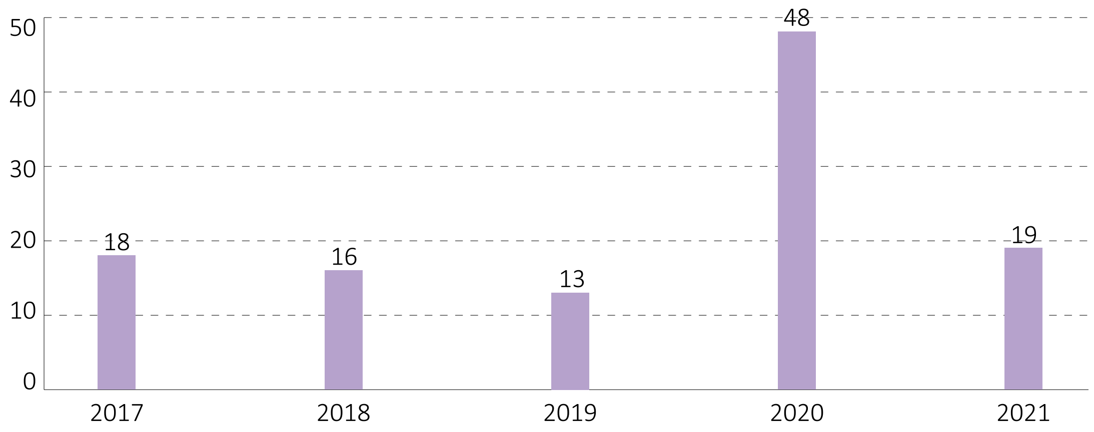
System reliability is defined as the ability to :
- ensure normal system operation (normal frequency range, voltage, current, short-circuit power) in both normal conditions and in the event of unforeseen issues, in accordance with risk control rules;
- minimise the number of incidents and prevent major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

03. Supply-demand balance and frequency control

3.1 IMPROVED MANAGEMENT OF THE SUPPLY-DEMAND BALANCE DESPITE THE ENDURING EFFECTS OF THE HEALTH CRISIS

In 2021, 19 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.**

Level-A SSEs linked to shortfalls in SDB upward margin



This number has fallen sharply compared to 2020 and has bottomed out to the level of previous years. Pressures on the supply-demand balancing mechanism arose primarily at the beginning and end of 2021.

The 2020/2021 winter was long and harsh, and the generating fleet continued to be impacted by the effects of the health crisis on essential maintenance, as well as by industrial action. Against this background, the first nationwide Ecowatt red alert was triggered on Thursday 7 January 2021.

Although on average, over the year, the nuclear fleet posted an additional available capacity of around 2.5 GW more than the previous year, the end of 2021 was marked by low availability, including the shutdown of the reactors at the Chooz and Civaux power plants. These unexpected shutdowns, coupled with a heavy maintenance schedule that was severely disrupted by the effects of the health crisis, led to historically low availability at year end, below even the level seen at the end of 2020.

Furthermore, the upturn in generation relative to 2020 remains 15 TWh below the 2019 figure.

Around 20 GWh of demand response capacity was activated in 2021, in other words, almost twice as much as in 2020. It was the highest since 2018. The greatest need for demand response occurred in January 2021, when stresses on the electricity system caused by the low availability of generating assets rendered its activation economically viable.

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

Regarding **shortfalls in downward margin,** the number of situations with tight margins was stable compared to 2020. However, instances when the requirement for a 15-minute downward margin was not achieved are deemed to be frequent.

These instances did not require the dispatching of system notices.
These shortfalls mostly arose in the spring and summer; as in the previous year, **they can be explained by the increasing lack of dispatchable and flexible sources with, in particular, a growing share of renewables that does not yet contribute to the balancing mechanism.**
As in 2020, this is consistent with the analysis of the Adequacy Report, which presents a stable and balanced electricity system, but with smaller margins than in previous years.

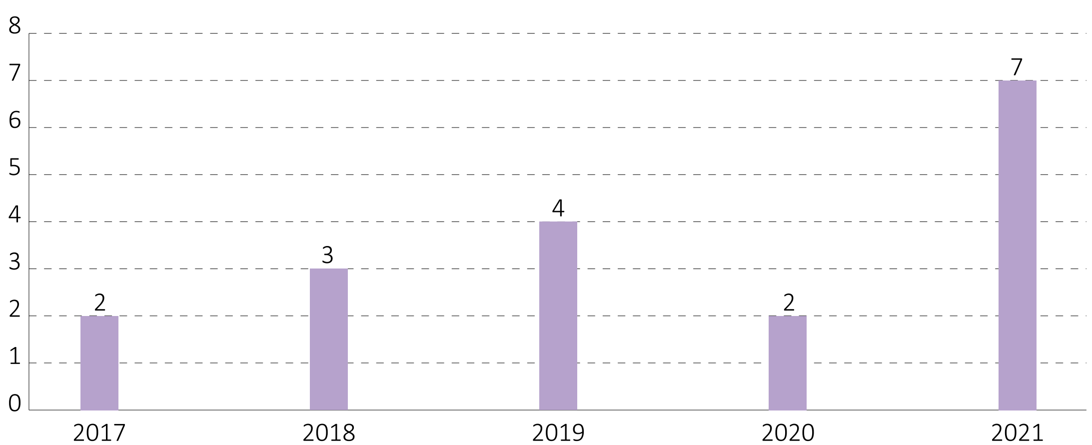
3.2 EUROPEAN ELECTRICITY SYSTEM FREQUENCY CONTROL UNDER CONTINUED SCRUTINY

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, though there was a worsening again in 2021, a clear indicator that continued vigilance is needed and that the European TSOs must not slacken off.

With 78 significant and sustained frequency deviations in 2021, **European frequency control has deteriorated compared to 2020** (41 frequency deviations). Most frequency deviations are deviations below the target value (that is to say, when generation is lower than consumption, and frequency drops below 50 Hz). To varying degrees, France was involved in 65 of the 78 deviations recorded in 2021.

There was a notable increase in significant frequency deviations in 2021 compared to previous years: **7 level-A SSEs were reported in 2021.**

Level-A SSEs: frequency deviations



French frequency control operations contributed to varying degrees to these 7 SSEs. 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 in response to hourly changes in generation schedules.

This phenomenon of **deterministic frequency deviations at hourly intervals** - characterised by short-lived frequency variations above 100 mHz during the hourly synchronisation of generation schedules across Europe – is still prevalent (185 deviations of more than 100 mHz this year, versus 174 in 2020).

In 2021 (as in previous years), France met the two criteria stipulated by European network codes for quality of control of 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, these criteria must not be above a given power threshold for more than 5% or 30% respectively of the time in the year, as an average.

Year	2019	2020	2021
Level 1 threshold (<30%)	11%	9%	9.2%
Level 2 threshold (<5%)	3.6%	3.0%	3.4%

Although compliance with the indicators for 2021 was maintained, lack of flexibility in the balancing mechanism and uncertainties over volumes of renewable generation had a negative impact on the quality of French frequency control in April and in May.

The contractual framework governing **generating units operating under the premium tariff mechanism** (around 6 GW of installed capacity as at end 2021, primarily renewables) leads 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 occurred on several occasions in 2021. Special attention is now needed whenever there are negative market prices: the volumes involved amount to around 1,500 MW, roughly equivalent to the French 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. A WG to raise awareness in the renewables sector was held in the autumn of 2021, and bilateral exchanges have provided RTE with the opportunity to explain its requirements and understand the obstacles to the sector's participation in the balancing mechanism. The emergence of offers with short deadlines and activation times would indeed be an effective way of mitigating 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 21% of the time in 2021, versus 19% in 2020 and 8% in 2018.

Furthermore, **the total annual duration of shortfalls in primary reserves remained stable** (7 days of cumulative failure versus 6 days in 2020).
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 for **the balancing mechanism to restore the required reserves 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.

In order to address these difficulties, RTE has initiated discussions and actions with stakeholders in France (CURTE, CRE, etc.) and in Europe (going beyond the existing procedures for mutual support between the TSOs of the European Union, Switzerland, and Great Britain):

- the **ramping up of certification for primary frequency control purposes of storage units (batteries) and distributed clusters:** 177 MW of batteries certified for primary frequency control by the end of 2021 (in other words, more than a third of the volume required for primary frequency control);
- continued efforts in 2021 to incorporate new flexibility services **into the balancing mechanism.** Since the premium tariff system was extended to renewable generating units, they have been able to participate in the balancing mechanism; **in August 2021, renewables fleets put forward their first tenders for downward reserve provision** under the premium tariff mechanism, leading to the activation of reserves, in volumes that are still limited;

- **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, using indicators to trigger requests for action plans if predefined thresholds are exceeded; RTE pays particular attention to its compliance with these indicators, and has modified its strategy for predicting periods of high variations in exchanges;

- **a change in the method used for setting the size of secondary reserves, taking into account the recommendations of the European network codes,** has been in effect since early November 2021. The size of reserves is now determined in the light of past discrepancies in assessment. A difference is now made between upward and downward reserve requirements in response to the asymmetric provision capacity of some reserve entities;

- the roll-out in summer 2021 of a **new system for automatically calculating reserve margins,** which now delivers a more accurate calculation of available reserve margins and **maximises** (using a model that is less conservative regarding the volume of sources that can be activated) **the volume of available offers** in steps of 15 minutes, and not solely at peaks and dips in consumption;

- **since summer 2021, the real-time publication on RTE's customer website of the reserve margins that are close to expiry, and of the predicted imbalance** of the electricity system in the hours ahead, thereby providing an overview of expected strains on system balancing;

- **an enhancement in the method for calculating the contribution of renewables** to supply-demand balance, by including forecasts instead of the programmes put forward by suppliers, which delivers greater accuracy and increases the volumes taken into account.

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 aiming 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 manual frequency restoration reserves 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 early December 2020.**

RTE's participation in the different TERRE daily gates steadily increased in 2021, during the period of monitored operation. From the second half of the year onwards, there was an increase in activated balancing volumes on the TERRE platform, though they remain relatively low. On average they accounted for 5% of the total balancing volume for 2021, but around 20 to 30% over the last two months. The remaining balancing operations are still based on offers made under the French balancing mechanism. Connection to the PICASSO and MARI European platforms (in 2023 and 2024 respectively) will increase the share of offers, as required by the Electricity Balancing Code.

Furthermore, RTE has started **preparations for the 2022/2023 winter against a background of limited nuclear fleet availability, low hydropower capacity in Southern Europe (Portugal, Spain, Italy), and uncertainty over the impact of Russian gas supplies on the European supply-demand balance.**

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:

- **frequency containment and automatic restoration 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 generation 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.

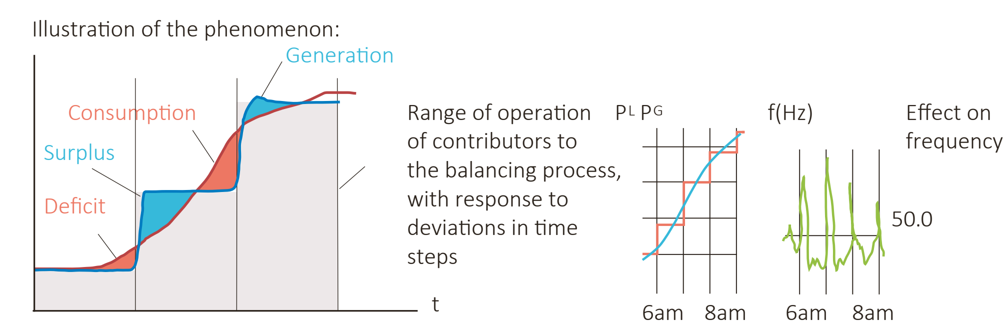
When these conditions are not met, RTE issues a system notice (one day-ahead), a degraded mode notification (real time) or, where applicable, a system safeguard alert (also in real time).

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.



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.

04. Risk control underpinning system reliability

4.1 NETWORK STABILITY

LOSSES OF SYSTEM STABILITY DUE TO LOSS OF SYNCHRONISM

On 24 July, a fire in the Aude region led to the tripping of two 400 kV lines close to the Spanish border. The operational teams were not made aware of this fire and preventive protection measures were thus not implemented. Cascade overloads led to the loss of the interconnectors between France and Spain.

As the maximum transmissible power was exceeded, **eight 400, 225 and 63 kV lines tripped on activation of loss of synchronism protections,** in accordance with expectations.

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 2021, 98% of the 373 faults on 400 kV lines were addressed in keeping with expectations (the figure has been between 96 and 98 % since 2015). 82% of faults are single-phase faults.

Good results for the 225 kV lines, which are central to the network's stability, also contributed to this high level of reliability: 96% of faults were resolved within 200 minutes.

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 99.93%** (and has remained above 99.2% since 2015).

INTER-AREA FREQUENCY OSCILLATIONS

Inter-area frequency oscillations in the European power network occurred on 11 October 2021, for a total of 4 hours, with up to 600 MW of active power oscillations in a 400 kV line between France and Spain.

Monitoring of the damping of power oscillations at the Franco-Spanish border revealed that this damping could be inadequate over long periods, which led to the implementation of a modified procedure for the proactive management of the direct-current link between France and Spain.

The commissioning of a system for detecting inter-area oscillations is scheduled for the summer of 2022. This system will be able to identify these oscillations in real time, and inform dispatch centres of the correct damping measures.

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 improve initial stability;
- adjusting operating plans, 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 bring about 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 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 2021 (versus 17 in 2020 and 15 in 2019). The activation threshold for the Western and Northern Automatic Schemes against Voltage Collapse (ADO and ADN) **was never reached.**

The improvement seen in 2021 was largely the result of the increased availability of generating units in Western and North-West France during the winter months.

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.

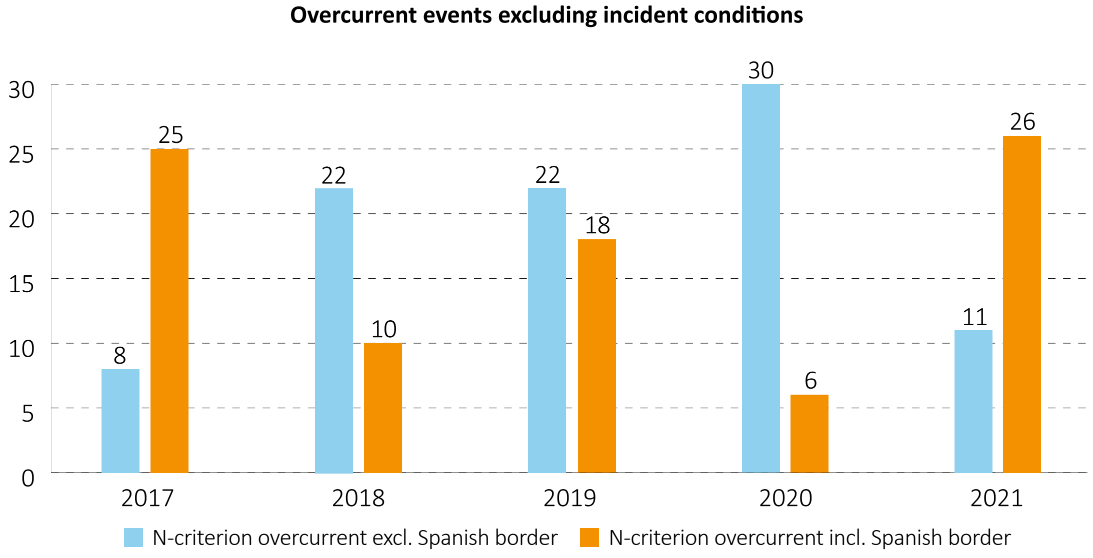
Importing a supply of top-up power from a neighbouring area causes major voltage drops in the network. Automatic on-load tap changers, installed in the network transformers supplying customers, compensate for these voltage drops. However, this results in increasing the inrush current and therefore in 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 automatic 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 controllers activate a volume of localised load-shedding, just enough to prevent an uncontrolled spread of voltage loss, thereby avoiding more widespread power outages.

4.3 MANAGEMENT OF NETWORK FLOWS

Over the last five years, excluding incident conditions, the overall number of separate start-ups of 225 and 400 kV overload protection systems has remained stable. These overcurrent conditions were always rectified within established timeframes, and did not jeopardise the reliability of the electricity system.



The **Spanish border (interconnection and upstream network)** accounted for a significant portion of the cases of line flow limits exceeded, and even constituted the majority in 2017 and 2021.

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.

Improved management of changes to cross-border trading schedules, and the ability to predict the East-West distribution of these exchanges, resulted in effectively reducing the occurrence of flows with limits exceeded. In 2021, two factors led to a **new increase in excess flows across the Spanish border:**

- the unavailability of an installation close to the border;
- **greater uncertainty over line flows, with the Iberian Peninsula experiencing deviations in supply-demand control owing to the ramping up of mechanisms for shared European balancing reserves.**

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

Leaving out the Spanish border, the cases of flow limits being exceeded is decreasing. Nevertheless, **the ability to comply with flow limits (excluding incident conditions) is affected by the significant inter-region transmissions associated with cross-border exchanges and by changes to power generation schedules.**

Thus, in 2021, during high levels of international exchanges, three situations highlighted the difficulties in complying with RTE's frame of reference (control of flows in the event of line trips).

These events led to the reporting of SSEs classified above level A (while no SSE above level A has been reported to date).

Measures were taken to minimise exceeded flow limits, such as pre-empting response thresholds and strengthening the **coordination between operating centres.**

A **new system for monitoring and predicting constraints** was rolled out in 2021. Other R&D work is also underway, focusing on predictions and on the management of the topology of the network.

The work undertaken to reduce uncertainties over the quality of the research data shared with the Spanish and Portuguese TSOs will continue in 2022.

A conductor replacement project has been rolled out at the Franco-Spanish border. In the short term (2022 and 2023), the operation of this area will be challenging, as the work will require the unavailability of some installations, which will increase the loads on others and the load transfer coefficient on available lines.

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.

Therefore, maximum values are set for every 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 extent of current overload), the affected installation is automatically disconnected from the network on activation of its overload protection.

The power flows carried by this installation prior to the trip are transferred to nearby installations. Depending on the severity of the phenomena, there may be further overloads and then 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, from network investment to the real-time management of operations, network studies are carried out for different timelines. The process for conducting these studies has changed in response to the energy transition and 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 has also evolved, thanks to the alignment of information processes for advance information on works, earlier notification of 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 to real time.

This data is continuously shared with the 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 2021, the nuclear power plants performed **8 successful islanding operations (out of a total of 11),** with a rolling four-year success rate of 93%, a highly satisfactory result given the multiyear target of 60%.

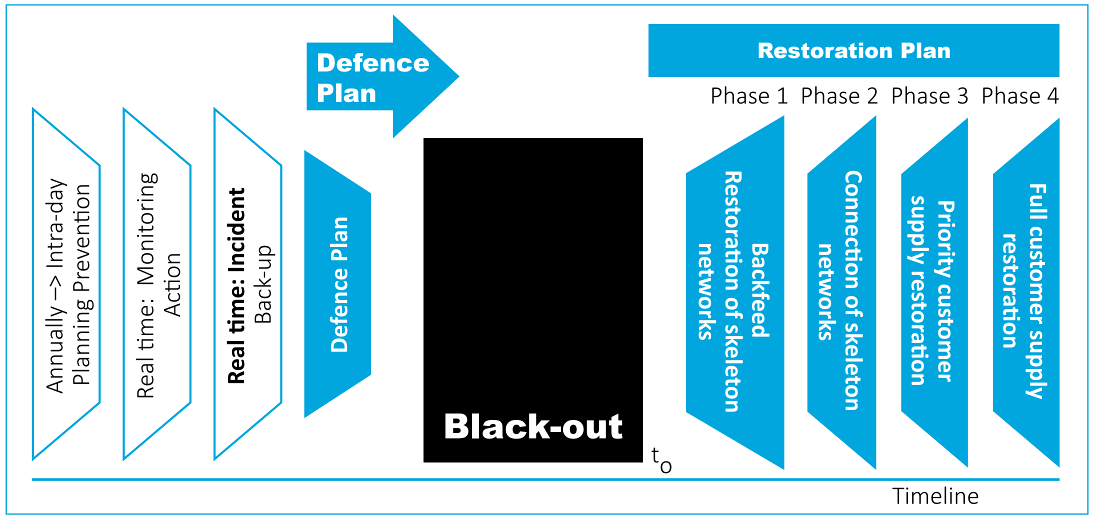
NUCLEAR UNIT HOUSELOAD OPERATION AND SKELETON NETWORKS

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



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, and 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 upon frequency drop of non-priority loads;
- the tailored automatic schemes under RTE's Defence Plan (ADO/ADN, etc.);
- the automatic locking of transformer on-load tap changers.

RESTORATION PLAN

An abnormal combination of adverse events can lead, despite RTE's deployment of all the levers of action at its disposal, to a total collapse of the power network of a region, of the 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.

05. Threshold overruns of high-voltage limits

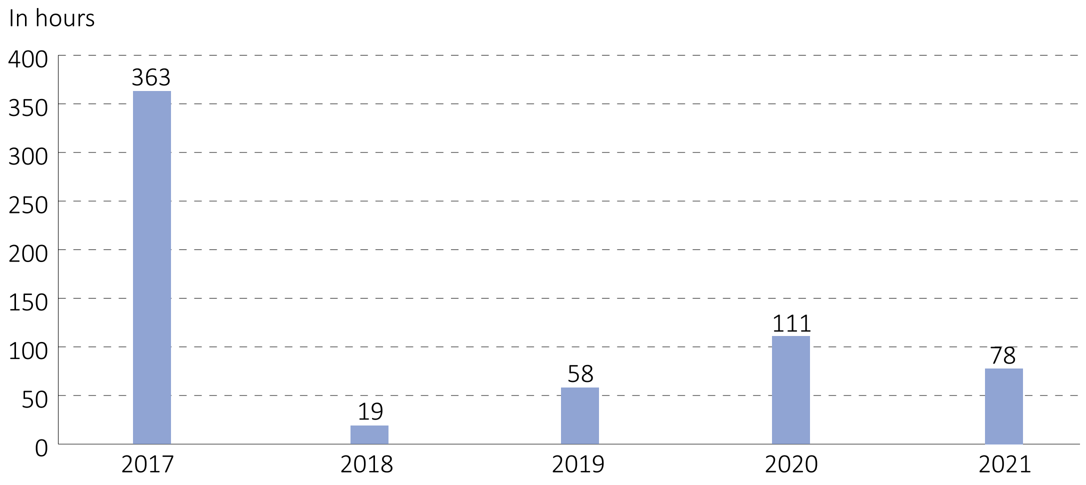
THRESHOLD OVERRUNS OF HIGH-VOLTAGE LIMITS ON THE INCREASE

Although these phenomena are still seasonal (linked to periods of lower energy consumption), they are now occurring throughout the year.

In 2021, two situations highlighted difficulties in complying with RTE's frame of reference (compliance with maximum voltage ranges in the event of line trips) when work on the electricity system increased its vulnerability. These situations led to the reporting of level-A SSEs (while no level-A SSE has been reported to date).

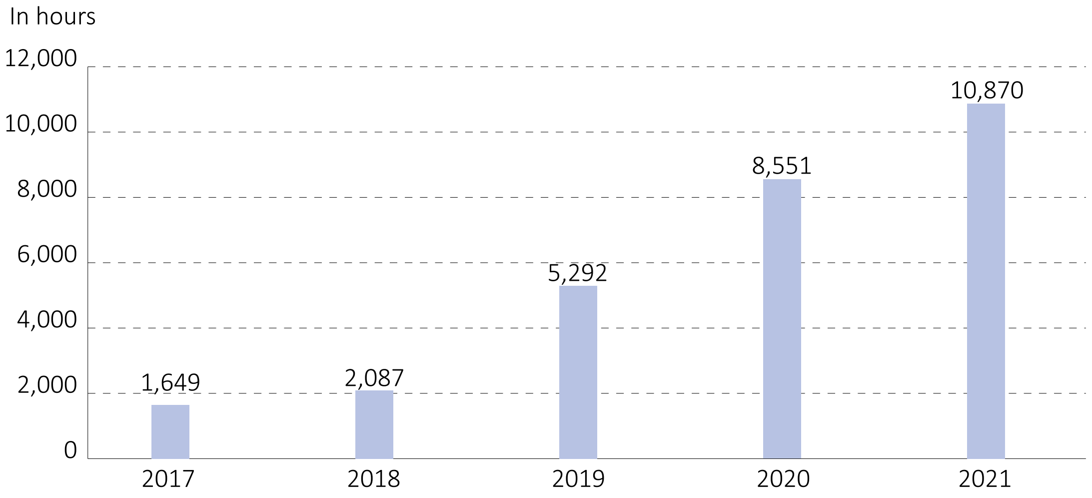
Threshold overruns of limits in the 400 kV system were slightly down from 2020.

Cumulative duration of 400 kV system limit threshold overruns



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

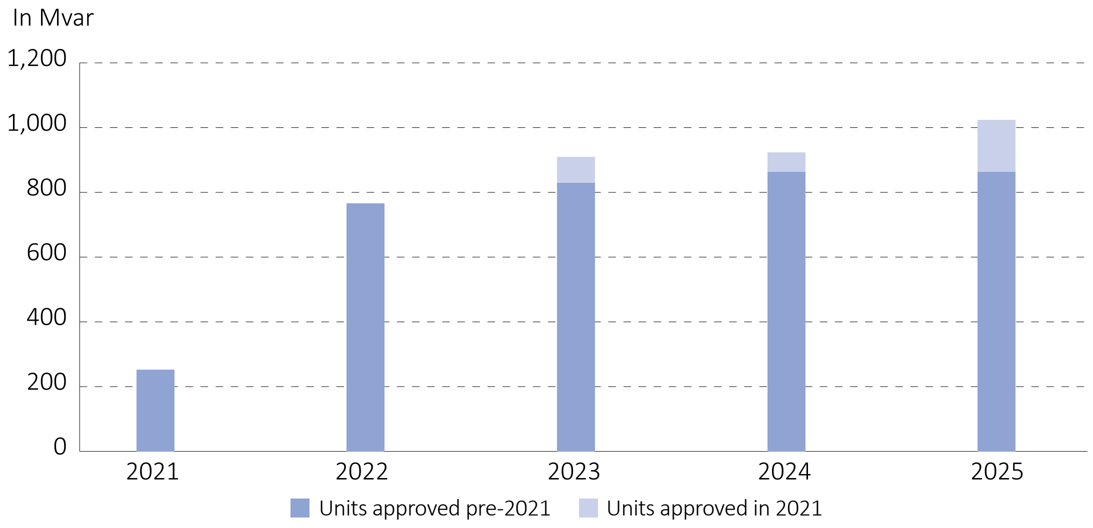
Cumulative duration of 225 kV system limit threshold overruns



RTE is proceeding with its power compensation installation programme for better control of high voltage: 250 Mvar of inductors (voltage-drop inductors) were connected in 2021.

High-voltage constraint studies guide decisions to install inductors at key locations in the network (2,590 MVar of units approved in 2020, 300 Mvar of units in 2021).

Inductor projects (excl. offshore windfarm connections) by commissioning year



Consultations on the voltage-control participation of new sources (wind or solar power installations connected to the distribution system, batteries, HVDC lines) are still ongoing, and trials are likely to take place in the TURPE 2021-2025 tariff period (public transmission system access tariff). 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.

LA PROBLÉMATIQUE DES DÉPASSEMENTS DU SEUIL DES PLAGES DE TENSION

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 generating 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 of a 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 very high in 2021.

Control systems

In 2021, two significant events occurred in relation to **control systems:**

- **on 3 June, the loss for around one hour** of the remote control systems (SNC, SRC, and frequency and voltage control systems) used by the National Centre for System Operation (CNES) and the dispatch centres in southern France (Lyon, Toulouse, Marseille), following a malfunction with fibreoptic equipment (severity level B SSE);
- the detection of the unavailability of the remote control system for a 400kV substation, without prior alarm warning (level-A SSE).

These **events led to the implementation of targeted action plans** (resilience, software updates and configuration, skills enhancement, integration of the national operational centre CORSEN).

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 2021, SIDRE was used on 19 occasions, 13 of which ensured that grid observability and operation were maintained throughout the incidents.

Other electricity network control room systems

In 2021, the availability rate of RTE's Alert and Safeguard System (SAS) equipment was satisfactory. Only 1 level-A SSE and 5 level-0 SSEs were reported (versus 2 level-A SSEs and 1 level-0 SSE in 2020).

The number of SSEs **resulting from inappropriate actions or failure to acknowledge system notices, by generation companies, distribution companies or RTE operators,** in cases of genuine "critical status, inadequate reserve margins" alert notices (severity level A), decreased from **67 in 2020 to 31 in 2021.**

The increase in 2020 was linked to a significant rise in the number of SAS notices sent to generating companies, owing to pressures on the supply-demand balance, and improved tracking for this type of SSE.

In 2021, the drop in the number of situations with pressures on demand-balance meant that fewer system notices were sent, resulting in fewer SSEs.

An e-learning package on how to use the SAS system, aimed at the contributors to network reliability, will be posted online in 2022, and the system reliability related training being delivered to them is now monitored more closely.

In 2021, work continued on the SAS 2 Project to replace the architecture of the current SAS system, by bringing it in line with technological developments and thus easing the integration of new contributors to reliability, such as the renewable energy companies. This updated system is due to be commissioned in 2025.

ALERT AND SAFEGUARD SYSTEM (SAS)

SAS ensures the secure transmission of RTE's alerts and notices of actions required from 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 pre-drafted notices and messages safely, accurately, and rapidly, including:
- system safeguard notices, for fast 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 2021, the overall availability rate of the datacentre hosting it was in line with expectations, and no unavailability was recorded. 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, 2 level-A SSEs and 1 level-0 SSE in 2021 were linked to Convergence. They involved an unmet deadline for scheduled work, a non-reproducible malfunction at an operator workstation, and a missing setting for the application-addressing mechanism.

The **IPES** system is used for short-term studies on system operation; it provides estimates, for a selectable time period ranging from 4 days ahead to 2 days after, of **the output of wind and solar energy sources, as well as forecasts of the power they will generate** at local, regional, and national level.

In view of the increased failure of the generating companies' telemetry, joint action was taken, and a new version of the system will be operational in 2022, enhancing the reliability of this data that is so strategically important today for the reliability of the electricity system.

There were 10 level-0 SSEs (no level-A SSEs) linked to the availability of the systems used for analysing the supply-demand balance, and balancing and markets, compared to 8 and 1 respectively in 2020; these malfunctions are mostly due to the complexity of the functional chains and to recent developments in supply-demand balance management platforms, in particular the interface between RTE's systems and the European platform TERRE.

6.2 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 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" remote control, the exchange of information between the electrical fault protections and secure telephony.

In 2021, 1 level-B SSE linked to work on electrical supplies and 1 level-0 SSE (contractor equipment failure) are attributable to the ROSE infrastructure (2 level-0 SSEs in 2020).

In order to mitigate obsolescence in its 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, is designed to carry essential services and align RTE's fibreoptic networks.

Four level-A SSEs and 13 level-0 SSEs were reported in relation to the operation of the Secure Telephony System (STS), compared to 15 level-0 SSEs in 2020. Three of the level-A SSEs were resolved by restarting the equipment, while 1 was caused by equipment failure. Twelve of the level-0 SSEs were caused by failures, or by work carried out by generation or distribution companies.

RTE's new "HORUS" datacentre and telecommunications network infrastructure was commissioned in 2020. It has hosted reliability-critical applications since 2021.

Cybersecurity

The security of RTE's information system is an essential component 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 2021, risk assessments, 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, particularly for the new HORUS datacentres and for the national oversight centre for information and telecommunications systems (CORSN) set up in 2021.

THE NEW 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.

The HORUS infrastructure, with the 2 associated datacentres, the new telecommunications networks, and the new operations systems, all fall within the scope of CORSN.

6.3 EMERGENCY RESPONSE ORGANISATION (ORTEC)

In 2021, 6 separate events called for the activation of the emergency response organisation. There were different causes for these emergency responses (electricity network, fire, flooding, information system, and remote control).

The year was marked by two nationwide emergency response exercises: one scenario focused on a heatwave requiring coordination between two transmission system operators, and the other played out a cyberattack on RTE's tertiary information system.

The year was also marked by the execution of the action plan drawn up following an internal audit of the 2020 ORTEC arrangements (improved training system, with greater effectiveness and responsiveness).

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 applicable.

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 restoration. The System Operation Guideline provides a set of common principles for electricity system operation.

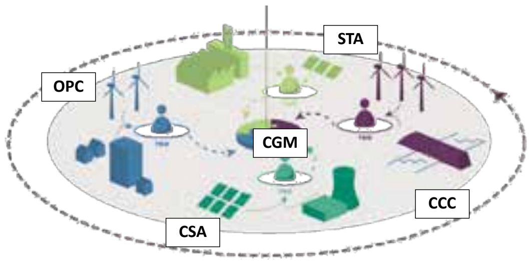
In regard to markets, reliability is a cornerstone of the Electricity Balancing codes, which address the supply-demand balance, and of the Capacity Calculation and Congestion Management Guideline, which aims to structure short-term electricity exchanges.

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, 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 EUROPE'S 3RD ENERGY PACKAGE NETWORK CODES

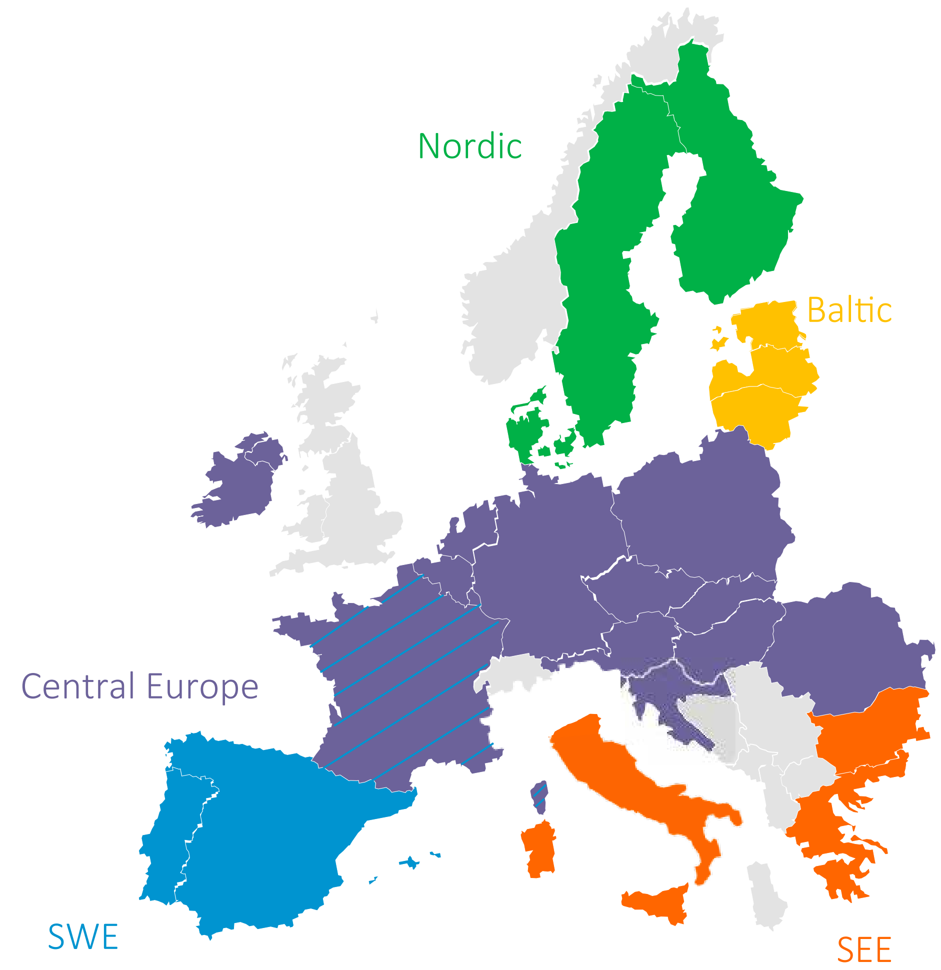
2021 saw the roll-out of the process for creating common grid models (CGM). CGMs are forecasts of future conditions in the European electricity system (generation, consumption, energy flows, etc.) at different time intervals upstream of real-time (from yearly to intraday). They are produced daily by the Regional Services Centres (RSC), which compile the forecasts provided by each TSO. The provision of CGMs is one of the 5 RSC services stipulated in the network codes. It is designed to strengthen the operational reliability of the European network. CGMs form the basis of other coordinated processes, namely, coordinated risk assessments (CSA), coordinated capacity calculations (CCC), outage planning coordination (OPC), and European short-term adequacy (STA) studies. These processes are now being implemented.



7.2 CLEAN ENERGY FOR ALL EUROPEANS PACKAGE

The Clean Energy Package sets a minimum 70% target for the capacity of interconnected installations to be made available for cross-border exchanges, a target that must be reached by 2025. The expected increase in cross-border exchanges requires ever-greater coordination between European TSOs, so as to comply with the operational limits of the European electricity system, and to manage the resulting congestion. Since 2020, RTE has been developing so-called "validation" systems to increase capacity, and ensure compliance with the 70% target without compromising system reliability. These systems were rolled out in the CWE region in February 2021 and in the North Italy region in October 2021, and are scheduled for deployment in the SWE region early 2022.

Furthermore, the Package provides for the creation of System Operation Regions (SOR), new geographical groupings in which operational coordination between TSOs makes sense. The operation of these regions will be coordinated by new entities, Regional Coordination Centres (RCC). The configuration of SORs has been the subject of discussions between ACER and ENTSO-E since 2020. The final version will be revealed in the spring of 2022. **RTE is likely to fall within two SORs: Central Europe (with 21 other TSOs) and SWE (with the Spanish and Portuguese TSOs).** CORESO will be one of two RCCs for the Central region, along with TSCnet, and the sole RCC for the SWE region.



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, and will be submitted to parliament for scrutiny early 2022.

Lastly, the TSOs are preparing for the new roles assigned to the RCCs in per the Clean Energy Package, which will further strengthen the resilience of the electricity system. Some preliminary ideas were put forward in 2021 regarding the network restoration support services in post-accident conditions, as well the arrangements for TSOs to share and exchange reserves.

In addition to the Clean Energy Package, and at the European Commission's request, in summer 2021 the Agency for the Cooperation of Energy Regulators (ACER) communicated guidelines for the **drafting of a new network code addressing the cybersecurity of the electricity system.** The code is expected to receive final approval in 2022 and enter into force in 2023. This is the first major joint project carried out by the associations of European TSOs and DSOs.

7.3 NEW STATUS OF CORESO AND THE ROLL-OUT OF COOPERATION WITH THE NEIGHBOURING RSC

For the CORESO RSC[1], 2021 was marked by:

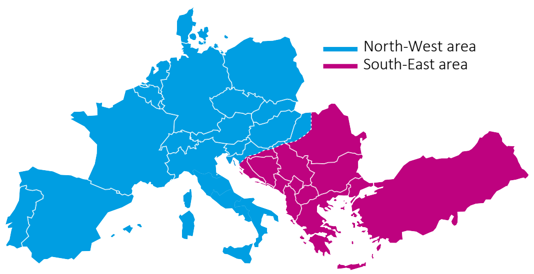
- the ongoing deployment of the five services that will be provided to the TSOs, and in particular the start of the process for creating CGMs. In addition, following on from the work initiated in 2020, CORESO and the second active coordination centre operating in the CORE and NIB regions (TSCNet) have continued to map out their "CorNet" programme of cooperation for the implementation of services in the two regions. This cooperation led to the signing of a cooperation agreement in 2021, followed by a European call for tenders for the development of the first CSA process modules;
- preparations for the final stages of the transition to the new status of RCC, the future regional body for European coordination, which in July 2022 will replace the existing RSCs, as stipulated in the Clean Energy Package.

7.4 MAJOR EVENTS IN EUROPE IN 2021

8 January 2021: two-way split of the Continental Europe Synchronous Area

Against a background of significant East to West energy flows, the tripping of a busbar coupler in Croatia at 2:04pm led to cascaded trips and the de-energisation within one minute of around fifteen installations, resulting in the **separation of continental Europe into two areas,** as shown below:

Event on 8 January



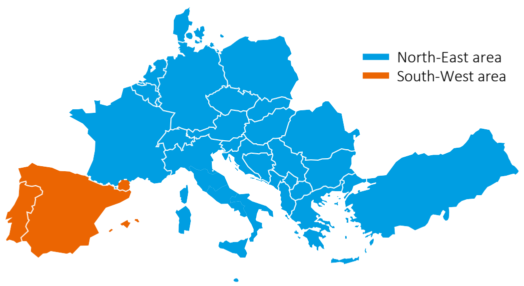
This separation triggered a drop in frequency in the western zone, and an increase in frequency in the eastern zone. In the West, the frequency dropped to 49.745 Hz; frequency restoration to 50 Hz was achieved in particular through the **automatic actions of the interruptibility scheme, which disconnected 1.7 GW of loads in France and Italy,** and through the manual actions taken in real-time by the operators. Once frequency had been restored to 50 Hz in both areas, coordination between the operators ensured the re-synchronisation of the two networks within an hour.

It should be noted that the ENTSO-E wide Awareness System (EAS) supports the real-time exchange of system data between all the TSO-members of ENTSO-E. It was set up in response to the incident of 4 November 2006, which led to the European system separating into 3 areas and the disconnection of 15 million consumers. On 8 January 2022, EAS produced a rapid diagnosis of the separation of the European network and speeded up the re-synchronisation of the two areas.

24 July 2021: separation of the Iberian Peninsula from the rest of the Continental Europe Synchronous Area

A fire in the Aude region led to the tripping of two 400 kV lines close to the Spanish border, and to the loss by overload cascades of the interconnections between France and Spain. As there was no notification of this fire, RTE was not able to deploy preventive protection measures. Prior to the incident, France had been exporting around 2,500 MW of electricity to Spain. After the network separation, the frequency in the Iberian Peninsula fell to 48.7 Hz, resulting in 2,350 MW of under-frequency load shedding in Spain, and 650 MW of industry disconnection in Portugal. Re-synchronisation was achieved very rapidly (in just over 30 minutes) thanks to effective coordination between the French and Spanish operators.

Event of 24 July



These two incidents were classed level 2 on the Incident Classification Scale. They therefore called for in-depth investigations, whose reports set out recommendations aimed at reducing the risk of future system separations and their consequences.

Lastly, the incident in Poland on 17 May 2021 underlined the resilience of a highly interconnected European electricity system. Thus, the 3,300 MW of lost generation in this incident was compensated by the other generating units connected to the synchronous area, resulting in a limited drop in frequency of 158 mHz, which was restored to 50 Hz without load shedding.

THE IMPACT OF BREXIT

In accordance with the Trade and Cooperation Agreement (TCA) between the United Kingdom and the European Union, signed on 30 December 2020, the English TSO NGESO officially withdrew from ENTSO-E in December 2021.
Nevertheless, meaningful exchanges between NGESO and ENTSO-E have allowed both parties to consider the continued involvement of NGESO with some European coordinated systems and processes supporting network reliability. This desire to cooperate gave rise to the signature of a Memorandum of Understanding. The next step will involve updating the respective contracts governing these coordinated processes. This is due to take place in 2022.

(1) Regional Services Centre

08. Reliability audits and internal controls

In accordance with its internal control 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 implemented control measures and their effectiveness. The internal controls carried out in 2021 highlighted an acceptable level of reliability management.

In 2021, the internal audits centred on two reliability-related areas of focus:

- the operation of the electricity system: the defence plan and the restoration plan;
- network repair and restoration in emergency conditions.

These two audits, within their designated areas, concluded that there had been satisfactory control of the reliable operation of the electricity system.

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, the 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 supply-demand balance requirements. This is achieved by means of the balancing mechanism, which allows RTE to pool the resources of contributors through a permanent and 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 partners in the synchronous network. Rules are set by the ENTSO-E Continental Europe regional group, to guarantee that actions 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.
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 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 in 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 in keeping with 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

TERM	DESCRIPTION
SECURE TELECOMMUNICATIONS NETWORK	The secure telecommunications network consists of a dedicated telecommunications infrastructure, essentially owned and operated by RTE, and tasked with conveying all the information (voice, data) required for remote control. These systems fulfil the following functions: • the ("low-level") transmission of data for the remote control of 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 data for remote control, and the transmission of telephone conversations between dispatch centres and the substation group management centres; • the transmission of data for remote control, and the transmission of telephone conversations between generating units and dispatch centres; • the transmission of data for remote control, 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. The 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
ANSSI	National IT Services Security Agency
BCP	Business Continuity Plan
BM	Balancing mechanism
BRP	Business Recovery Plan
CNES	National Centre for System Operation
CORESO	Coordination of Electricity System Operators
CR	Current rating
CSEA	Economic Oversight and Audit Committee
CURTE	Power Transmission System Users' Committee
DSO	Distribution system operator
ENTSO-E	European Network of Transmission System Operators for Electricity
FW	Firewall – key component of internet access architecture
HVDC	High-voltage direct current
ICS	Incident Classification Scale
LPM	Defence Programme Law
mFRR	Manual frequency restoration reserve (BM)
OC	Operating Centre
ORTEC	RTE emergency response organisation
PER	Regional Exchange Gateway: dispatch centre remote control system
RCC	Regional Cooperation Centre
ROSE	Secure Fibreoptic Network
RPD	Public electricity distribution network
RPT	Public electricity transmission network
RR	Replacement reserve (BM)
RSC	Regional Services Centre
SAS	Alert and Safeguard System
SDB	Supply-demand balance
SFPC	Secondary frequency-power control
SIDRE	Regional Dispatch Centre Support Group
SNC	National Control System
SRC	Regional Control System
SSE	Significant System Event
SVC	Secondary voltage control
SVC	Static var compensator
TSO	Transmission system operator

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