Le réseau
de transport
d'électricité

2019
Reliability Report

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SUMMARY

THE RESULTS AND ANALYSIS OF KEY INDICATORS FOR 2019 SHOW A SATISFACTORY LEVEL OF OPERATIONAL RELIABILITY

Every year, RTE draws up a reliability report that provides key information on the reliability of the power system for the past year and the measures implemented to guarantee reliability in the future.

In a context of energy transition, the penetration of new technologies for generating renewable energies, changes in the behaviour of operators and European integration, require RTE to make adaptations on an ongoing basis. Indeed these changes disrupt the operation of the power system and can undermine reliability.

Watchpoints for 2019 include:

- **A further increase in the number of Significant System Events (SSEs).** This continuous increase since 2017 is the result of an increasingly balanced and adjusted power system, with generation facilities offering less opportunities in terms of **flexibility and systems services** than before and more variable flows in terms of **direction and intensity, accompanying the transformation of the energy mix.**

- **Continuous decline since 2015 of reliability margins on the supply-demand balance.** This situation, which is consistent with RTE's forward estimate analysis, restates the importance of availability and maintenance of the performance of generation facilities, in an environment where new technologies for renewable energy generation do not yet offer equivalent services.

- In a context of **significant reduction in the number of frequency deviations** (reflecting occasional imbalances between demand and supply, in particular during changes made to generation and trading schedules, hourly on the hour) on the European power system, **two substantial reductions in the European frequency have activated the French interruptible load program.**

- **The number of high voltage ceiling overruns has further increased,** mainly due to a decrease in extractions from the transmission grid due to the development of power generation in the distribution grid.

To address these risks, RTE conducts, **with stakeholders** in France (CURTE, DGEC, CRE….) or in Europe within the framework of ENTSO-E, a number of actions to guarantee a high level of reliability:

- Support to the development of **power generation flexibility and modulation potential of renewable energies** in order to contribute to supply-demand balance management and reliable system operation (managing flows, systems services).
  This development must continue to be supported by market and contractual mechanisms in order to take advantage of the various operators' **flexibility reserves and service offerings,** in coordination with distribution system operators.

- Ongoing actions in France and in Europe to **guarantee a satisfactory level of margins with regard to the supply-demand balance** and ensure sustainable improvement in the quality of frequency (activation of new flexible products incorporated into calls for tender led by RTE, implementation of European trading platforms, etc.).

- **Enhanced cooperation between transmission system operators and Europeans coordination centres,** leveraging the implementation of services provided for in the European grid codes.
  Cooperation among all TSOs is an advantage for power supply reliability. Amongst others, it maximises cross-border capacities for power imports/exports by market operators and, where necessary, organises trading in emergency cases between countries. **Given this context, it is important to maintain all EU and non-EU TSOs fully integrated** into all mechanisms put in place that contribute in particular to power supply reliability in France and in all interconnected countries.

- **Increasing cross-border electricity transit capacity.**

- Continuation **of the compensation measures programme.**

1

NUMBER OF SIGNIFICANT SYSTEM EVENTS (SSE) STILL ON THE RISE

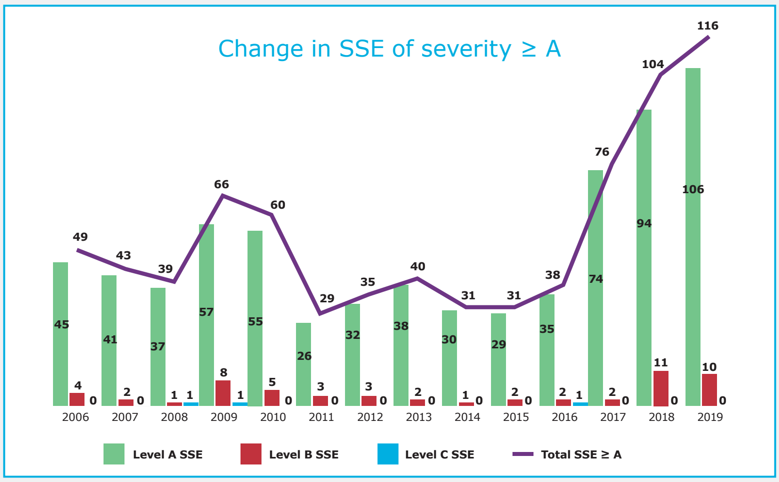
With 106 level A events and 10 level B events, **2019 again marked an increase in the number of Significant System Events (SSE) compared with the years prior to 2017.** During an SSE of level A or B, the reliability of the system is not however significantly affected.

This continuous increase since 2017 is the result of an increasingly balanced and adjusted power system, **accompanying the transformation of the energy mix** with:

- generation facilities offering less opportunities in terms of **flexibility and systems services** than in the past. Accordingly, the number of SSEs relating to the required availability and the flexibility of generation facilities has risen from 7 in 2015 to 42 in 2019;
- more variable flows in terms of **direction and intensity.** The number of SSEs relating to temporary overruns of acceptable flows on RTE's structures has risen from 0 in 2015 to 40 in 2019.

2019 highlights:

- At the end of the year, reliability was undermined due **reduced availability of generation facilities** in the west of France, made worse by a decline in generation due to industrial actions.
  This led to **a surge in difficult situations for the supply-demand balance, for frequency, and an increase in the number of degradations of the voltage plan, causing a total of 25 SSEs.**
- **Overload protection start-ups** on infrastructure underpinning trading between France and the Iberian Peninsula, but this year due to **damage to one of the interconnection lines (6 SSEs).**
- **Two major events affecting European frequency led to the activation of the French interruptible load programme (level A SSE).**



INFORMATIVE INSERT

Operational reliability of the power system

Today, electric power is not stored on a large scale and transmission capacities of electricity infrastructures are not unlimited.

Guaranteeing reliability means ensuring round the clock balance between the generation and consumption of electricity, as well as the transmission of power flows from generation centres to consumption centres. This means managing the changes and reactions of the power system in the face of different contingencies (short-circuits, unforeseen change in consumption or production, unplanned unavailability of generation or transmission infrastructure, etc.), by reducing as far as possible the risk of a blackout across the country or vast areas of the country.

The origin of a large-scale incident is always characterised by four main phenomena that, regardless of their initial causes, occur one after the other or combine throughout the incident.

These phenomena are:

Cascading overloads

- In the event of overruns on one or more links following multiple or beyond-design incidents:
  - → links automatically shut down
  - → transfer of the flow to other links
  - → risks of new overloads… (cascading overloads) and loss of others links
- RTE's implementation at all times of a flow risk management method ensures that such a cascade cannot occur following a simple contingency.

Significant frequency variation

- In the event of multiple contingencies affecting generation, exceeding the frequency control margins, there may be a risk of an overall decrease in frequency. In cases of major contingencies, this decrease may lead to shedding.
- The use of frequency containment and automatic restoration reserves for frequency control and restoration in the event of contingencies affecting the largest connected generation unit in Europe allows RTE and TSOs in synchronous Europe to prevent such a situation.
- In the event of beyond-design incidents, the defence plan (with metric-frequency shedding) prevents a potential major drop in frequency.

Voltage collapse

- In the event of multiple damages, in particular to generation or the voltage control systems, the voltage can drop and this drop can spread.
- RTE's implementation at all times of a voltage risk management method ensures that such a collapse cannot occur following a simple hazard.
- RTE has also equipped the grid with automation equipment which, through targeted shedding actions, stops a voltage collapse in the event of an unfavourable generation and consumption plan, if there is a contingency on several generation units.

Loss of synchronism

- In the event of a short-circuit near a generation unit, there is a risk of acceleration of the concerned unit.
- Stability studies conducted by RTE in the different operating configurations allows the prevention of such localised frequency changes.
- In the event of loss of synchronism that could result in beyond-design incidents possibly coupled with technical problems on the generation units, RTE maintains in operation, as part of the defence plan, the protection relays against ring opening due to loss of synchronism. These stem the spread of any loss of synchronism to other parts of the grid.

System reliability is defined as the ability to:

- Ensure normal operation of the power system (normal frequency range, voltage, intensity, short-circuit power) in a design state and in the event of a contingency, in accordance with the risk management rules.
- Limit the number of incidents and prevent major incidents.
- Minimise the consequences of major incidents when they do occur.

Significant System Events - the SSE Grid

Every year, RTE measures the grid's operational reliability by recording Significant System Events (SSEs) ranked on a severity scale ranging from 0 and A to F. These events correspond to incidents that can result from a broad range of causes. The RTE classification is more differentiated and is in line with ENTSO-E's four level ICS (Incident Classification Scale) severity scale. Tracking of SSEs over several years flags up weak signals and provides a means of measuring over time the efficiency of all actions undertaken to improve grid reliability.

Events ranked from A to F are considered as having a proven impact on reliability: it is incremental from A (localised, single and controlled incident) to FF (widespread incident). Events ranked 0 are considered as having no direct proven impact on reliability (weak signals) and give rise to trend analysis.

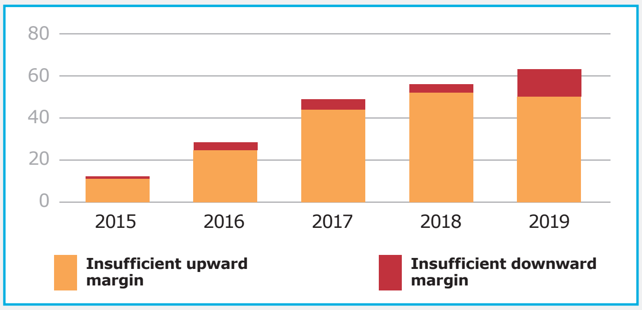
The SSE ranking grid contains five columns: Operation, Grid, Control resources, Generation, Distribution.

2

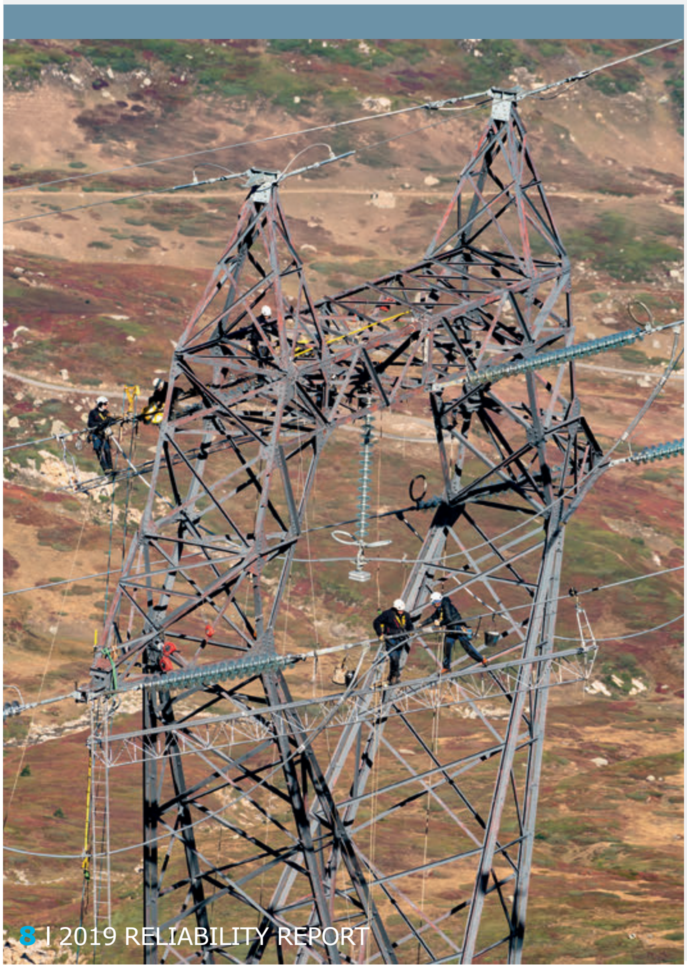
MONITORING OF SUPPLY-DEMAND UNDER SURVEILLANCE

2.1 MARGIN FREE SYSTEM AGAINST THE BACKDROP OF BALANCED AND ADJUSTED POWER SYSTEM AND TRANSFORMATION OF THE ENERGY MIX

In 2019, there were 63 situations when available margins were below the required volume, and which led to the issue of safeguard orders in real time, on a continuous rise since 2015.



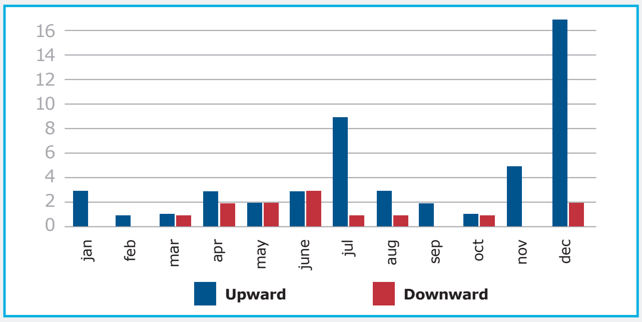
Insufficient supply-demand balance margins



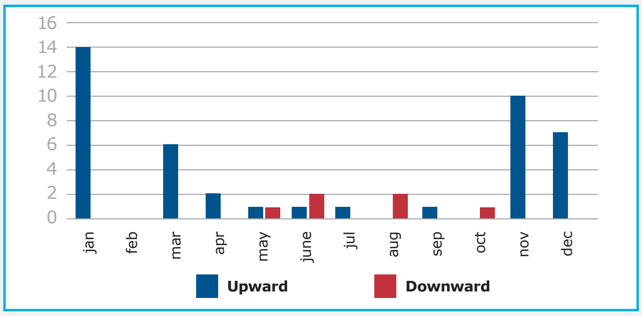
Overall, the number of upper margin shortfalls has remained stable since 2017: unavailability of nuclear facilities and industrial actions which caused declines in generation were offset **by moderate winter consumption.**

2019 also saw a sharp increase in the number of situations when the volume of downward power balancing resources was lower than expected: 13 situations encountered, against four in 2018.

The difficulty of guaranteeing reliability margins, historically characteristic of very specific periods (upward in winter and downward in summer), is gradually spreading over the entire year, due to changes in the availability of generation facilities.



2019 - Margin deficits per month



2017 - Margin deficits per month

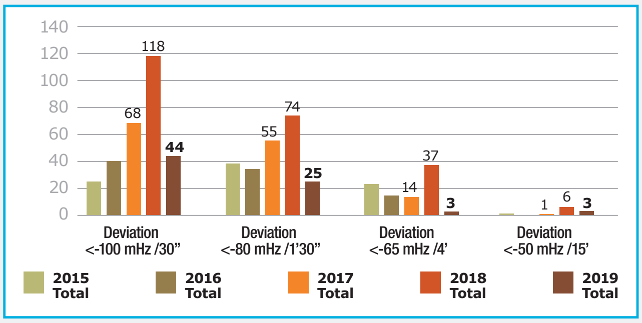
This is consistent with the long-term Adequacy Report, **which depicts a balanced and adjusted power system presenting lower margins than in previous years, in particular for downward balancing.**

2.2 EUROPEAN GRID FREQUENCY CONTROL IMPROVING, BUT TWO MAJOR EVENTS PROMPT FOR CONTINUATION OF ACTIONS UNDERTAKEN

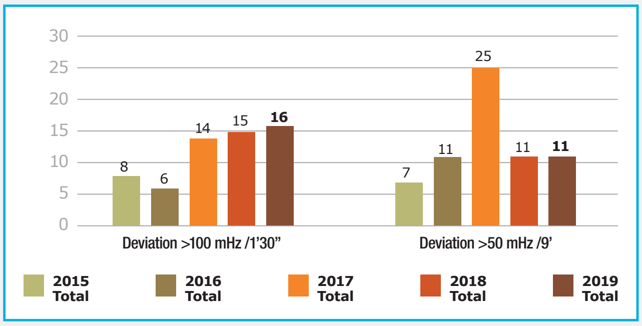
In 2019, 102 European frequency deviations (deviation from normal operating ranges in terms of the depth and duration) were recorded, compared with 261 in 2018 and 177 in 2017.

This is by far the best result of the last four years.

While the number of upward deviations has remained stable overall since 2018, **downward frequency deviations are on a sharp decline.**



Total number of downward frequency deviations



Total number of upward frequency deviations

Although deterministic frequency deviations, characterised by frequency drops of more than 100 mHz over short durations when changes are made to generation schedules synchronised hourly on the hour, are still present, **the vigilance measures taken by all TSOs in Europe, to which RTE contributes actively, have had a positive impact** on the number of deviations recorded.

Nevertheless, this reduction in the number of deterministic frequency troughs in no way reduces the risk exposure for the European power system.

Two significant events occurred in 2019: on 10 January (frequency drop to 49.81Hz) and on 7 October (49.82Hz), each time at 21:00, pushing the frequency to levels not reached since the event of 4 November 2006 in Germany.

For these two days, other contingent events, coinciding with the 21:00 change of schedule (wrong power measurement on an interconnection between Austria and Germany causing a supply-demand imbalance of 1000 MW on 10 January and loss of a 900 MW generation unit in France on 7 October) accentuated the drop in frequency, which is normal during these schedule changes, and which drove down the frequency below the threshold for **activation of the French interruptible load programme. The instantaneous consumption interruption mechanism of interruptible consumers stopped the drop in European frequency.**

There was also a significant transient frequency increase (but with no proven impact on the operation of the power system) on 24 January 2019 at 06:00, reaching 50.175 Hz, a level not reached in several years.

France accounted for 62 of the 102 deviations recorded in 2019, compared with 25 in 2018; the most significant of them were upward and night deviations.

Coupled with, particularly during trough consumption periods, a **lack of controllable and flexible facilities** (growing share of renewable energies not included in the balancing mechanism, low MW volumes at night, maintenance shutdown and technical constraints of generation units), **the French power system increasingly faces difficulties in balancing generation downwards** (driving frequency up).

This difficulty to offset the system's imbalance affects the quality of the French frequency control, resulting in frequency deviations about three times higher upward than downward.

The French power system is also subject to **more frequent shortfalls in frequency containment and automatic restoration reserves.**

In spite of meeting the criteria set out in the grid codes, the quality of French control is on a continuous decline since three years. The correct automatic rebalancing level, following an instantaneous variation of more than 1000 MW of the supply-demand balance, has fallen from 80% in 2017 to 12% in 2019.

The difficulties encountered are due to:

- irregular compliance throughout the day, by those responsible for reserves, with the recommendations for restoration reserves (financial incentive mechanism not very effective). Thus, the planning by operators fell short 15% of the time in 2019, compared with 8% in 2018 and 4% in 2017.
- The difficulty to rebuild the required reserves, on the balancing mechanism, due to the reduction in the available reserve. This difficulty is made worse when units supplying systems services are stopped to address the increase in frequency.

Frequency containment reserves, conducted mainly by generation units, which were till now not concerned by these planning difficulties, is starting to face shortfalls too. An overall failure with a total duration over the year of nearly 14 days was thus recorded in 2019, compared with only two in 2018.

To meet these challenges, RTE has undertaken initiatives and discussions with stakeholders in France (CURTE, CRE...) and at European level (extending beyond mutual support procedures already existing with TSOs in the European Union, Switzerland and the United Kingdom):

- **Certification of frequency containment reserve batteries in 2019** (nearly 10MW in 2019, with the prospect of around 70 MW in 2020).
- A **contractual incentive,** incorporated into calls for tender in 2020 on manuel frequency restoration and replacement reserves (and to be renewed in 2021), **to provide products that can be activated at short notice and for short periods,** to preventively cover changes in cross-border trading arrangements occurring on the hour.
  Discussions have been initiated for a dedicated call for tender in 2022 and on contractual arrangements for downward rapid reserves. Since the introduction of the additional remuneration system for renewable energy generators, the latter can participate in the balancing market. It is thus possible to look forward to stronger reserves. **A first testing of the capacity of wind farms to rapidly adjust downward during consumption troughs was in fact carried out on February 2019.**
- **The introduction on 1 January 2020, following a joint and pro-active decision of TSOs, of a European incentive subject to compliance with participation in frequency control by** each TSO during changes in cross-border trading arrangements occurring on the hour.
- **A roadmap for the dimensioning of secondary reserve, incorporating the recommendations of the European grid codes.**

The implementation of the **European Electricity Balancing code will also allow RTE to benefit from additional flexibility resources for the Balancing Mechanism at European level.**

This Code aims to establish real-time cross-border mechanisms for creating automatic reserves and controlling the supply-demand balance in real time, in order to harmonise European practice, pool reserves and reduce costs.

However, RTE pays special attention to compatibility between standard European products and the flexibility currently offered by French power generation facilities. RTE believes there is a risk to frequency if product activations are synchronised at the European level and do not meet the expected delivery profile in terms of dynamics.

RTE is involved in the three projects aimed at establishing European platforms, namely TERRE (Trans-European Replacement Reserve Exchange) for managing replacement reserves the second half of 2020, MARI (Manually Activated Reserves Initiative) for managing rapid reserves and PICASSO (Platform for the International Coordination of the Automatic frequency restoration process and Stable System Operation) for managing Automatic frequency restoration reserves by 2022.

INFORMATIVE INSERT

Margins and margin restoration

To guarantee the supply-demand balance at all times and control frequency, RTE can activate the following levers:

- the **frequency containment and automatic restoration reservesmainly supplied by controllable generation units** (also called frequency systems services the total of which represents slightly less than 1500 MW) to firstly respond to generation or consumption contingencies affecting the grid
- **the replacement reserve** aimed at restoring, in terms of the depth and duration, the supply-demand balance, and restoring systems services when these have been consumed during a contingency.

Upward and downward **operating margins** are calculated for these various reserves.

Their level (and thus using **the supply available on the balancing market**) must meet minimum requirements, which are based on timing:

- The level of the **15' margin** (frequency Restoration Reserve) is designed to address at any time, and in less than 15 minutes, the loss of the largest connected generation unit in the grid (upward margin), or the loss of the most significant extraction or an export (downward margin).
- **The 2 and 8 hours balancing margin** aims to cover contingencies that may arise in the coming hours: deviation from consumption forecast, technical problem, forecast error regarding wind and solar power generation, etc.

When these conditions are not met, RTE issues an alert and safeguard message.

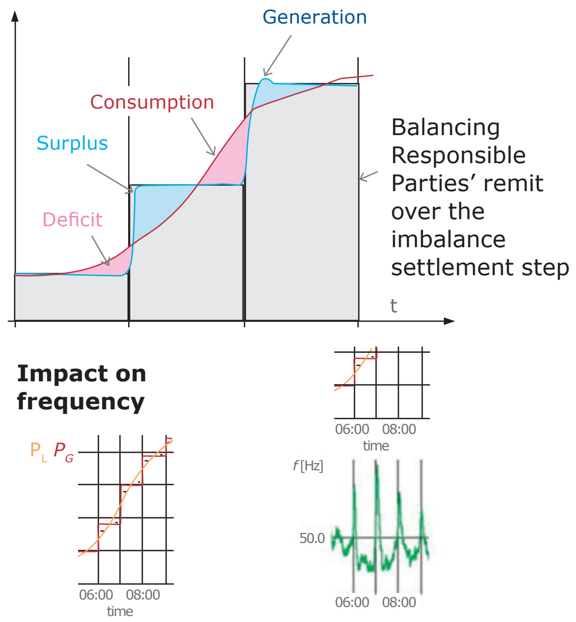
As much as the upward activation of resources can strengthen the level of current systems services (by starting generation units), downward activations can weaken this level by causing the shutdown of units that are part of the systems services.

Deterministic frequency deviations

Deterministic frequency deviations occur during changes in cross-border trading arrangements occurring on the hour. This trading reflects transactions in market products among the European power market operators.

Thus on the hour, generation by certain European groups changes very rapidly and is (momentarily) decorrelated from demand (consumption + trading), which, for its part, continues. The supply-demand balance is therefore affected for a few seconds or minutes: the frequency varies significantly, depending on the time taken for the automatic control mechanisms to start (thus consuming primary and secondary reserves fully or partly). If an event affecting the supply-demand balance (such as the loss of a generation unit) occurs at the same time, this can accentuate the frequency variation and in some cases cause the activation of the French interruptibility mechanism, and even metric-frequency shedding in more serious situations.

Illustration of the phenomenon:



When consumption increases, the frequency falls slowly just before the change of hour, reflecting the power shortfall, and increases rapidly just after, following the start of rapid units, such as hydroelectric units.

The interruptibility mechanism

In France, the interruptible load programme, defined in the legislation and implemented by RTE since 2014, allows the immediate drop in consumption of sites that are large energy consumers, on a voluntary basis and remunerated for this service. This mechanism, automatically activated when the grid frequency falls below a certain threshold, contributes to the restoration of the frequency by reducing the consumption level. In 2019, 22 industrial sites offered this service, representing a reserve of 1500 MW available in less than 30 seconds.

3

RELIABILITY RISKS UNDER CONTROL

3.1 LOSS OF STABILITY

LOSS OF SYNCHRONISM

In 2019, **three operating situations (level B SSE), for which a contingency could have led to a loss of stability of generation units,** were encountered, **compared with six in 2018 (one in 2017 and 2016).**

Two situations (compared with three in 2018) could not be avoided due to difficulties met by generation units to respond to requests for power reduction made by RTE, so as to guarantee their reliability in the event of a short-circuit on the grid.

Works conducted with EDF in 2019 and **deployed in 2020 at all the concerned sites, to forestall and coordinate in such situations,** will further reduce its occurrence.

PERFORMANCE OF THE PROTECTION PLAN

Swift elimination of short-circuits on infrastructures improves grid stability.

On the 400 kV grid, in 2019, 97% of the 330 short-circuits were eliminated in line with expectations (this rate is between 96 and 98% since 2015). The good results on the 225 kV grid, a key requirement for grid stability, also contribute to this high level of reliability.

The rate of availability of differential busbar protection devices in the 400 kV grid, which play a major role in the swift and selective elimination of faults occurring in substations (rare but highly risky for reliability), **is 99.7%, a slight improvement over 2018** (this rate is above 99.2% since 2015).

There was no event affecting protection devices involving ring opening upon loss of synchronism (DRS) in 2019. The reliability rate of these protections remains very high.

CROSS-ZONE FREQUENCY OSCILLATION

In 2019, no cross-zone and frequency oscillation was detected on the European grid.

Taking better account of this issue following the events of the past years led to:

- The change in operational parameters of the direct current link between France and Spain in January 2019.
- The start of a project relating to the development of a monitoring and forecasting tool for power system oscillation modes (in particular the identification of high-risk situations).

INFORMATIVE INSERT

Loss of synchronism (local frequency oscillation)

Under the design operating state, the alternators of interconnected generation plants in Europe operate at the same frequency, around 50 Hz: it is called the synchronous operation of the grid, with the grid being the "synchronising link" between the electrical machines.

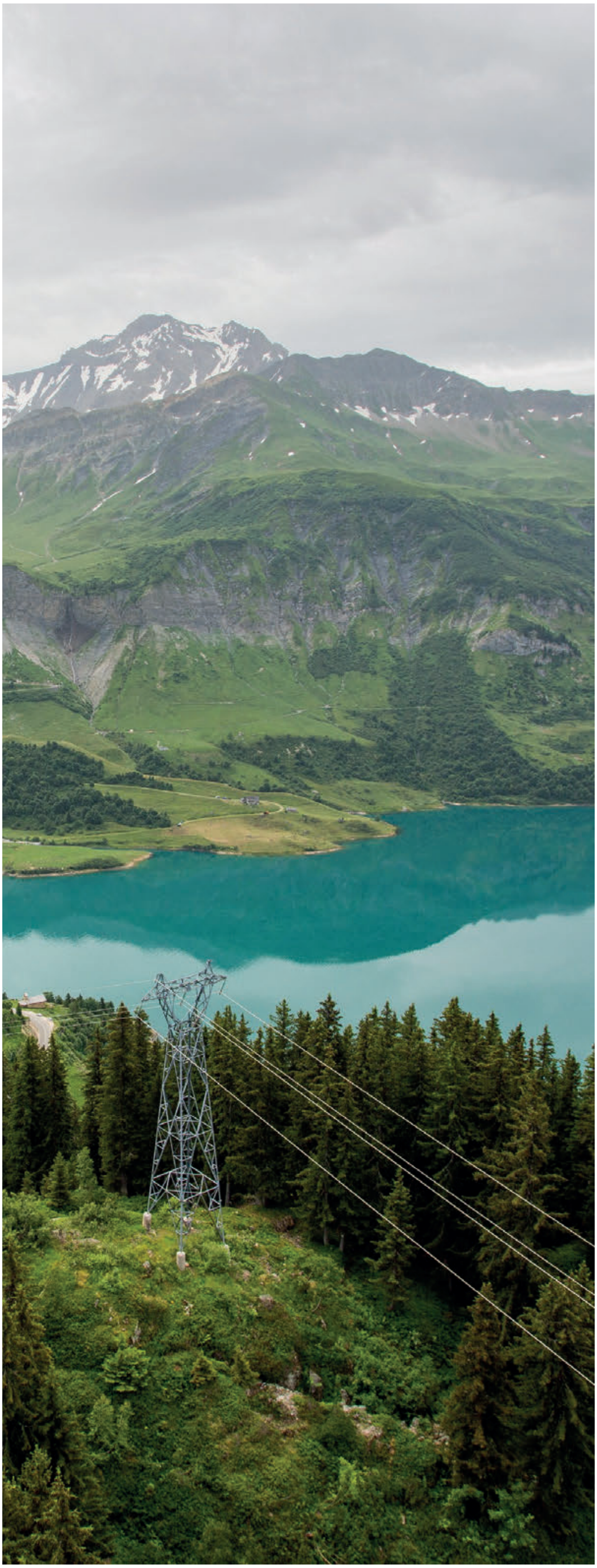
This balance can be disrupted during short-circuits, and these increase the rotation speed of the alternators. If the short-circuit is not eliminated fairly rapidly, or if the unit was not in a sufficiently stable initial state, the alternators may not be able to again align on the frequency of the general grid: a loss of synchronism then occurs. If this condition continues, it spreads to other units. To prevent this spread, the protection devices against loss of synchronism come into action by splitting the grid into predefined zones, so as to isolate the affected zone.

To guarantee the stability of interconnected units, RTE conducts specific studies at various time intervals, and takes the necessary preventive actions:

- Determining and complying with the maximum time limits for elimination of short-circuits.
- Limiting the area of operation of the units in terms of active and reactive power, to ensure greater initial stability.
- Adjusting operation plans and optimising the timings of withdrawal of infrastructures.
- Monitoring the performance of generation units controls and of protection systems.

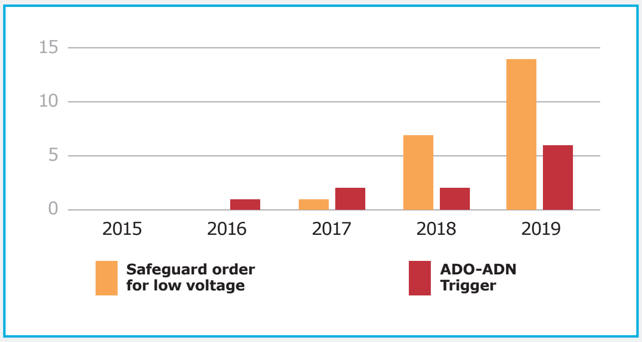
Cross-zone frequency oscillation

Cross-zone oscillations or modes are complex electromechanical events between two or more parts of the European power system oscillating antiphase and causing active power oscillations, in particular on interconnection lines, presenting real risks to reliability in Europe if they approach frequencies consisting in modes specific to the European power system.



3.2 VOLTAGE COLLAPSE

The number of safeguard orders sent for low voltage has increased over the past winters.



Voltage degradation

Last year, safeguard orders sent were due to the cold spell of February.

In 2019, due to an unfavourable generation plan in the west of France (units shut down for maintenance or limited in terms of supply of reactive power, decline in generation due to industrial actions), consumption levels in the north-west quarter of France, although not exceptional this winter, **many times reached the threshold for triggering the west and north defence programmable controllers** (ADO and ADN).

These programmable controllers were triggered on a preventive basis six times in 2019. However, their activation threshold, which consists of targeted automatic shedding, was never reached. The risk of voltage collapse remained under control, and recourse to post-market resources was not necessary.

This problem of low voltage management in the north-west quarter of France has been identified as part of analyses complementary to the 2018 Long-term Adequacy Report and the forecast analysis of the 2019-2020 winter.

INFORMATIVE INSERT

The risk of voltage collapse

The grid voltage is controlled from multiple reactive power sources (generating units, capacitors, reactances, Static VAR Compensator, etc.) across the grid.

For a specific zone, the reactive power sources may no longer be sufficient to meet requirements following, for instance, the loss of transmission structures or generation units.

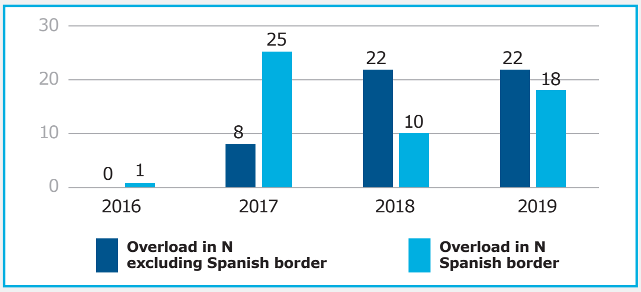
Importing the required power from neighbouring zones causes major voltage drops on the grid. Automatic on-load tap changers installed in the transformers of networks supplying customers make it possible to make up for these voltage drops. However, this increases the current draw and therefore further reduces the zone’s voltage.

Below a certain low voltage level, called critical voltage, the limit of transmissible power is reached. This leads to a voltage collapse if no step is taken.

RTE has therefore installed on the network, two programmable controllers, ADO and ADN, as part of the voltage defence plan to prevent the risk of voltage collapse. In the event of an incident on the grid resulting in a major voltage drop, these programmable controllers activate a volume of localised consumption shedding and just enough to prevent an uncontrolled spread of the grid collapse, thus avoiding a more significant volume of outage.

3.3 MANAGING FLOWS

Since three years, excluding incident procedures, there is a significant increase in the number of overload protection relays start-ups in 225 and 400 KV.



IST overruns

The Spanish border (interconnection and upstream network) accounts for about 50% of these overruns of transit limits.

With trading between France and Spain having more than doubled since 2015, the zone's infrastructure load has come close to the limits of operation and the number of overload protection relays start-ups has increased.

With better account taken of changes in cross-border trading at the end of 2017, overruns decreased substantially in 2018.

The new increase, observed in 2019, is mainly due to transit limitations due to damage to one of the interconnection links (6 level A SSEs), and, at the end of the year, to an unusual generation repartition and difficulties in obtaining files on studies that satisfactorily incorporate the forecast assumptions for renewable energies (6 level A SSEs also).

Excluding the Spanish border, the breakdown for 2019 shows that overruns of transit limits overall are not deep and of short durations.

It is also to be noted that in 2019, two level A SSEs were recorded for the issue of safeguard orders in relation to transit management, following the loss of structures during operation under winter conditions.

As regards the Iberian Peninsula, additional actions have been undertaken to further reduce the number of high-risk situations, while maximising the trading capacity between the two countries, **in particular concerning the quality of study data exchanged with Spanish and Portuguese TSOs.**

More generally, several work programmes have been initiated by RTE **to limit the number of overload protection relays start-ups,** in particular as regards **forecasting them through the improvement of study tools and the implementation of a new monitoring tool.**

INFORMATIVE INSERT

Cascading overloads

If very high intensities in a link are not controlled, they lead to overheating which can:

- Damage the components of the link, and can even the break the conductor.
- Expose persons and property to risks by causing the expansion and elongation of cables, which then come close to the ground encroaching on the safety distances between the overhead line and its environment.

Maximum values are therefore defined for each structure:

- The maximum current that the line can withstand during a time limit (IST), without limitation over time, but which is reached only occasionally and for limited periods.
- Transient intensity thresholds (IT), higher than the IST but for much shorter limited periods (less than 20 minutes).

To protect against the risk of exceeding these limits, so called overload protective devices are used in France in 225 and 400 kV grids. If the intensity overload is not removed within a given time after its start-up (between a few seconds and 20 minutes, depending on the overrun observed), the concerned structure is automatically disconnected from the grid, through its overload protection mechanism.

The flow borne before the trigger by this structure is then transferred to neighbouring structures. Depending on the seriousness of the phenomena, there could be new overloads and new tripping actions. Successive load transfers leading to the occurrence of a cumulative phenomenon can, through a cascading effect, lead to the loss of a significant portion of the grid.

The transit risk management method applied by RTE ensures that such a cumulative effect cannot occur following a simple contingency.

3.4 CAPACITY TO RESTORE POWER TO THE GRID FOLLOWING A BLACKOUT

INFORMATIVE INSERT

House load operation of nuclear power plants and structures

For a nuclear reactor, house load operation is the shift from its design operating state (discharge of its full power on the grid) to an isolated state of the grid. The reactor then only generates the electric power necessary for its own operation.

Successful house load operation of nuclear power plants in the event of a widespread incident is important for nuclear safety and is vital for reinstating the grid and restoring power supply to customers as soon as possible.

This restoration relies on the step by step reconnection of the 400 kV structures, called regional structures, which link up the nuclear units to supply stations in major consumption zones.

In 2019, 11 house load operation were performed on nuclear power plants, with a 100% success rate (100% for 12 trials in 2018 and 93% in 2017). The success rate was 96.4% over a four-year rolling period, which is highly satisfactory compared to the 60% long-term target.

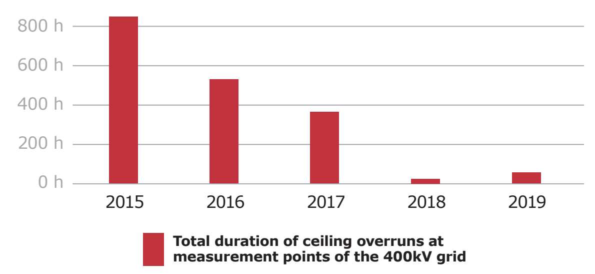
4

HIGH VOLTAGE THRESHOLD OVERRUNS ON THE RISE

The total number of upward voltage threshold overruns has doubled between 2018 and 2019 and the total duration of these overruns has increased two and a half times.

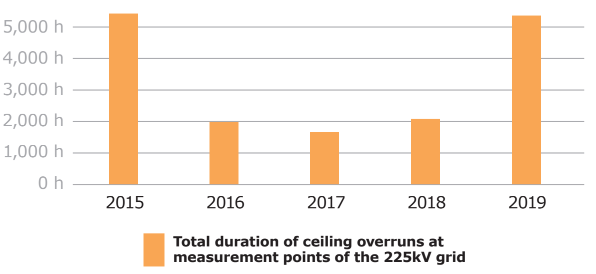
Although these phenomena are still a seasonal nature (due to lower consumption periods), they now occur throughout the year.

400 kV overruns have increased compared with 2018, but remain under control: the duration of overruns in 2018-2019 is five times lower than in 2016-2017.



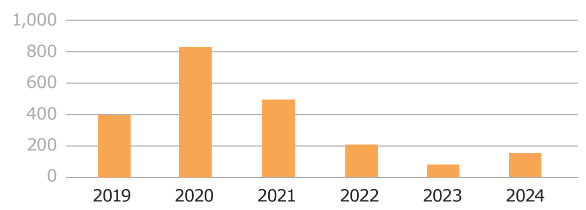
400 kV overrun voltage

The number of 225 kV overruns has increased sharply; however, individual overruns remain of low amplitude and duration.



225kV overrun voltage

RTE implements a number of compensation measures to reduce high voltage: in 2019 further 400 Mvar of inductors were installed. New investments are also scheduled for the coming years.



Inductors projects (in Mvar)

Studies are under way to reassess these guidelines, in particular in light of the heavy stress on **generation units operating under the synchronous compensation mode, specifically for voltage management,** in particular in the Massif Central.

Consultation on the **participation in voltage control of new resources (wind and solar farms connected to the transmission or distribution grid, consumer sites and batteries.) is ongoing,** with a view to testing in the next TURPE tariff period (2021-2025). Works are also ongoing with distributors under the current framework.

INFORMATIVE INSERT

The problem of upward voltage threshold overruns

High voltage occurs when the components controlling the reactive power (generation units, Static VAR Compensator, inductors) can no longer absorb the reactive power generated by the grid (capacitors, lines or cables not highly loaded, reactive power generated by customers, etc.). These phenomena, which historically were encountered during consumption troughs on summer weekends, are now spread out throughout the year.

This is due to three main factors:

- The extensive development of renewable energies in distribution grids, which reduces active extractions from the transmission grid and thus increases the grid's reactive power generation. The minimum extraction volume on the RTE grid was 24 GW in August as well as in September 2019, compared with 25.5 GW in 2018, and is on a steady decline since several years.
- Changes in the structure of transmission and distribution grids, which are increasingly installed underground and therefore generate more reactive power.
- Lastly, changes in the technical nature of consumption leading to a decrease in consumption of reactive power. The volume of reactive energy injected from the distribution grid has thus increased by about 50% from 2017 to 2019.

As far as reliability is concerned, high voltage has less short-term impact than low voltage. However, it can adversely affect equipment lifetime and cause degradation that impacts power quality.

5

DEPENDABLE AND AVAILABLE RELIABILITY TOOLS

5.1 CONTROL ROOM TOOLS

Except for certain supply-demand balancing tools, **the availability of tools ensuring reliable system operation** was very good in 2019.

CONTROL SYSTEMS

In 2019, important events concerning the control systems (level B SSEs) were:

- Unplanned unavailability of the National Control System (SNC) with shutdown of transmission at automatic load-frequency control level for 114 minutes;
- For the Regional Control Systems (SRC), one event, leading to the loss of the Alert and Safeguard (SAS) function of one of the regional dispatching centre.

These two events occurred during strained conditions of operation.

Three other events concerning the availability of control tools (two level A SSEs and one level 0 SSE) were due to power cuts of dispatching equipment, in spite of redundancies.

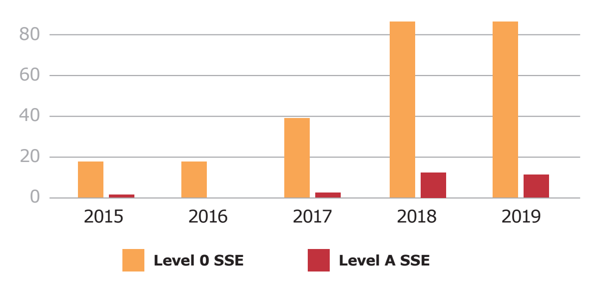
These **events prompted the implementation of special action plans** (resistance to breakdowns, software upgrades, audit of power supplies and their maintenance).

RTE launched the STANWAY project to deal with **ageing of programmable logic controllers (PLC)** currently in use in order to procure a unique PLC system. The project aims to **replace the SRCs and SNC. The commissioning of the new tool is scheduled in 2021 for the eight RTE control rooms.**

The regional inter-dispatching support system (SIDRE) allows the resumption of operations across different operation centres. It has been operational since June 2015 in the three cross-zone bubbles. Skills upkeep is mainly based on monthly changeover testing (partial or total), conducted at a regular pace, and measures for maintenance of operator skills. In 2019, the SIDRE was used 17 times, including nine for incidents that ensured the observability and operation of the grid.

OTHER POWER SYSTEM CONTROL ROOM TOOLS

In 2019, 86 level 0 SSEs and 12 level A SSEs concerning the **SAS** were recorded.



Number of SSEs due to SAS

A high number of SSEs is due to messages not being acknowledged by generators, distributors, or RTE operators during periodic testing (severity 0) or within the context of real critical situation orders for insufficient margins (severity A).

This number has remained stable compared with 2018, in spite of a sharp increase in the number of safeguard orders sent.

The increase since 2017 is mainly due to better monitoring of deviations.

Given the increase in the number of SAS orders sent, RTE has implemented tools to reinforce the traceability of these orders and provide feedback, which will be submitted to the concerned reliability operators. RTE is also working to promote its external training in reliability.

INFORMATIVE INSERT

The Alert and Safeguard System (SAS)

The SAS is a secure system for the transmission of alerts and actions to be executed by reliability operators, for managing high-risk or degraded conditions.

The safeguard of the system requires coordination and prompt actions between dispatching units and:

- Generators' and distributors' operations centres.
- RTE's operational teams.

With the SAS, RTE's dispatching operators can send predefined messages and orders reliably, accurately and quickly, including:

- Safeguard orders, which speed up the implementation of actions by operators, in strained situations when the reliability of the electric system could be compromised.
- Alert messages used in the event of disturbances.

The **Convergence grid test platform** is the tool used for grid testing, from development phase up to real time operation, and is thus important for reliability. The overall availability of the platform was in line with expectations, at 99.98% in 2019.

It has improved following actions undertaken after several incidents that occurred in 2018: rendering the application redundancy more reliable, fine-tuning the business recovery and continuity plan, and improving impact assessments for operations.

Two level A SSEs and 12 level 0 SSEs concern the availability of supply-demand balancing or market tools compared with a total of three in 2018; these malfunctions were mainly due to software upgrade issues as part of the roll-out of new supply-demand balance management platforms.

Improvement actions were undertaken at the end of 2019. Discussions are ongoing for the revamping of the concerned tools.

5.2 THE TELECOMMUNICATION NETWORK AND THE INFORMATION SYSTEM

Operational reliability of the power system is closely linked to the proper working order of security telecommunications networks, and the information system (IT) system, as well as their ability to withstand cyber attacks.

The ROSE Optical Security Network, an infrastructure owned and operated by RTE, is distributed over approximately 22,000 km of optical routes and provides reliable telecommunication services which contribute to system reliability: high-level remote operation, information exchange between electrical fault protection systems and safety telephones.

In 2019, only one Significant System Event of severity level 0 affected the ROSE infrastructure (compared with two level A SSEs and two level B SSEs last year; there was no event in 2017 and two events in 2016).

The operation of the Safety Telephone System (STS) was affected by two level A SSEs in 2019, the same number as in 2018 and 12 level 0 SSEs (26 in 2018). The two level A SSEs were due to the loss of power supply in dispatching units. Of the level 0 SSEs, six were due to generator or distributor failures or works, while one concerned unavailability due to the works of a service provider.

The operational deployment of RTE's new telecommunication network infrastructure "HORUS" is scheduled for 2020. It will host the STANWAY application in two data centres and create the related telecommunication network between the Operations Centres and these data centres.

RTE IT system security is pivotal to the operational reliability of the power system. This applies in particular to the industrial IT system as well as to the way in which information is shared with customers, market participants and partners.

In 2019, RTE's Operational Security Centre tackled over 10,000 attacks, prevented 3 million spam emails and eradicated 200 viruses on RTE's IT system.

New in-house training programmes on information system security have been put in place.

In 2019, risk assessments, audits and intrusion tests of RTE's information system were carried out to assess the level of resilience in the face of cyber attack threats and to ensure the continuity of its critical activities. Most of the major information systems have been subject to detailed studies and now have an internal approval.

Measures for the physical protection of premises, which hosts these systems, have also been defined and are being deployed in sensitive substations.

5.3 RTE CRISIS MANAGEMENT SYSTEM

In 2019, crisis cells of the ORTEC (RTE emergency response arrangements) system were opened nine times, covering a large spectrum of events.

The year was marked by the implementation of a digital tool for sharing information quickly and in real time when a significant event occurs. The professional skills of operators in crisis cells have been enhanced through training and awareness creation. The professional skills enhancement also encompassed crisis exercises, conducted as far as possible with external partners: in particular this year it is worth mentioning the Blackout exercise (simulating a blackout event) and the Gigawatt exercise (jointly managed by the General Secretariat for Defence and Security of Paris).

INFORMATIVE INSERT

The ORTEC (RTE emergency response arrangements) system

RTE must be able to tackle, at any time, different contingencies affecting its infrastructures and activities. This organisation, based on Management's presence and on-call availability levels, ensures quick information by management and the implementation of preventive or curative actions. This may include mobilising specific resources, expertise, and external communication actions.

In concrete terms, emergency response teams can be rapidly deployed across all of RTE's entities and at its headquarters. In addition, Priority Response Groups have the main aim of ensuring that the lines that have sustained serious damage, and which are particularly important for power system reliability, can be restored in less than five days.

6

CONTINUED STRENGTHENING OF EUROPEAN COOPERATION

6.1 IMPLEMENTATION OF GRID CODES

Other than operational implementation, the main issues over the period of **effective implementation of all the codes by 2021/2022** are:

- approval of the broad options on **sharing of balancing offers and building of reserves, with the development of the corresponding platforms,** as well as sharing with French market participants and the CRE;
- definition of the methods of **coordinated analysis of regional safety,** in particular countertrading and redispatching aspects and sharing of the related costs for the four regions of concern to RTE;
- transition to a **common grid model** for all data exchange with other TSOs and with the regional coordination centres (RSC).

6.2 REGIONAL COORDINATION CENTRES

2019 highlights for CORESO:

- the continued deployment of the five services to TSOs: establishment of common grid models, regional commercial capacity calculation, analysis of regional safety with transnational corrective actions, assessment of supply-demand balance reliability in the short term, coordination of isolations.
- The intensification of exchange with the neighbouring coordination centre (TSCNet), to ensure optimal coordination of the implementation of services in Core regions (Central Europe) and northern Italy (northern Italy and associated borders). RTE contributes actively to the implementation of services in these regions. More generally, across all regions to which RTE contributes (Core, NIB, SWE and Channel), the concerned TSOs submitted in December 2019 the methodology for the regional coordination of regional safety. These are expected to be approved in 2020 for commissioning by 2023-2025.

6.3 IMPLEMENTATION OF THE "CLEAN ENERGY FOR ALL EUROPEANS" PACKAGE

The law sets a minimum threshold of 70% of the capacity of interconnection infrastructures to be made available for cross-border trading in electricity. It is mandatory for this threshold to be reached by 2025.

The expected increase in cross-border trading will require enhanced coordination among European TSOs in order to comply with the operational limits of the European power system and manage the related congestion.

The gradual implementation of this threshold will enable RTE to develop the necessary tools and methods to ensure compliance while guaranteeing reliable system operation. **Of the three capacity calculations regions of concern to RTE, implementation could last up to the second half of 2020.**

The Clean Energy Package also provides for the creation of **Operating Regions,** which are new geographical networks within which it is expedient to organise the operational coordination among the TSOs. The operation of **these regions will be coordinated by new entities, the Regional coordination centres.** The final configuration of the Operating regions is known since the start of 2020; **CORESO is called upon to become one of these Coordination centres.**

6.4 MAJOR INCIDENTS ON THE EUROPEAN GRID

Besides the activation of the interruptibility mechanism in France over two frequency troughs of the European grid, **another major incident occurred in 2019: blackout in the UK** on 9 August.

The incident was caused by a lightning strike to an overhead line of the transmission grid leading to the loss of about 2,000 MW of generation following voltage or frequency variations: 1200 MW on the transmission grid (combined cycle gas turbine, offshore wind farm) and 800 MW of diffuse generation on the distribution grid.

Frequency dropped below 48.8Hz triggering the first level of the metric-frequency shedding system, causing a power cut of about 900 MW of consumption (over one million households).

Most of the actions implemented in the UK following this incident are already in place or are being implemented in the French and continental systems. Other actions (concerning relations at distributors and generators) are under consideration and could be undertaken by RTE.

INFORMATIVE INSERT

European integration

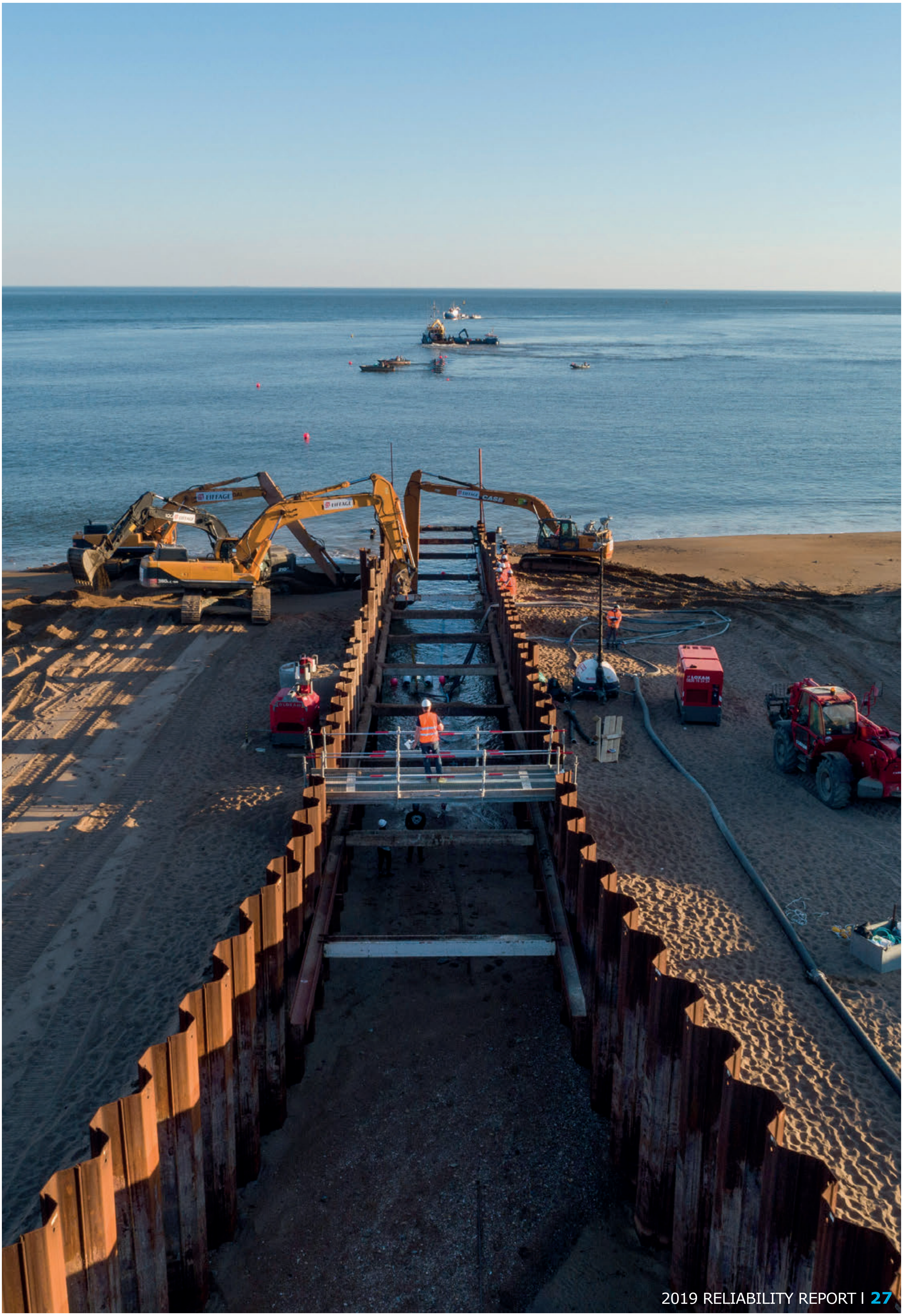
The power transmission system is a European system. The 43 TSOs operating in 36 countries are now linked by around 420 interconnections, around 50 of which cross the French border. Therefore, the reliability of the French system relies partly on the operation of the European power system.

The grid codes of the Third European Energy Package set out the main rules applicable to all players with regard to interconnected grid operation. All the codes have been published and are now applicable.

Covering different areas (operation, markets, connection), the codes contribute within their scope to the reliability of the interconnected European power system:

- The Emergency and Restoration code sets out common rules for managing emergency and grid restoration situations. The System Operation Guideline code combines the common principles for grid operation.
- As regards markets, reliability is a key issue for the Electricity Balancing codes, which cover the supply-demand balance and Capacity Calculation and Congestion Management. The aim is to organise short-term trading in electricity.
- The Requirements for Generators code incorporates among its requirements regarding the connection of generation facilities, technical requirements so as to enhance the resilience of the power system.

The Fourth Package, called Clean Energy for All Europeans package, came into effect on 5 July 2019 and must be transposed into national law for each Member State before 31 December 2020. It brings about, through its objectives of reinforcing European integration and developing renewable energies, new challenges and opportunities for the reliability of the power system.



7

AN OPERATIONAL INTERNAL CONTROL SYSTEM

As part of RTE's **internal control system,** it assesses on an annual basis the management of operations (and therefore reliability) in light of the risks identified and placed in order of priority, mitigation measures implemented and their effectiveness. **Internal controls conducted in 2019 showed a satisfactory level of reliability management,** while areas of improvement were identified regarding the management of high voltage and coordination among regions.

Two reliability internal audits were conducted in 2019 on the following topics:

- The risk management method - Short-circuit intensity
- Human factor and reliability: improved performance through professionalism and management of human errors impacting operations.

The findings of these two audits, covering the topics audited, are that the operation of the power system to ensure reliability was broadly satisfactory.

INFORMATIVE INSERT

Internal audits, in the specific area of reliability are conducted every year on behalf of senior management. The topics targeted by the audits are designed to ensure that all major reliability aspects are covered over a period of three to four years, depending on the risk level assessed. Audit findings are presented to the RTE Executive Committee. Recommendations are made to improve risk management. The actions undertaken on the basis of the recommendations are covered by an action plan, which is submitted to the Executive Committee.

APPENDIX 1 : GLOSSARY OF TERMS

Term	Definition
Balancing Mechanism (BM)	Under French law, generators must provide RTE with technically available power for balancing supply and demand. This is carried out via the Balancing Mechanism, whereby RTE pools all resources available from operators in the form of a continuous and open mechanism, and whereby operators can value their demand response capacity or their generation flexibility. Based on price-volume proposals, RTE makes the necessary balancing adjustments by classifying proposals on the basis of their price until its needs are met. Provisions are made for cases of shortages: • for a timeframe of over 8h, RTE requests additional proposals via an alert message; • for less than 8h, RTE uses a "degraded mode" message to secure exceptional proposals, besides any additional proposals, and resources not offered for the balancing process.
Primary and secondary frequency control	Primary control is for automatically ensuring that balance is restored virtually immediately after any contingencies affecting balance between generation and consumption, by all of the partners involved in synchronous secondary interconnection working together as one. Rules are laid down by the ENTSO-E's regional "continental Europe" group so that this action then maintains the frequency within defined limits. Thereafter, secondary control of the partner behind the disruption automatically cancels the residual frequency deviation relative to the reference frequency, as well as deviations from the scheduled cross-border trade between the various control zones.
ENTSO-E	ENTSO-E (European Network of Transmission System Operators for Electricity), created at the end of 2008, has been the sole association of European TSOs since 1st July 2009. The role of ENTSO-E is to strengthen cooperation among TSOs in key areas such as the development of grid codes relating to technical aspects and market operation, coordination of operation and development of the European transmission grid and research activities. In accordance with its articles of incorporation, the association's main decisions are taken by the General Meeting. An Executive Board is responsible for overall management and for establishing strategic guidelines. The operational work is carried out by four main committees and their sub-structures, the Markets Committee (MC), the System Development Committee (SDC), the System Operation Committee (SOC) and the Research and Development Committee (RDC), along with a legal analysis group. RTE is represented in each of these groups. To ensure the technical coordination of synchronous interconnected TSOs in continental Europe and the assessment of reliability commitments, as defined in 8 policies and agreed upon under the Multi-Lateral Agreement signed by the members of the former association, UCTE, the SOC has created an ad-hoc sub-group, the Regional Group Continental Europe (RGCE). See: www.entsoe.eu
Security tele-communications networks	This security network is based on a dedicated telecommunications infrastructure, mostly owned and operated by RTE, which carries all information (voice, data) necessary for remote operation. These systems take care of the following functions: • transmission ("low level") of remote operation data of all remote substations and of a limited number of telephone conversations between main transmission grid substations and area transmission substation groups; • transmission ("high level") of remote operation data and telephone conversations between area transmission substation groups and dispatching centres; • transmission of remote operation data and telephone conversations between generation plants and dispatching centres; • transmission of remote operation data and telephone conversations between distribution grid operations centres and dispatching centres.
Performance controls on generation facilities	Given the criticality of services rendered by generation facilities when connected to the transmission grid, they can be subject to performance controls. Controls serve to assess the behaviour of generation units towards primary and secondary load frequency controls (static gain, scheduled reserves, response time, etc.) and towards primary and secondary voltage controls (availability of the contractual field in the U/Q diagram, response dynamics).

APPENDIX 2: GLOSSARY OF ABBREVIATIONS

ADN ——— Northern defence programmable controller

ADO ——— Western defence programmable controller

ANSSI —— National information service security agency

BCP———— Business Continuity Plan

BM ———— Balancing Mechanism

BRP———— Business Recovery Plan

CACM——— Capacity Allocation and Congestion Management

CORESO — CO-oRdination of Electricity System Operators

CR ———— Complementary reserves (BM)

CSEA ——— Economic Monitoring and Audit Committee

CSPR ——— Static reactive power compensator

CURTE —— Committee of electricity transmission grid users

DSO ——— Distribution System Operator

DTR ——— Reference Technical Documentation

EAS ——— ENTSO-E Awareness System

ENTSO-E — European Network of Transmission System Operators for Electricity

HVDC——— High Voltage Direct Current link (IFA)

ICS ———— Incident Classification Scale

IST ———— Maximum current that a line can withstand during a time limit

LPM———— Military programming law

ORTEC —— RTE emergency response arrangements

RCC ——— Regional Cooperation Centre

RfG———— Requirements for Generators

ROSE ——— Optical Security Network

RPD ——— French public electricity distribution grid

RPT———— French public electricity transmission grid

RR ———— Rapid reserves (BM)

RSC ——— Regional Service Centre

RSFP ——— Secondary load frequency control

RST ——— Secondary voltage control

SAS ——— Alert and Safeguard System

SDB ——— Supply-demand balance

SIDRE —— Regional inter-dispatching support system

SNC ——— National Control System

SOGL——— System Operation GuideLine

SRC ——— Regional Control System

SSE———— Significant System Event

SSY———— System Services

STANWAY — SRC replacement project

STS———— Safety Telephone System

TCD ——— Remote operation

TCM ——— Telecommunication

TSO ——— Transmission System Operator

TURPE —— Transmission grid usage tariff

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