2026 Continental Europe Synchronous Area Frequency Stability Study

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SG SPD – TF Inertia

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Abbreviations

Abbreviation	Description
CE SA	Continental Europe Synchronous Area
DE	Distributed Energy
EPC	Emergency Power Control
ERAA	European Resource Adequacy Assessment
EV	Electric Vehicle
FCR	Frequency Containment Reserve
GFM	Grid Forming
GSS	Global Severe Split
HP	Heat Pump
HVDC	High Voltage Direct Current
IL	Interruptible Loads
IP	Iberian Peninsula
ISA WG	Intersynchronous Area Working Group
LFDD	Low-Frequency Demand Disconnection
LFDD-C	Low-Frequency Demand Disconnection Consumer
LFSM (-O, -U, -UC)	Limited Frequency Sensitive Mode (Over-Frequency, Under-Frequency, Under-Frequency Consumer)
NC DC	Network Code on Demand Connection
NC ER	Network Code on Electricity Emergency and Restoration
NCD	Non-Compliant (or Non-Conform) Disconnection

NT	National Trend
OWF	Offshore Wind Farm
PS	Pump Shedding
ps	past splits
pgss	potential global severe split
RGCE	Regional Group Continental Europe
RoCoF	Rate of Change of Frequency
SBM	System Balance Model
SG SPD	Sub-Group System Protection & Dynamics
SOGL	System Operation Guideline – EU Regulation 2017/1485
SPS	Special Protection Schemes
SREL	Self-Regulating Effect of Loads
TP	Transparency Platform
TSO	Transmission System Operator
TYNDP	Ten Year Network Development Plan

Introduction & Scope

The SG SPD (Sub-Group System Protection & Dynamics) under RGCE (Regional Group Continental Europe) investigates system stability aspects in the CE (Continental Europe) power grid on ENTSO-E level. One of its tasks is to assess the frequency stability of the CE SA (Synchronous Area), in line with the requirements set in Article 39(3)(a) of Regulation EU 2017/1485 (SOGL, System Operation Guideline).

The study verifies whether security criteria are met (e.g. the maximum frequency deviation and RoCoF) that the CE system may experience in case of different power imbalances. Various measures are considered in this study based on defence plan functionalities and SPS (Special Protection Schemes) that are triggered by the frequency (or its rate of change). The goal of the system defence plan functions that act upon frequency is to compensate for the active power imbalance caused by a disturbance and keep the frequency within the limits of the system design.

Hence, the frequency stability criteria and the appropriate behaviour of the system defence plan measures are investigated for the reference incident and for some considered extreme power imbalances that allow to assess the behaviour of the system defence plans. Previous assessments (such as [1], [2] and [3]) demonstrated that the system defence plan of CE functions properly and protects the system from blacking out, if:

- the system remains interconnected (no system-split) and
- if the active power imbalance does not exceed the reference incident, and extreme power imbalances up to ±6 % to ±10 % (depending on the scenario) of the interconnected system's load/generation.

The scope of this study is to conduct the prescriptive assessment for CE SA pursuant to Article 39(3)(a) of SOGL and to reassess the performance of the system defence plan under the light of recent developments in grid codes, grid topologies and market scenarios. The investigation in this document will:

- present the investigated market scenarios followed by a detailed model description, including the implemented system defence plan functions and
- evaluate the system behaviour for interconnected operation in reference incident and extreme power imbalances to fulfil the requirements of SOGL Article 39 (3)(a).

Methodology

Simulation Scenarios

Four different scenarios are investigated within this study at three different time horizons: 2024, 2030 and 2040:

- the CG (Current Grid) 202X scenario is based on ENTSO-E Transparency Platform data [4] from 2024. Missing data is complemented by additional public data. Moreover, this scenario already considers the system topology shown in Figure 1 (incl. the synchronous connection of Baltics and Ukraine).
- The NT (National Trends) 2030 scenario is a TYNDP (Ten Year Network Development Plan) 2024 scenario,
- the NT 2040 scenario from the TYNDP 2024 and
- the DE (Distributed Energy) 2040 scenario from the TYNDP 2024.

The scenarios provide load and dispatch data for different generation types on an hourly basis for a whole year and each market zone[1]. This data is aggregated to country level for countries with multiple market zones. The TYNDP data is based on the standard output of the Plexos market simulation. Using the 2024 ERAA (European Resource Adequacy Assessment) demand data (ERAA 2025 demand data can be found in [5]) and other public sources, timeseries data for EVs (Electric Vehicles) and HPs (Heat Pumps) were added to the TYNDP input data[2]. Figure 1 shows all countries that are considered in the scenarios synchronously connected within CE.

[1] The TYNDP dataset contains 8736 hours per scenario (31st of December is missing). The CG202X scenario contains 8784 hours (as it is based on leap year 2024).
[2] HP and EV data for 2040 was extrapolated.

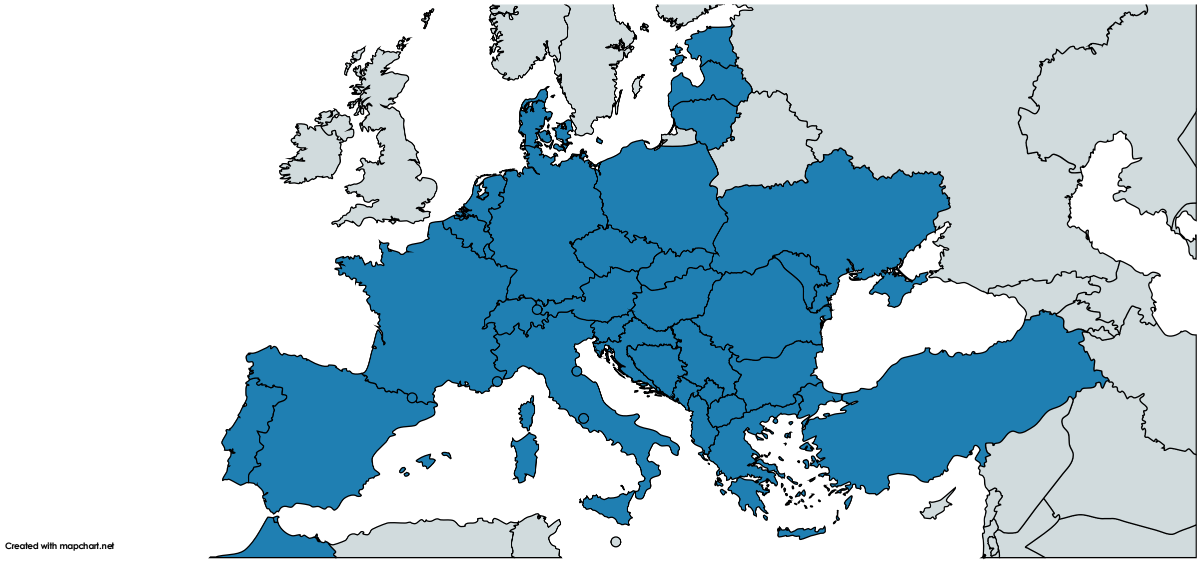

Figure 1: Countries that are considered in the different simulation scenarios in **blue**; generated with *www.mapchart.net*

The prescribed scenarios will be used in this report to assess the dynamic system frequency performance of the CE power system based on two criteria.

To verify frequency dynamic stability, first, it is checked if the global initial absolute RoCoF remains below 1 Hz/s. The second criterion assesses whether the frequency exceeds the limits of 47.5 Hz and 51.5 Hz. More details on the criteria will be provided at the end of this chapter.

Assumptions Regarding Kinetic Energy Based on the Simulation Scenarios

The kinetic energy and the contribution of different technologies to the system defence plan can be calculated based on the simulation scenarios. An extensive overview of country-wise inertia values from the past TYNDP 2022 can be found in [6, pp. 32-34]. The kinetic energy duration curves of the four scenarios that are investigated in this report are shown in Figure 2 and Figure 3.

Moreover, assets providing significant inertia, such as synchronous condensers with flywheels, GFM (Grid-Forming) STATCOMs with a dedicated storage etc. are considered in the scenarios. The contributions from these assets increase by several hundred GWs from the current grid to the 2040 scenario. The implementation is based on information provided by the corresponding TSOs.

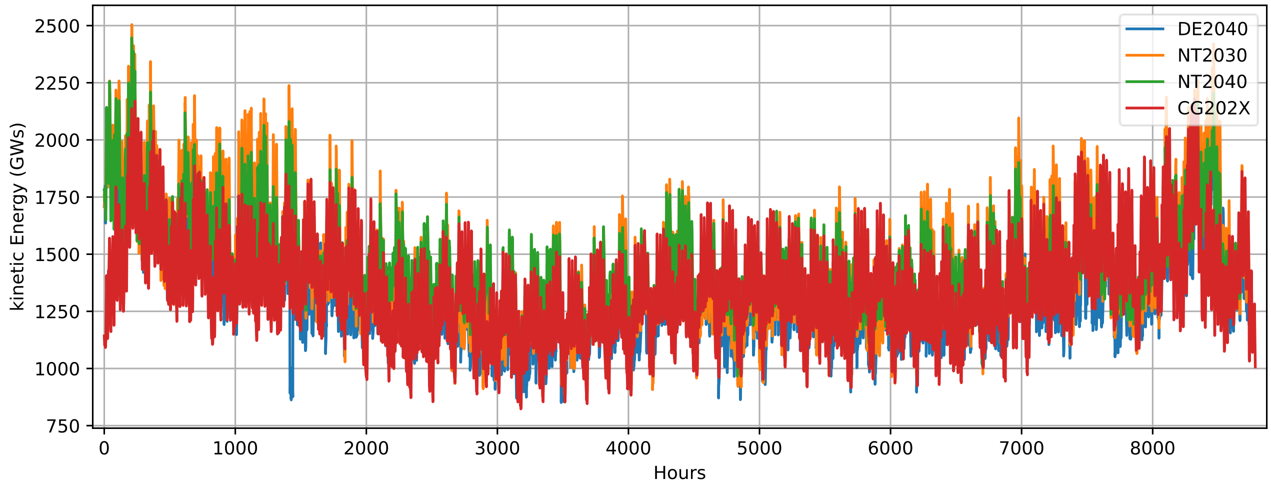

Figure 2: Duration curve (unsorted) of kinetic energy of all 4 scenarios used within study

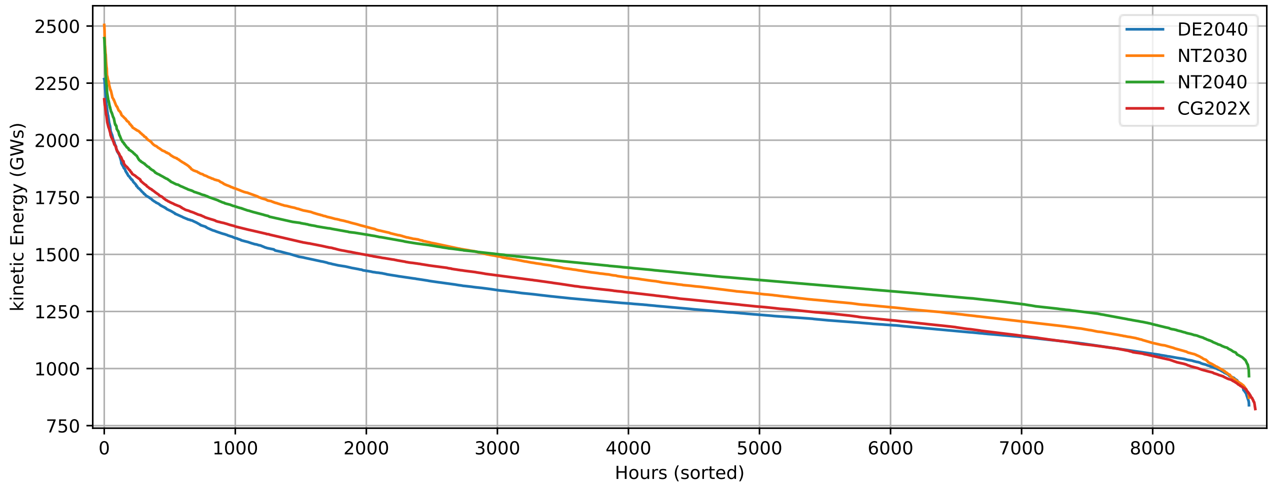

Figure 3: Duration curve (sorted) of kinetic energy of all 4 scenarios used within study

Simulation Model Basics

This section describes the simulation model used in the study at hand. The model is called SBM (System Balance Model) and is developed and maintained by TF (Task Force) Inertia under SG SPD.

The model is implemented in Python. It reads the market data of each scenario and derives various quantities, such as inertia and RES (Renewable Energy System) share. The model uses an iterative numeric solver that solves the following equation in each timestep:

$$\dot{f} = \frac{\Delta P \cdot {f_0}^2}{2 \cdot f \cdot E_{\text{kin}}} \quad , \qquad (1)$$

where $\dot{f}$ is the RoCoF (Rate of Change of Frequency) in Hz/s, ΔP is the active power imbalance (surplus or deficit) at each timestep (e.g., due to the initial power imbalance or system defence plan action) in W, f_0 is the nominal grid frequency in Hz, f is the frequency at this timestep in Hz and E_{kin} is the kinetic energy of the system in Ws. The calculation timestep is 10 ms and the simulation time 60 s by default. More information can be found in the last report on the system defence plan [1]. In contrast to past reports this model was extensively enhanced. Where previous versions were limited to manually created scenarios, the SBM is able to produce statistical evaluations on hourly data of a whole year within minutes. The input data stems from the TYNDP and ENTSO-E Transparency Platform as described in the previous section. Adding new defence plan measures or specialized SPS of individual TSOs is now possible as well.

The frequency and RoCoF are therefore the global RoCoF and frequency (*centre of inertia)*, while local frequencies or RoCoFs can differ from the global values calculated by the SBM [7].

Implemented System Frequency Reactions

In case the frequency deviates from the nominal frequency of 50 Hz (e.g., due to the initial power imbalance), first the regular load-frequency control processes act and, if frequency drops over prescriptive thresholds, various system defence plan measures step in to stabilize the frequency. The individual measures are activated at different frequency thresholds. The SBM allows a stepwise (discrete change at specific frequency thresholds) or linear implementation (proportional to frequency) of the load-frequency control reaction and the defence plan measures with individual activation delays t_{delay}. All linear functions are modelled as PT1 blocks, i.e. first-order-lag behaviour. The delay of linear functions is caused by the units having to perform a reliable frequency measurement (approx. 120 ms) and setpoint adaptation (almost instantly for power electronics). The delay of stepwise functions includes—in addition to a reliable frequency measurement—the time it takes to operate a breaker. Therefore, all stepwise functions have a delay of $t_{\text{delay}} = 0.3$ s consistent with [7] and [8].

The main structure of the SBM is shown in Figure 4.

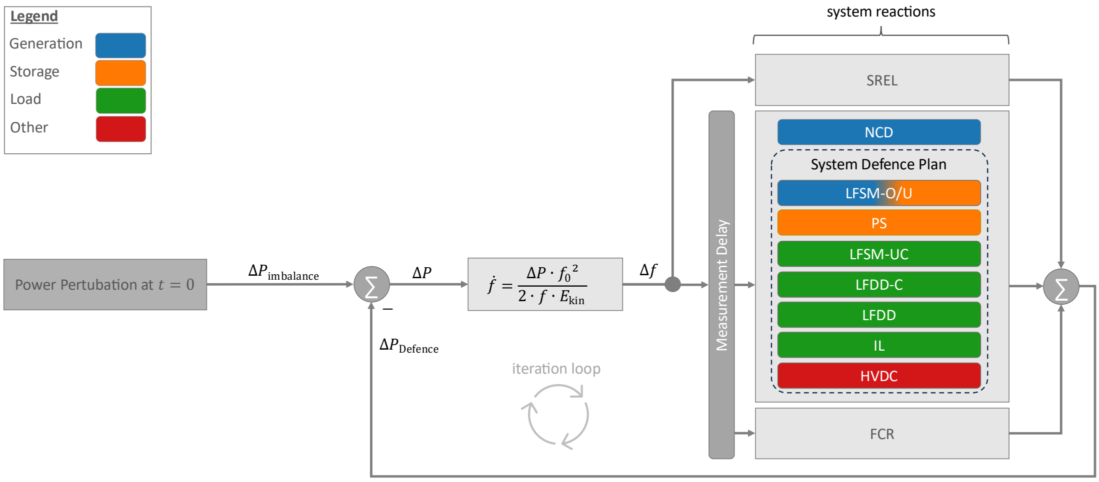

Figure 4: Basic structure of the SBM

All system reactions are described in detail in Table 1.

Table 1: List of implemented system defence plan functions

System Reactions (Type)	Description
SREL (linear)	The Self-Regulating Effect of Loads is not a system defence plan measure in itself but rather an inherent property of the loads of the power system. For 202X and 2030 scenarios a value of 2 %/Hz has been used. To respect an increasing amount of inverter connected loads in the future, for 2040 scenarios the SREL is decreased to 1.5 %/Hz. These assumptions are in line with those of [3] and are effective inherently (without delay).
FCR (linear)	Based on the updated values from 2026, the Frequency Containment Reserve is specified with 3.562 GW for all scenarios. The share of FCR is distributed country specific.
LFDD (stepwise)	Low-Frequency Demand Disconnection relates to the shedding of DSO grids and large consumers between 49.0 Hz and 48.0 Hz in CE. According to the NC ER (Network Code on Electricity Emergency and Restoration) [8], each TSO is required to have 45 % ± 7 % of the current system load available for LFDD activation at any moment in time. Based on detailed datasets from individual countries obtained within the ENTSO-E LFDD monitoring campaign, a *Lasso* regression with cross-validation was performed to derive country-specific LFDD models. This model more realistically represents the available LFDD in each hour, which can be significantly below the NC ER requirement during moments of high infeed of RES. These models quantify the relationships between

	available LFDD and key system variables like dispatch of photovoltaics (PV) and wind ($Wind$) in each hour. This approach was investigated in [9] and is adopted therefrom. For each country, the resulting LFDD estimation model has the following general form and is calculated hourly-wise: $LFDD = k_0 + k_{\mathrm{Wind}} \cdot Wind + k_{\mathrm{PV}} \cdot PV$ where: • k_0 is the intercept (MW), • k_{Wind} and k_{PV} are the regression coefficients. The coefficients have been chosen to approximately represent a country's average available LFDD, as obtained by the LFDD monitoring campaign. The simulation model also considers the fact that each step of LFDD activation directly decreases load inertia. At this point, the model cannot represent detailed load models, thus, a generic inertia constant is assumed for the load.
LFDD-C (stepwise)	Low-Frequency Demand Disconnection Consumer relates to stepwise shedding of consumer level units. LFDD-C acts at levels different from conventional LFDD. In this study, only a certain share of future HPs belong to this category and are shed between 49.6 Hz and 49.1 Hz (uniformly distributed in 0.05 Hz steps). This is in line with the recommendations given by [3] for the NC DC (Network Code on Demand Connection) 2.0. In the 202X and 2030 scenarios, no HPs are shed between 49.6 Hz and 49.1 Hz as it is not expected that a significant part of HPs is already compliant in 2030. In the 2040 scenarios, 50 % of HPs are assumed to be compliant with the new requirements and are hence shed between 49.6 Hz and 49.1 Hz.
LFSM-O/U (linear)	Limited Frequency Sensitive Mode Over-/Under-Frequency relates to the frequency-dependent power injection/absorption of the following generation and storage types: RES, Electrolyzers, BESS and synchronous machines.
LFSM-UC (linear)	Limited Frequency Sensitive Mode Under-Frequency Consumer relates to the frequency-dependent power injection/absorption of EVs and HPs, connected to the consumer level. Though HPs are also allowed to perform LFSM-UC instead of LFDD-C, in this study they are expected to only react via LFDD-C. In the 2040 scenarios, 50 % of EVs are assumed to be compliant and perform LFSM-UC. LFSM-UC is not considered in the 202X and 2030 scenario.
IL (stepwise)	Interruptible Loads relate to large consumers that may be shed at certain frequency levels below 50 Hz. The amount of available IL per TSO has been obtained via a survey.

PS (stepwise)	Pump Shedding relates to large pumps in pumping mode (load) that may be shed at certain frequency levels below 50 Hz. The amount of available PS per TSO has been obtained via a survey. The maximum available PS per TSO varies according to the available hydro generation in the respective hour.
NCD (stepwise)	Non-Compliant Disconnection relates to generation units that are not compliant with the RfG and may disconnect before the system frequency reaches the lower limit of 47.5 Hz or the upper limit of 51.5 Hz. Data of a 2022 and 2025 survey have been evaluated to collect the approximate amount of NCD at each frequency threshold. The current values of the surveys have been used for all scenarios. Though the surveys may not capture all NCDs within the CE grid, this is seen as a pessimistic assumption, as it is expected that a significant amount of NCD will be faded out in 2030 and even more in 2040. As many NCD are RES units connected with grid codes prior to the RfG, the amount of active NCDs in each hour is scaled with the ratio of dispatch of RES in this hour relative to the maximum dispatch of RES of all hours. Comparable numbers of the 2022 survey are given in [1].

HVDC (linear)	High Voltage Direct Current systems can support frequency stability if:
	• connected to OWF (Offshore Wind Farms) with Choppers,
	• connected to other synchronous areas
	    ○ via GFM control or
	    ○ EPC (Emergency Power Control) functions or
	    ○ LFSM-U/O or
	    ○ other fast frequency control functions.
	However, in the model only LFSM by HVDCs is considered, which is based on a TSO survey (without future projection). The droop is specifically set for each HVDC link.

Table 2 transparently lists the parametrization of the different linear system defence plan functions. The droop of BESS is diverging from the 1.6 % droop proposal in [3]. In this study it was set to 5 % to represent the lower end of the possible requirements according to the draft of RfG 2.0 and hence make a pessimistic assumption. Requirements for EV and HP only become effective after the release of the new RfG 2.0 and NC DC 2.0, which are still pending, so both types are only considered in the 2040 scenarios with 50 % of the overall EVs and HPs being compliant. It is important to note that the parametrization shown in Table 2 is not to be understood as a recommendation but used within this study as an assumption of an average behaviour of past and upcoming units of the respective generation types. P_{max} relates to the maximum active power of a unit and P_{act} to the actual power that is dispatched in the hour considered.

Table 2: Parametrization of system defence plan measures

Generation Type	Function	t_{delay} (s)	PT 1 Time Constant (s)	Droop	Reference Value
-	FCR	0.120	15.0	17.81 GW/Hz	3562 MW
BESS	LFSM-O	0.120	1.0	5.0 %	P_{max}
BESS	LFSM-U	0.120	1.0	5.0 %	P_{max}
RES	LFSM-O	0.120	1.0	5.0 %	P_{act}
Electrolyzers	LFSM-U	0.120	1.0	5.0 %	P_{act}
Synchr. machines	LFSM-O	2.000	3.0	5.0 %	P_{act}[3]
EV	LFSM-UC	0.120	1.0	5.0 %	P_{act}
HVDC	HVDC (LFSM-O/U)	0.120	1.0	0.2…0.6 GW/Hz	

Model Simplifications

While BESS (Battery Energy Storage Systems) that are considered in the TYNDP scenarios provide LFSM, the model does not yet consider them to be GFM and hence they do not provide inertia. This is a pessimistic simplification, where the behaviour—in reality—is expected to be more favourable (e.g., smaller RoCoF, if batteries in the respective subsystems are GFM).

Today, in CE SA, FCR is already provided by a significant amount of BESS that act much faster than conventional generation plants. Hence, the FCR reaction might be faster in reality than modelled in the SBM.

Large power plants (e.g., gas power plants) may trip or loose synchronism, if the global absolute RoCoF exceeds 1 Hz/s [10]. This would cause a resultant loss of generation and associated frequency drop that can significantly degrade the performance of the system in the most severe situations. Recollecting that the tool only calculates the global RoCoF, situations where the absolute value of the global RoCoF does not exceed 1 Hz/s may lead to more critical situations, if—in reality—larger

[3] The reference value should be P_{max} but due to restrictions of the model it is currently set to P_{act}. The impact of this simplification on the results is expected to be low.

local RoCoFs lead to large power plants loosing synchronism or cause them to trip [7]. This is out of scope for this analysis and subject to further investigation.

The generation dispatch is not provided plant-specific by the input data, so average inertia constants and average apparent power ratings per generation type (nuclear, coal …) are used to calculate the inertia of a country. These average values were collected via a survey from TSOs. For some countries these average values have not been available and hence the average of all provided values from other countries was used. Also, LFSM is modelled without hysteresis in all cases, however, units with hysteresis are still present in the grid.

The ERAA data that is used to generate timeseries data for HP and EV is not available for each country within CE. For example, no HP and EV timeseries are available for France. Neglecting their contribution to the system defence plan functions is a pessimistic assumption but also expected to be of limited impact.

NCDs and the pre-defined power imbalance do not change the actual load, generation or inertia in this hour. For example, if a power imbalance of 10 GW load is simulated, this 10 GW is not subtracted from the total load in this hour (as it would happen in reality). The total load is for example used to calculate the defence plan measures (e.g., SREL). However, considering that the total load (or generation) in all hours is much larger than the maximum power imbalance (±20 GW), this simplification is considered to have little impact on the results. Moreover, NCDs with larger delays (in the range of seconds) are currently not considered in the model.

Upcoming HVDC projects between CE and other synchronous areas that will support the frequency via LFSM, EPC or similar function are also not considered as of now.

Evaluation Criteria

In the following sections, different simulation scenarios are evaluated. Each scenario contains all hours of a year, thus clear evaluation criteria are important, since individual analysis of each hour is not feasible. For the evaluation of the dynamic performance of the CE power system in a certain hour the following criteria will be checked:

$|\dot{f}|$-Criterion

This criterion is violated if the initial absolute RoCoF (positive or negative) is equal to or greater than 1.0 Hz/s. The RoCoF relates to the global RoCoF of the respective (sub-)system as described in previous paragraphs. It is calculated in the first timestep based on formula (1) without a measurement window.

Even though power systems outside of CE may be designed to withstand higher RoCoFs [11] (especially in small islands with a high share of converters), past experiences show that large, interconnected power systems could not remain stable when this criterion was violated [1], [3], [12], [2].

Nevertheless, improving the system resilience to withstand larger RoCoFs (e.g., by improving protection systems etc.) remains a reasonable option to ensure effectiveness of the defence plans. This is subject of future research.

f-Criterion

This criterion is violated if the following two conditions are fulfilled: the frequency leaves the band of 47.5 Hz to 51.5 Hz and the $|\dot{f}|$-criterion was not violated before. Here, even low RoCoFs cause a blackout due to insufficient frequency restoration reserves (e.g., LFSM etc.) in the respective (sub-) system.

Results on Interconnected Operation to Fulfil SOGL Art. 39 (3)(a)

The following analysis is presented as the update of the common study by all TSOs of the Continental Europe Synchronous Area in accordance with SOGL Art. 39 (3)(a) [13]. This article requests a comprehensive analysis of the suitability of the load-frequency control processes and system defence measures on a regular basis. It shall be investigated if a minimum inertia requirement is to be established taking into account the costs and benefits as well as potential alternatives. Frequency stability is assessed with a system that remains in interconnected operation. This approach is in line with Article 39(3) SO GL. Article 39(3)(b), which may be triggered by the outcome of the study performed under Article 39(3)(a), refers to the possible need for TSOs to deploy minimum inertia in real time “to maintain operational security and to prevent violation of stability limits”. Considering that “maintaining operational security” under SOGL refers to the interconnected operation of the system, this study under Article 39(3)(a) is, therefore, understood to concern interconnected operation. Hence, this study uses this approach, however the models have significantly been improved compared to previous studies.

Power Imbalances

The most relevant power imbalance to be considered in interconnected operation is the reference incident of CE with ±3 GW, as defined in Art. 153 of [13]. FCR was originally dimensioned based on this reference incident, to prevent the frequency deviation exceeding ±200 mHz in all hours. Though FCR is sufficient to arrest the frequency in case of a 3 GW imbalance in each hour per design, it still makes sense to investigate this imbalance to verify that inertia levels are also sufficient in all hours and hence FCR can react fast enough.

There are no other imbalances defined, whose behaviour needs to be validated. However, imbalances exceeding 3 GW—where the system remained interconnected—have already occurred in the past (see [14]). There are various possible causes for these imbalances, such as human error, non-conform generation/load behaviour (e.g., non-compliant FRT capabilities of distributed generation or loads) or outages of multiple HVDCs or HVDC hubs.

Hence, in addition to the normative ±3 GW imbalance, larger extreme imbalances of ±5 GW, ±10 GW and ±20 GW, are investigated. It should be noted that these large power imbalances are unlikely to occur in practice in interconnected operation. With larger imbalances it becomes increasingly unlikely that the system remains interconnected.

Results

Each power imbalance is analysed in a separate table that summarizes the behaviour of the system. The table shows the hourly number of violations of the previously defined criteria. In addition, the tables show in how many hours LFDD was activated.

Table 3 shows the simulation results of the CE reference incident of an outage of 3 GW generation (+3 GW) or load (-3 GW). In none of the scenarios and hours, the system is expected to violate any of the criteria and hence remain stable. The frequency always remains within the band of approx. 49.80 Hz and 50.21 Hz and absolute RoCoFs never exceed 0.14 Hz/s.

Table 3: Results for imbalances of +3 GW (left number in each cell) and -3 GW (right number in each cell)

Scenario	Number of hours with $\lvert\dot{f}\rvert$-criterion violated	Number of hours with f-criterion violated	Number of hours with LFDD activation
CG202X	0 / 0	0 / 0	0 / 0
NT2030	0 / 0	0 / 0	0 / 0
NT2040	0 / 0	0 / 0	0 / 0
DE2040	0 / 0	0 / 0	0 / 0

Table 4 shows the simulation results of an outage of 5 GW. In none of the scenarios and hours, the system is expected to violate any of the criteria and hence remain stable. The frequency always remains within the band of approx. 49.69 Hz and 50.33 Hz and absolute RoCoFs never exceed 0.15 Hz/s.

Table 4: Results for imbalances of +5 GW (left number in each cell) and -5 GW (right number in each cell)

Scenario	Number of hours with $\lvert\dot{f}\rvert$-criterion violated	Number of hours with f-criterion violated	Number of hours with LFDD activation
CG202X	0 / 0	0 / 0	0 / 0
NT2030	0 / 0	0 / 0	0 / 0
NT2040	0 / 0	0 / 0	0 / 0
DE2040	0 / 0	0 / 0	0 / 0

Table 5 shows the simulation results of an outage of 10 GW. In none of the scenarios and hours, the system is expected to violate any of the criteria and hence remain stable. The frequency always remains within the band of approx. 49.15 Hz and 50.39 Hz and absolute RoCoFs never exceed 0.3 Hz/s.

Table 5: Results for imbalances of +10 GW (left number in each cell) and -10 GW (right number in each cell)

Scenario	Number of hours with $\lvert\dot{f}\rvert$-criterion violated	Number of hours with f-criterion violated	Number of hours with LFDD activation
CG202X	0 / 0	0 / 0	0 / 0
NT2030	0 / 0	0 / 0	0 / 0
NT2040	0 / 0	0 / 0	0 / 0
DE2040	0 / 0	0 / 0	0 / 0

Table 6 shows the simulation results of an outage of 20 GW. In none of the scenarios and hours, the system is expected to violate any of the criteria and hence remain stable. The frequency always remains within the band of approx. 48.90 Hz and 51.12 Hz and absolute RoCoFs never exceed 0.61 Hz/s.

Table 6: Results for imbalances of +20 GW (left number in each cell) and -20 GW (right number in each cell)

Scenario	Number of hours with $\lvert\dot{f}\rvert$-criterion violated	Number of hours with f-criterion violated	Number of hours with LFDD activation
CG202X	0 / 0	0 / 0	8736 / 0
NT2030	0 / 0	0 / 0	0 / 0
NT2040	0 / 0	0 / 0	0 / 0
DE2040	0 / 0	0 / 0	0 / 0

Conclusion

The investigations on the impact of normative and extreme power imbalances in interconnected operation show that positive and negative power imbalances of up to 20 GW do not bear any significant risk for the CE power system concerning frequency stability. The inertia and frequency reserves of the system are sufficient to limit the RoCoF to 1 Hz/s and keep the frequency in the specified range in all hours.

In the case of a 20 GW loss of generation, the first stage of LFDD is triggered in the CG202X scenario, which demonstrates a proper system reaction to a very large imbalance. LFDD-C by HP is expected to be activated in some cases for imbalances of +10 GW and +20 GW, since frequencies occasionally drop below the activation threshold of 49.6 Hz. LFDD-C only leads to temporary HP outages, posing minor restrictions to HP users. In contrast, the activation of LFDD significantly affects grid users (power outage), therefore, the activation threshold is set lower. LFDD activation only appears in the CG2020X scenario, in 2030 onwards the LFDD threshold is not triggered, because the LFSM-U contributions of BESS and offshore wind are much higher.

Besides the 3 GW reference incident, no other power imbalance is specified that needs to be successfully arrested by the system frequency defence plan. However, an investigation of power imbalances beyond ±3 GW has been undertaken which proves that the system can also remain stable from the frequency stability point of view for power imbalances up to ±20 GW. It can be concluded, based on the investigations, that no minimum inertia is necessary to be established for the system to remain stable for the ±3 GW power imbalances of the reference incident in interconnected operation, as well as for larger (extreme) power imbalances. Therefore, no further actions with regards to SOGL Art 39. (3)(b) need to be triggered at this point.

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