Ten-Year
Network
Development
Plan 2020

The inertia challenge in Europe – Present and long-term perspective

Insight Report

November 2020 – Version for public consultation

entsoe

The inertia challenge in Europe – present and long-term perspective

The TYNDP 2020 IoSN report[1] presented, from a technical perspective, the outlook and estimated inertia trends in all synchronous areas and for all TYNDP scenarios[2] and time horizons. The performed analysis, ranging from 2025 to 2040, clearly confirmed the steady tendency in the reduction of inertia from 2025 to 2040.

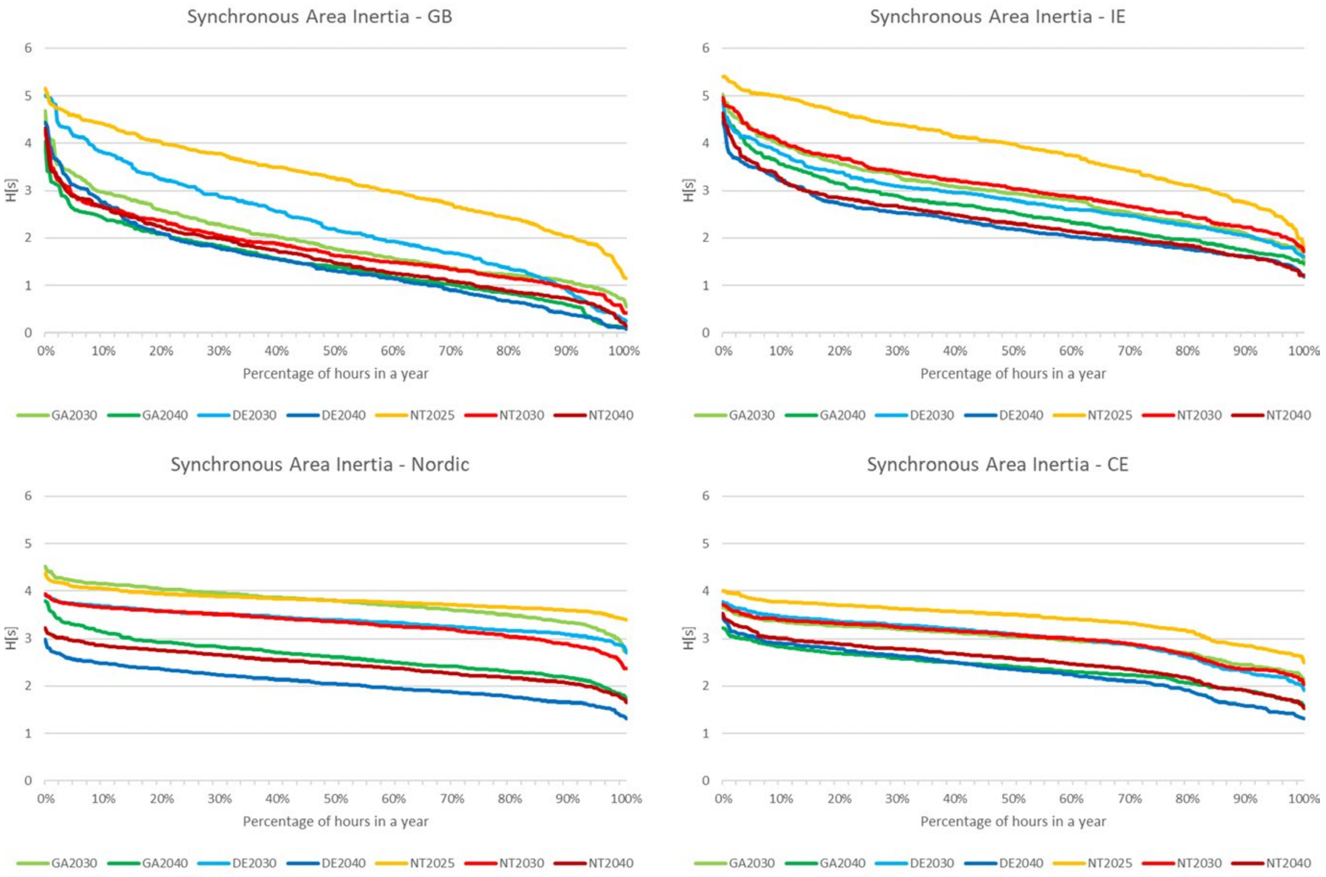

Figure 1 – **Steady tendency in the reduction of inertia from 2025 to 2040:** The duration curves present the percentage of hours in a full year where, for the synchronous areas, the equivalent system inertia is above a given value.

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[1] https://tyndp.entsoe.eu/system-needs/ System dynamic and operational challenges. Section 1.1 - Frequency related aspects. August 2020 · Draft version prior to public consultation

[2] NT-National Transition; DE-Distributed Energy; GA- Global Ambition. Scenarios description available at: https://www.entsos-tyndp2020-scenarios.eu/

How can the above curves be interpreted?

In simple terms, the equivalent system inertia H[s] for each synchronous area is the estimated kinetic energy stored in the rotating masses of the online synchronous generators in each hour divided by the total online generators capacity (synchronous and converter connected) during that hour. This enables an immediate and comparable perspective into the available inertia in relation to each synchronous area size. The lower the inertia, the higher the amount of converter connected generation without inertia in the energy mix.

The total stored kinetic energy in the rotating masses of the generators, and thus the capability to instantaneously counter deviations of a certain size in the generation-demand equilibrium will be smaller in a smaller system and larger in a larger system.

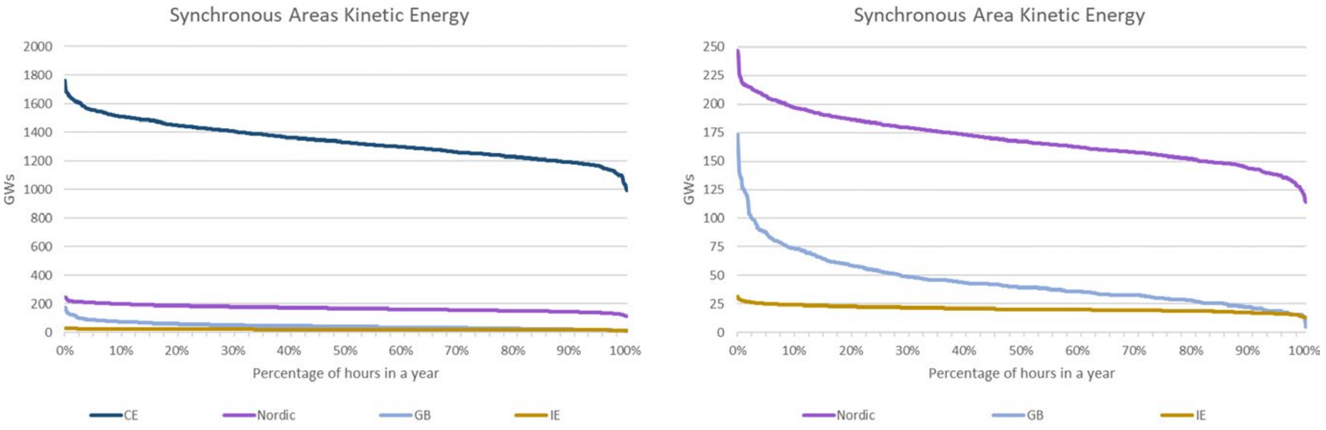
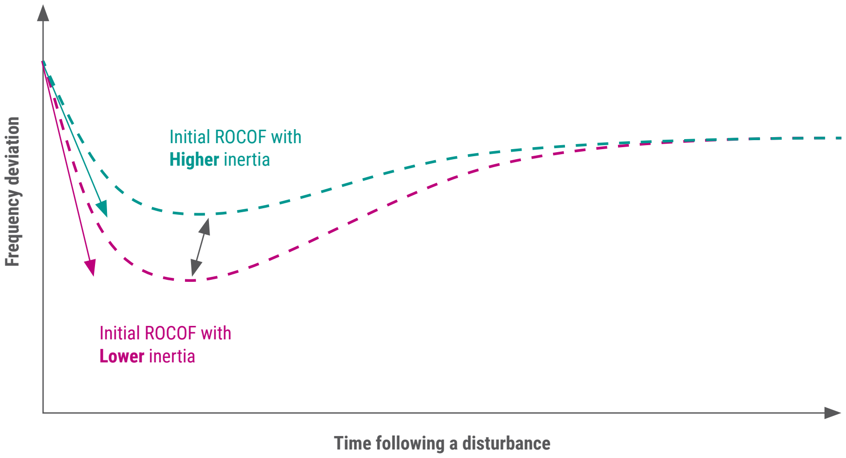


Figure 2 – **Kinetic energy in the rotating masses of synchronous generators for the different synchronous areas in NT2030:** As seen in inertia (H[s]), the stored kinetic energy will also follow the steady reduction tendency from 2025 to 2040.

What does the inertia reduction mean, presently and in the future, for the different synchronous areas?

Higher inertia means more capability to withstand instantaneous generation and load imbalances while maintaining the system frequency within acceptable variations and limits. Conversely, lower inertia, means lower capability to deal with the same issues. Small synchronous areas would see rapid and large frequency excursions following a normal generation loss, large synchronous areas would not see the same size of frequency excursions unless a significant disturbance occurs such as a system split.



Initial ROCOF depends on **inertia** and **generation demand imbalance**

_ Theoretical mitigation measures include acting on available inertia or limiting the potential initial imbalances

Subsequent frequency recovery will depend on the size and full activation time of **Frequency Containment Reserves**

_ Theoretical mitigation measures include acting on the speed and quantity of available active power control

Figure 3 – **Schematic representation of frequency deviations following a disturbance:** To be noticed the steeper Rate of Change of frequency (ROCOF) and lower frequency minimum in the case of a lower inertia case.

All systems share the need to ensure that frequency stays within predefined limits according to network codes. This can be achieved either by limiting the ROCOF or speeding up the Frequency Containment Reserves. The appropriate mitigation measures and the time where they will be required will vary in the different synchronous areas according to the power imbalances to be managed versus the system inertia available in real time operations.

Some synchronous areas are facing problems with Loss-Of-Mains protections based on ROCOF. This problem can only be solved by limiting the ROCOF.

- Minimum inertia and Rate of Change of frequency (ROCOF) are already relevant aspects in the IE and GB systems (real-time monitoring of system inertia in order to ensure that a minimum level of inertia is available in the system at all times is already put in place).
- In the Nordic system, presently, the highest concern is not the ROCOF but the maximum instantaneous frequency deviation, which has led to establishing the market for Fast Frequency Reserve (FFR).
- In CE, at the moment, ROCOF and frequency deviation are not a problem in normal interconnected operation, because in this case the occurring imbalances are small compared with the available system inertia. CE will not see very large frequency excursions unless a significant disturbance occurs such as a system split[3]. However, the trend shows that even in CE the reduction of inertia is noticeable.

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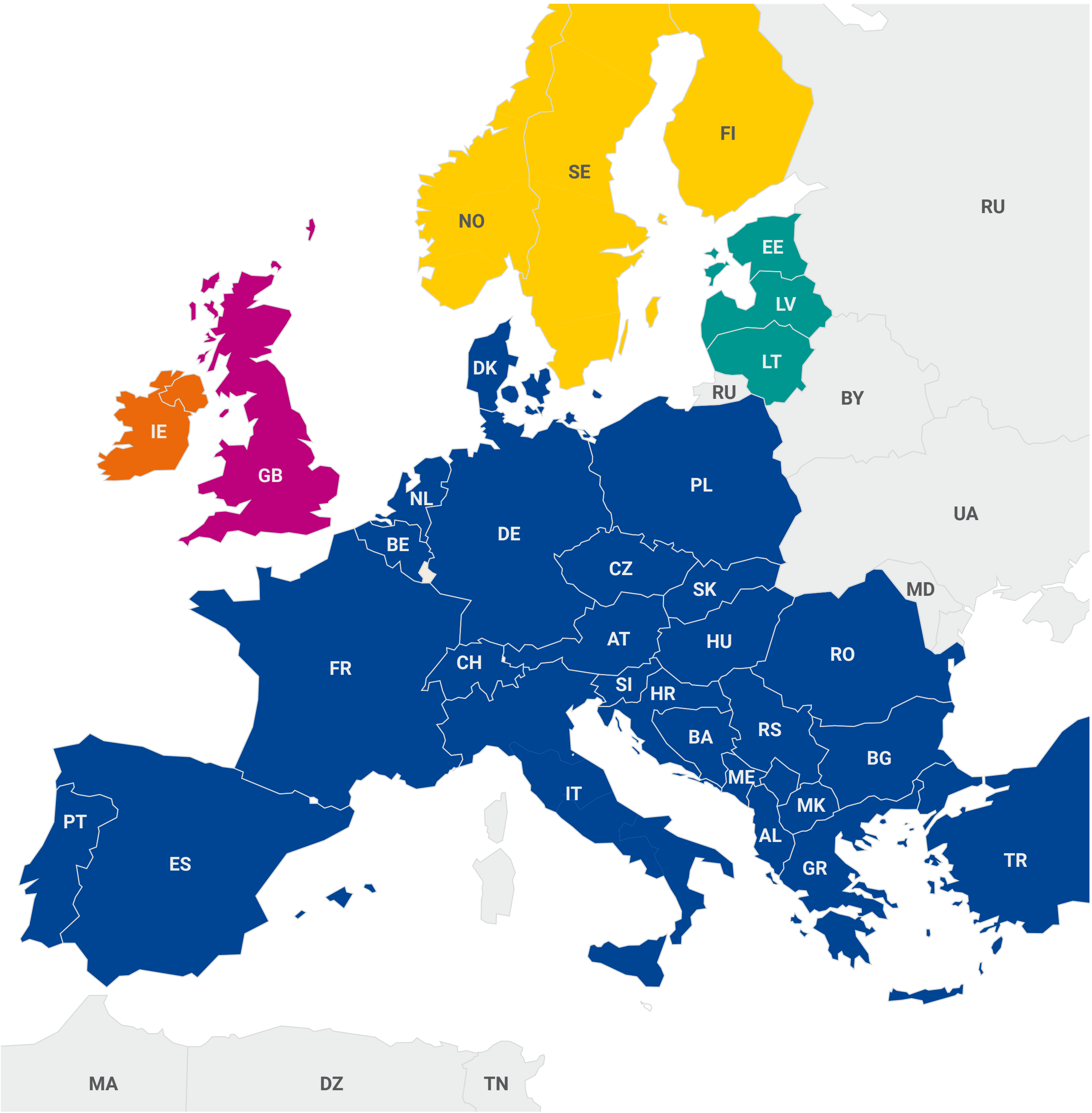
[3] Blackouts can occur even today when the CE network separates as was seen on 4 November 2006. https://eepublicdownloads.azureedge.net/clean-documents/pre2015/publications/ce/otherreports/Final-Report-20070130.pdf



IE (Ireland)

Effort to ensure that all generation is compatible with 1Hz/s ROCOF (change from 0,5Hz/s to 1Hz/s). In order to allow the maximum amount of variable renewable generation in every single moment, there is also the objective to bring the present simultaneous 65 % limit to 75 % in the coming years.

GB (United Kingdom)

New approach to increase inertia by agreed contracts with several parties, where synchronous condensers, i. e., conventional machines that are running without any emissions can provide inertia to the system when it is necessary. For this reason, a good evaluation of available inertia is necessary in real time.

CE (Continental Europe)

CE will not see very large frequency excursions unless a significant disturbance occurs such as a system split.

Nordic

Online monitoring of inertia.

Online estimation of maximum instantaneous frequency deviation after N-1 loss.

Market for Fast Frequency Reserve (FFR).

What do we know about a system split in CE?

Beyond past occurrences, one cannot predict when and where a system split will occur. It depends on the power transits between countries or regions and unforeseen contingencies. The ability to withstand the system split depends on the instantaneous imbalance (power transits between countries or regions prior to unforeseen contingencies) and inertia verified in each split region. In order to gain better insight into the scale of the challenge after a system split, an approximation analysis country by country, considering all possible combinations of system splits in all hours of the TYNDP scenarios, was performed.

The results showed the existence of some system split combinations and hours, where the estimated initial ROCOF may exceed 2 Hz/s, even excluding the cases where the system split leaves out only a small region of CE that can be easily resynchronized or where the initial imbalance is already very severe. Although not all system split situations can be secured, the results show that it makes sense to undergo further analysis on how to best defend the system in a context of reducing inertia.

The long-term

There are no simple or single solutions to the inertia challenge. All available measures have to be considered and weighed, either in present or in future. This includes technical devices, connection codes and standards and, operation and market.

Although there are already solutions to deal with frequency recovery, which can be faster and even more controllable than in the past, the only solution to effectively deal with the instantaneous inertial response is by adding inertia in the system. Currently, this is only possible by placing synchronous condensers or synchronous generators in the generation mix. While placing must-run synchronous generators is not an efficient solution, synchronous condensers can be more economical since the units run without direct emissions.

A promising technology that is worth exploring in terms of further research and development is Grid Forming Converters (GFC)[4]. This does not refer to a new type of converter, but rather to a different control strategy which allows voltage source converters to operate and form a grid without the need for synchronous machines. GFCs do not contribute to the physical inertia connected to the system. In fact, in a 100 % power electronics based system only with GFCs, the current concept of inertia would be largely irrelevant due to their different inherent dynamics compared to synchronous generators. However, in a mixed system with both synchronous generators and GFCs, the latter can facilitate the challenge of frequency containment through their instantaneous control, free from measurement and control delays associated with the current grid-following control strategy of converters. This however may necessitate the availability of dedicated energy stored behind the converter from which the energy has to be drawn. For example, this energy could be stored either in the rotor of a wind turbine or in another dedicated energy storage device, such as a battery for Solar-PV units.

On top of this, GFC could also provide a significant contribution in easing the system split challenge by contributing to a more uniform distribution of inertial response, hence, a further step to be part of the future solutions to unlock a “fully decarbonised” system.

As inertia decreases we need to move forward to meet the European energy goals at their full extension, ensuring the most efficient and economical solutions. GFC devices must continue to be further studied and developed, either at research and manufacturer level, so that this solution becomes more and more fit to support the system needs and viable to be applied in electrical networks at a large scale.

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[4] Grid-forming Converters (GFC) are power electronics devices designed in control and sizing in order to support the operation of an AC power system under normal, disturbed, and emergency conditions without having to rely on services from synchronous generators.

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