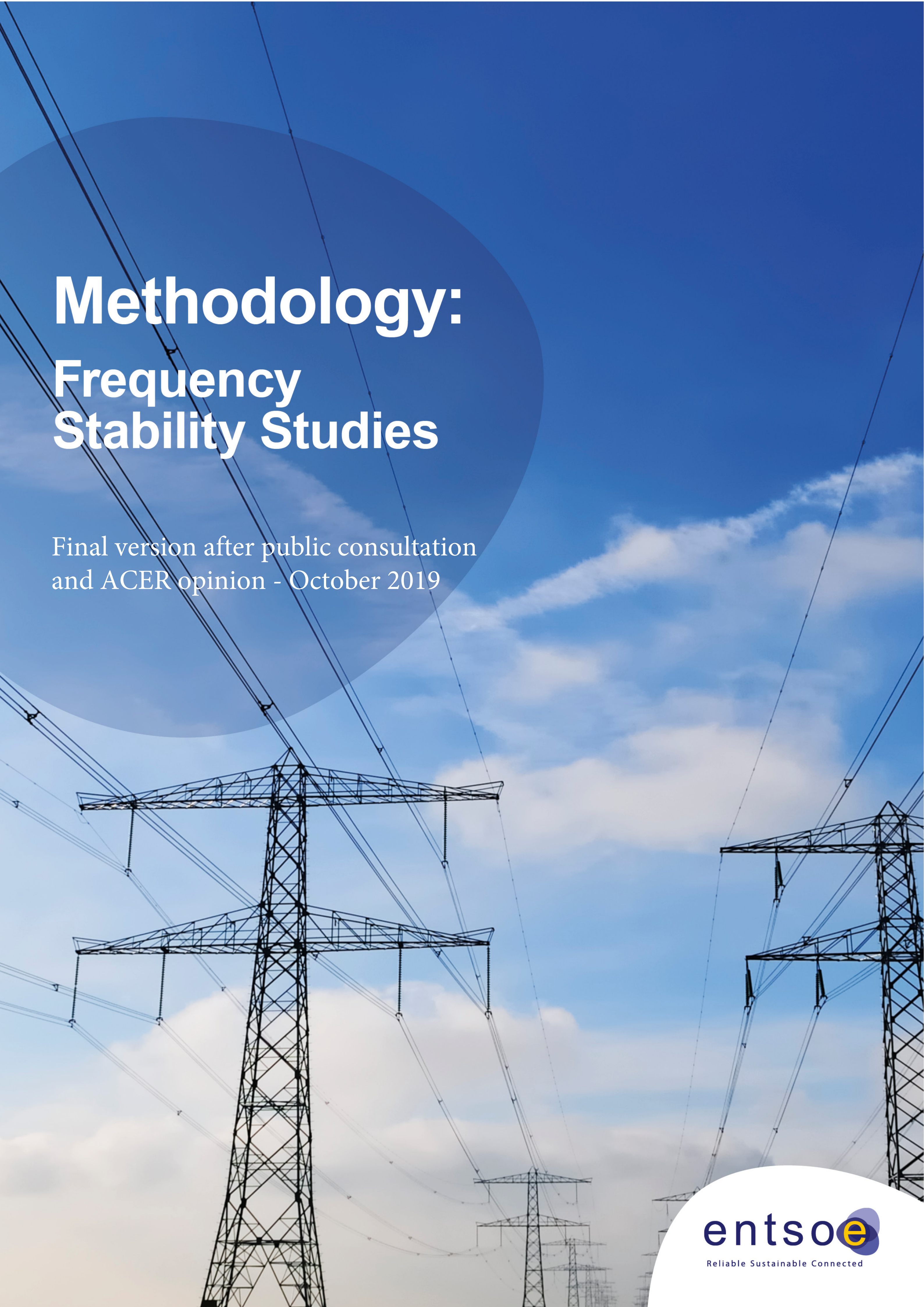
Methodology:

Frequency Stability Studies

Final version after public consultation and ACER opinion - October 2019



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Frequency Stability Methodology

This document presents the methodology for the in-depth analysis of the conditions that System Operators will be meeting when managing the grid in 2040. An overview of this study is presented in Chapter 5 of the European Power System 2040 report, with a more in depth overview in chapter 1.4 of the 'Technical Appendix' (Link).

Transmission systems in Europe are increasing in complexity. Conventional generation is being displaced by new generation technologies that have different performance capabilities, generation is moving from the higher voltage levels to the distribution network, and there is an increased level of interconnection between different synchronous areas. In order to address the challenges associated with the increased complexity of the power system, TSOs need to systematically assess the long-term changes in various operational parameters such as inertia and short-circuit current levels, operational requirements such as flexibility, and availability of ancillary services such as reactive power support, frequency response, and contribution to short-circuit current.

This methodology document looks at how ENTSOE have started to identify what the pan-european energy landscape will look like in terms of frequency stability based on the ENTSO joint scenarios.

The outputs for this study are;

- Energy
- System Inertia
- Wind and PV Contribution to demand
- Hourly Ramps of residual loads
- ROCOF

1. Data collection

The starting point for all the studies was the collection of data. This was an improvement of the TYNDP 2016 process where assumptions were used. In the 2018 TYNDP package, data was requested from all of the Pan-European TSOs. The data which was requested the inertia constant and the nominal capacity of all synchronous plants in the country. This information was then organized into sub categories based on technologies type. From this information the average inertia constant for each type of synchronous units was established per country. Average European inertia constants and capacities for each type was also established, where information was not collected for a country, the European average could be used, also based on the data collected.

2. Market Modelling output

ENTSOE use a wide variety of tools to ensure consistency in all results. For this study the market modelling tools used were Plexos, Bid and Antares. The inputs are taken from the joint ENTSO scenarios, which cover the time frames 2020, 2025, 2030 and 2040. Which include installed capacities, Demand, Climate data, Cross border capacities etc. For more information on the scenario building process including inputs and outputs please see the scenarios section on the TYNDP site (link).

The Market modelling outputs are given with an hourly granularity and shows the hourly dispatch for 39 units types for 54 countries. The document also shows the hourly demand.

3. Dispatch Units

The inertia studies are performed on 11 types of units, as shown below;

- Nuclear
- Lignite
- Coal
- Gas
- Oil
- Hydro
- Wind
- Solar
- Other Renewable
- Battery (Discharge)
- Bio

These units are further divided into 44 sub units based on technology type. Each subcategory has its own parameters for inertia constant and average capacity.

Process

4. Dispatched Units per Technology

The inertia study is a post process of the market modelling output, which is then combined with the inertia parameters collected by the TSOs. Firstly, the amount of energy coming from each unit must be calculated. As the model modelling simulation is not done for individual generation plants, an estimate of the number of units running for each technology must first be calculated. This is done by using the reference average capacity of a unit as collected from the TSOs, as well as the amount of power a particular each category unit is generating in the hour.

For example, if in France the average capacity of a coal unit is 100MVA, the loading is 0.95% and the unit is generating 300MW, we know 4 units would need to be running to produce this energy

$$100MVA\ x\ 0.95 = 95MVA$$

$$Units = \frac{300MW}{95MVA} = 3.16$$

$$Units = \frac{300MW}{95MVA} = 4$$

Since the number of units should be round up to the nearest whole number this would result in 4 units being dispatched to cover this capacity.

5. Rotational Energy

The rotational energy, in MWs, from a unit is the Dispatched units multiplied by the average capacity for the unit type Multiplied by the inertia constant of the unit type.

$$E_{rotational=}\ Units_n\ x\ Capacity_{unit}\ x\ I_{unit}$$

This process is done for each unit dispatched in a country per hour, and finally gives the total energy per hour in any given country.

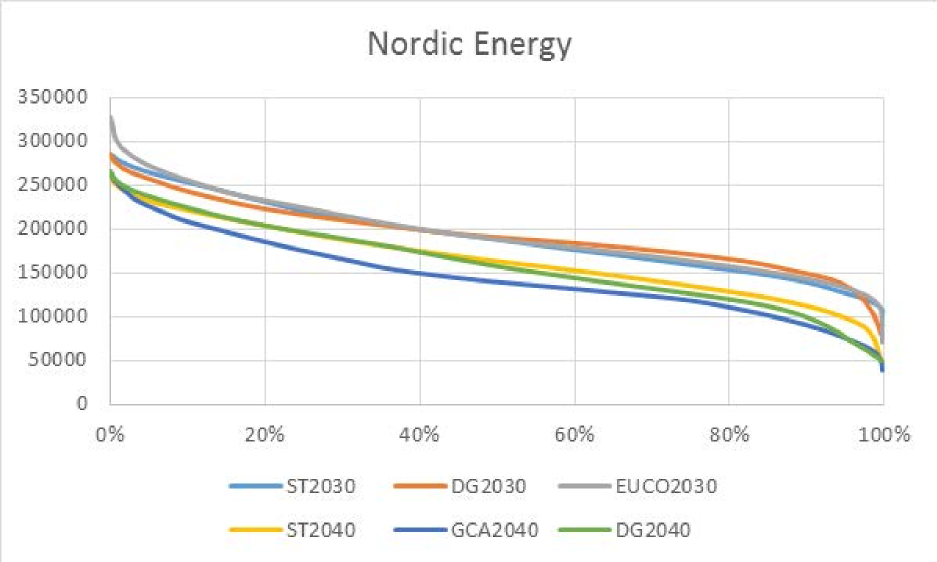

Figure 1 -Energy duration curve In the Nordic Synchronous Area

6. System Inertia

Once the rotational energy has been calculated, the system inertia can also be calculated. This is the total rotational energy in a country/Market node divided by the total generation, therefore the more non-synchronous generation present in the dispatch the less inertia in the system.

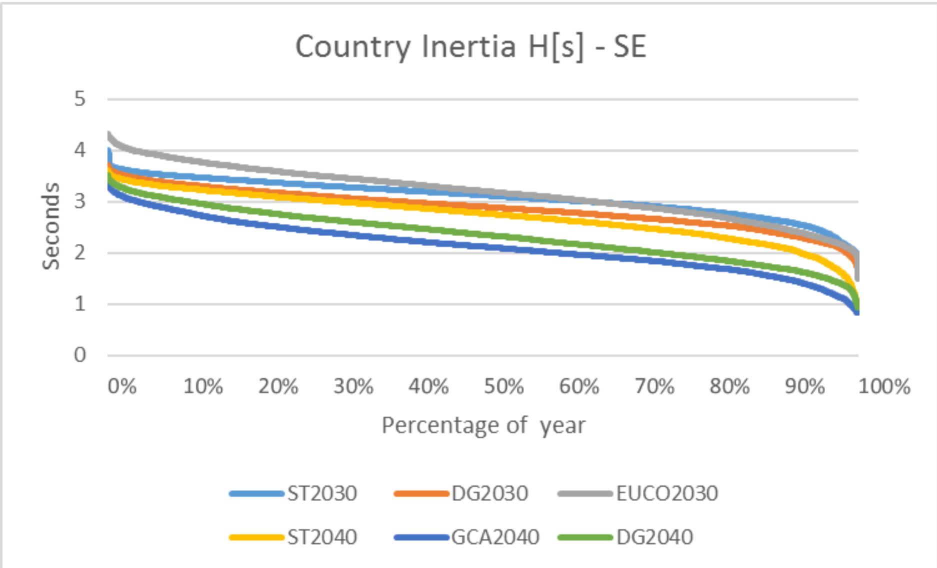

Figure 2 – Inertia duration curve in Sweden

7. RoCoF

The methodology for the calculation of Rate Of Change Of Frequency (RoCoF) is slightly different as compared to traditional calculations, where the largest loss on the system is tripped. In this simulation the capacity required to give a RoCoF of 1Hz and 2Hz is calculated.

The equation used to calculate RoCoF is shown below

$$\Delta P = \frac{RoCoF * 2h * P_{load}}{f}$$

$h = System\ Inertia, P_{load} = Demand, f = Nominal\ frequency\ (50hz), \Delta P = actice\ power\ imbalance$

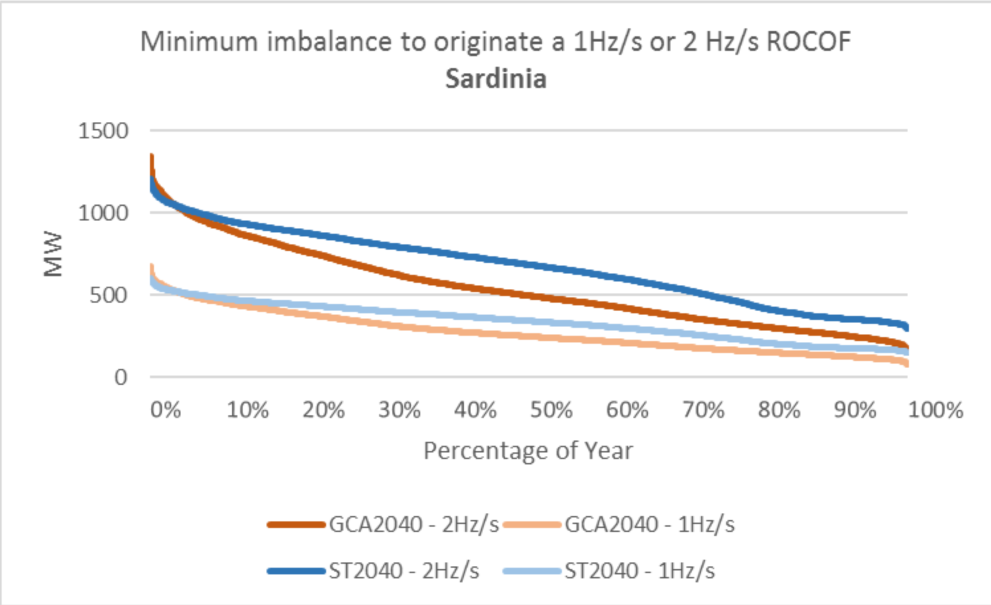

Figure 3 – ROCOF requirement duration curve in Sardinia

8. Residual Ramping Charts

The residual ramping calculation captures the capability of an electric system to accommodate fast and deep changes in the net demand (load minus intermittent RES) in the context of high penetration levels of non-dispatchable electricity generation. These changes are expected to increase in the future, which requires more flexible conventional generation to deal with the more frequent and acute ramping-up and ramping-down requirements. In this calculated, the load is all wind and solar is calculated per hour. The residual load ramp is the change in residual load from 1 hour to another.

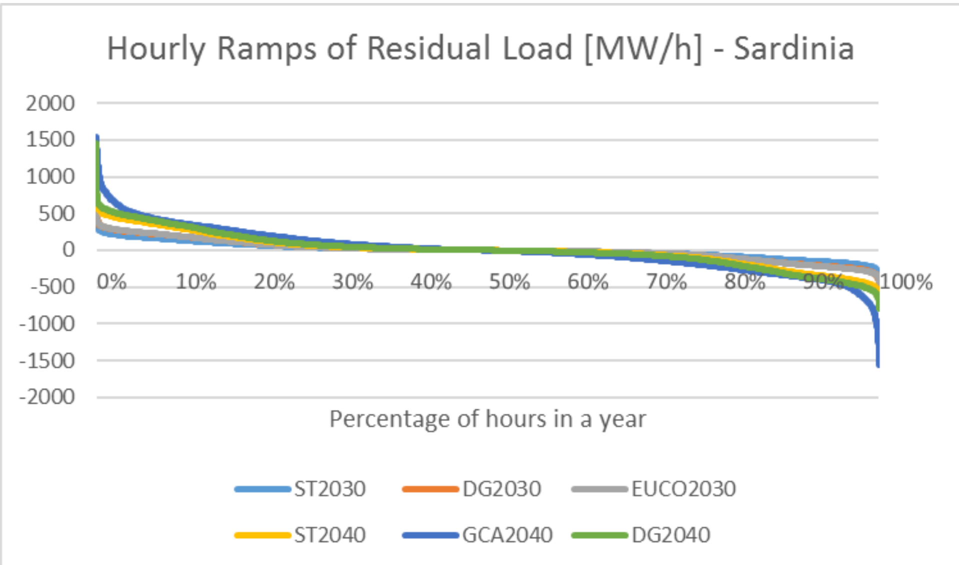

Figure 4 – Residual Load Ramps in Sardinia

9. Synchronous Areas

The country data is then aggregated on a synchronous level this is divided into 8 Areas.

- Nordics
    - Sweden
    - Norway
    - Finland
- Baltics
    - Estonia
    - Latvia
    - Lithuania
- GB
- Ireland
- Cyprus
- Sardinia
- Crete
- Continental Europe
    - Netherlands
    - Demark
    - Germany
    - Belgium
    - France
    - Poland
    - Spain
    - Portugal
    - Italy
    - Switzerland
    - Austria
    - Slovenia
    - Slovakia
    - Czech Republic
    - Hungary
    - Romania
    - Serbia
    - Bulgaria
    - Greece
    - Croatia
    - Serbia
    - Bosnia and Herzegovina
    - Montenegro
    - Albania