WindEurope position on grid-forming capabilities

MARCH 2023

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INTRODUCTION

With the increasing share of variable renewable energy, power system stability challenges are evolving and discussions to address them are gathering momentum. To tackle the new risks involved, Transmission and Distribution System Operators (TSOs and DSOs) will be required to deploy appropriate solutions[1]. Original Equipment Manufacturers (OEMs) will have to modify their current products as well as develop new ones. Generation asset owners will need to upgrade the development and operation of their assets to new capabilities and requirements.

Therefore, we expect transformation in the business of all major drivers of the energy transition: electricity system operators, technology suppliers and asset operators. This step will initially require significant resources and will add new costs[2]. But such transformation is indispensable in the long term for the cost-effectiveness of the European electricity system. To design and manage it correctly, relevant stakeholders need to define together the technical and investment framework and to identify the necessary regulatory updates.

CONTEXT

As it stands, nearly all converter-based renewable energy generators are grid-following: they follow the voltage and frequency of the grid while adjusting the injecting current to supply the suitable quantity of active and reactive power. But they are not inherently capable of maintaining rotational inertia which is crucial to ensure sufficient stability throughout the electrical grid.

Lack of inertia may lead to the power system being prone to system splits, vulnerable to blackouts and may lead to instabilities[3]. Large rotating generators such as fossil-fuel based generation, nuclear and hydropower inherently provide inertia. However, the EU Green Deal and REPowerEU set the EU target for deployment of renewable energy up to 45% by 2030. This means that converter-based renewable energy generators such as wind and solar PV will have to displace a large share of synchronous generators in operation today.

With larger share of variable renewables, general system stability measures are needed to uphold secure operation of the power system. Converter-based generators may be able to contribute to system inertia and maintain system stability by acquiring certain advanced capabilities called grid forming.

This position paper suggests a framework on how these grid-forming capabilities should be defined, developed and funded. It is structured in three parts: recommendations for the technical framework, market design aspects and necessary regulatory changes.

[1] ENTSO-E Technical Group HPOPEIPS, High Penetration of Power Electronic Interfaced Power Sources and the Potential Contribution of Grid Forming Converters, 2019
[2] WindEurope, Future system needs and the role of grid-forming converters, July 2019
[3] Renewable Energy World, 'Grid inertia: why it matters in a renewable world', 2019

RECOMMENDATIONS

1. The technical framework

The European Commission, energy regulatory authorities and system operators should agree on how to:

1. Quantify the need for grid-forming contributions and the timeline at EU and national level
2. Define and specify grid-forming capabilities at European level including hardware design
3. Set clear technical requirements and verify compliance of the assets that will offer them; and
4. Establish market design incentivizing investment for assets with grid forming capabilities

Definitions and technical specifications should be agreed at EU level to promote harmonisation of rules. Only harmonised rules can enable cost-effective technology development and well-coordinated deployment of grid-forming capabilities across the European power system. A fundamental aspect is to not have any country specific hardware changes, as this would lead to a direct increase in cost & risks. The Connection Network Code (CNC) for generators and for demand facilities along with the System Operation Guideline are the existing frameworks to drive such harmonisation of grid-forming requirements across Europe. The ongoing revision of the CNC is an opportunity to set clear technical rules which will not be subject to national interpretations.

To accelerate the necessary technology development and investments in grid-forming capabilities, OEMs and asset owners will need clear long-term investment signals. Adding grid-forming capabilities only as a technical requirement in the Network Codes without foreseen remuneration for the asset upgrades will only increase the current price pressure in auction design and subsequently delay investments in the expansion of renewables.

The ongoing and future work of the European Commission to reform the electricity market design is an excellent opportunity to clarify and reinforce market design for grid-forming contributions in parallel to the technical requirements. Section 3 gives our recommendations on how to address this in existing regulation.

1.1 Defining the need for grid-forming

The National Regulatory Authority should require system operators to:

- Quantify and justify their foreseen need for grid-forming capabilities in their ten-year Network Development Plans (NDPs) which should be aligned with the National Energy and Climate Plans (NECPs) but also aligned between transmission and distribution needs. TSOs and DSOs should support this quantification with publicly available cost-benefit analysis (CBA) studies subject to adequate public consultations;
- Clearly define technical specifications for the expected response of the assets in alignment with the EU Network Code including testing, simulation, compliance verification and later certification; and
- Specify a market-based framework for procuring grid-forming services and the respective pricing mechanisms to drive investments. If a fully market-based approach cannot be deployed from the beginning, requirements should be limited to the current hardware design of the assets to limit costs and risks to OEMs and asset owners.

1.2 Setting requirements for grid-forming capabilities

ENTSO-E recently published a proposal[4] on how to define and specify grid-forming capabilities in technical terms. According to this, a generator should behave at its connection point as "a voltage source behind an impedance" during the normal operating conditions and quasi immediately after a grid disturbance. Even though the proposed definition and requirements are technology neutral, they are too simplistic and not sufficiently clear. The proposal also does not give adequate information about the expected behaviour by grid users.

A definition of grid-forming capabilities by generators should:

a. Be based on specific asset type properties and preferably on physical quantities, while using terms which are unequivocally quantifiable and usable to verify compliance. Terms that require clear definitions in the ENTSO-E proposal[4] include voltage, current, frequency, power, damping, starting instant of a grid disturbance, elapsed time after the start of a grid disturbance (i.e., defining "quasi immediately"), voltage magnitude and phase angle disturbance, and stable and smooth transition.

b. Specify a minimum expected fault current contribution, facing a symmetrical or unsymmetrical voltage magnitude change (Over Voltage Ride Through or OVRT and Under Voltage Ride Through or UVRT) e. g., at generating unit terminals, in magnitude (per unit, pu) and duration (millisecond, ms). Referring to phasors simplifies such specification. Unless justified with a cost benefit analysis, the relevant system operator should not require fault current magnitudes exceed 1 pu. apparent current. Provision of a higher fault current than 1 pu should be allowed.

c. Specify a minimum expected increase or decrease of energy between the generator and the power system when facing a voltage angle step change, whereas the maximum permitted reaction time must account for technical & physical limitations. The requirement should be asymmetrical so a net positive exchange should be required separately from a net negative one.

d. Define the instant as of which any response by the generator counts as performing like a "voltage source behind an impedance". If any requirement addresses the sub-cycle time domain of the fundamental frequency, the definition of the 'starting instant' should be quantified in time domain. This will allow for the determination and verification of the fundamental frequency in sinusoidal quantities and/or phasors.

e. Specify a minimum expected contribution to power system damping in terms of frequency range and quantitative damping.

f. Explain expected control dynamics of the generator to contribute to the stability of temporary electrical islands if requested.

g. Include a technology neutral description of the transition out of the "voltage source behind an impedance" performance once the respective device reaches its existing design limits.

[4] Text proposal presented by ENTSO-E in their webinar on Connection Network Code Amendments (Grid forming and Rate of Change of Frequency withstand capability), 23 November 2022

h. Specify an expected cumulative distribution defining how often different sizes of frequency oscillations, frequency gradients and voltage magnitude dips and voltage angle steps are expected to occur in the grid. This profile will drive the new design of the mechanical systems.

2. The market design

Grid-forming capabilities will be essential for contributing to power system inertia and ensuring stability in the future power system. However, changing the technical characteristics of wind power, hydro power, PV and HVDC systems is not something which can be easily done within a few years with only minor control modifications. The change will be much more profound and will need to be driven by solid industry and regulatory consensus.

Renewable power plants providing grid-forming functionalities will have both increased life cycle operational cost (OPEX), currently difficult to quantify, and will require increased initial capital investment (CAPEX), e.g., to incorporate energy storage and to upgrade control technologies. An additional CAPEX and unknown OPEX will lead to important financing risks that will translate into higher costs for developers and eventually for electricity consumers.

Such risks would impose a significant burden on the wind industry, already challenged by inflation, market interventions, and supply chain bottlenecks. Hence National Regulatory Authorities, TSOs and DSOs will need to fully justify what share and which types of renewable energy generators will need to provide such features.

Preferably the provision of system stabilizing support such as by grid-forming should be driven by technology neutral market-based procurement accessible to all technologies that can qualify according to clear technical requirements. The market design should incentivize investment and as a minimum allow developers and asset operators to recover the increased costs. Moreover, long-term market visibility, e.g., foreseen need for grid-forming contributions in the next 10 years (especially in the TYNDPs) is crucial to accelerate technology development. The transmission network planning of the EU grid or of individual Member States for the coming 5 years or 10 years should also include specific locations of the network with low inertia, grid strength where grid forming capabilities make a significant contribution to strengthen and support the grid.

Making grid-forming capabilities mandatory in the CNCs will directly increase technology development costs that will need to be assumed by one or more parties in the respective supply chain. These investments must be properly compensated not to slow down the expansion of wind and solar overall due to higher finance risk.

Our recommendation is that grid-forming capabilities should be very clearly defined in the respective Network Codes and as harmonised as possible at EU level. However, they should not be mandatory for all generators unless such requirements are simultaneously linked to a well-defined market framework that can compensate grid-forming service providers. Wherever possible, the network operators should give a quantitative indication of possible revenue streams which will incentivise the developers and OEMs to consider the extra revenue in the project business cases.

3. Need for regulatory changes

Regarding definitions and technical specifications, the ongoing revision of the CNCs is a good opportunity to provide a clear technical framework that TSOs and DSOs can easily implement at national level. An update of the System Operation Guideline will most probably also be necessary.

To drive investments in grid-forming capabilities without delaying the expansion of renewables, National Regulator Authorities should be responsible for developing a clear remuneration framework that gives long-term visibility to OEMs and asset owners and that are compatible with existing remuneration frameworks for renewable electricity generation (e.g., auctions, corporate PPAs).

The Electricity Directive and Regulation are the existing tools that address the need for provision of flexibility and ancillary services and the procurement obligations for TSOs and DSOs. Their current versions do not do this adequately to drive investments in technology development and an expanded upgrade of assets at transmission and distribution level. An amendment of articles treating network development use of flexibility tasks of TSOs and DSOs is necessary. Revising these items, as part of the market design reform, could drive such developments more quickly than the development of a new Network Code for Flexibility.