Maintaining and Enhancing Electric Power Grid Stability and Security during Energy Transition

An IEEE European Public Policy Committee Position Statement

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As the European Union (EU) continues to accelerate the energy transition, as shown by the implementation of the "Clean Energy for all Europeans" package and the "European Green Deal", and prepares for finalising the "Fit for 55" package, the IEEE European Public Policy Committee (EPPC), representing a large community of European engineering professionals, calls on EU policy makers to take action to maintain and enhance the security and stability of the electric power grid during the transition to a greener power system.

The IEEE EPPC considers the electric power system as the backbone and a key enabler to achieve this transition, and grid stability as an essential requirement for effective and efficient energy system integration, which can only be successfully achieved when introducing changes to the current technical and regulatory regimes.

To this end, the IEEE EPPC recommends that EU policy makers work along the following 3 lines of action and consider the points raised therein for future legislative and non-legislative work.

Recommendations:

1. <u>Regulatory</u>
   - 1.1. Foresee technical minimum capability requirements, and develop a regulatory framework introducing incentives aimed at favouring the participation of consumers (loads) and distributed resources (e.g., photovoltaic and wind generators) in the provision of stability enhancing ancillary services, such as frequency regulation, voltage regulation, black-start capability, controlled islanding and stability-related services to the power grid.
   - 1.2. Introduce regulatory measures encouraging, incentivising, and potentially requiring the cooperation between Distribution System Operators (DSOs) and Transmission System Operators (TSOs) to provide grid support originating from distribution grids.
   - 1.3. Request the development of a new methodology to maintain grid stability with wider scope complementing requirements by existing EU Regulations concerning dynamic security assessment and management.
   - 1.4. Promote, including through the adoption of appropriate regulatory or policy measures, the application of conformity assessment and the integration of Information and Communication Technologies (ICT) including data model-driven approaches to achieve interoperability at all levels of the European power system.
   - 1.5. Encourage European TSOs to redesign system protection schemes in case of grid instability by replacing involuntary load shedding and/or rotating blackouts with controllable or interruptible customers (loads) providing also adequate compensation for such interruptible loads.

2. Research and Innovation
    2.1. Stimulate research, development, innovation, and deployment of technological solutions that enhance power systems' response to events and its stability. In particular, the IEEE EPPC encourages the European Commission to support specific research on grid stability utilising distributed resources, including application of artificial intelligence for improving real-time situational awareness, as well as the utilisation of probabilistic-based and risk-based tools, necessary due to the intermittent nature of the renewable generation.
    2.2. Encourage research and innovation actions funded by instruments like Horizon Europe to support work on pre-standardisation. Nowadays the interaction between research and standardization is minimal and takes place on a voluntary basis, which slows down the time to finalise crucial industry driven international standards.

3. Standardisation
    3.1. Seek opportunities to coordinate (and harmonise) on international standards activities, considering, amongst others, IEEE Std 1547-2018[1], and IEEE Std 2030.5-2018[2], leading to a set of standards facilitating distributed control, competition, and cost reduction.
    3.2. Encourage standardisation of data model-driven approaches to enable data interoperability at all levels of the power system. This applies to topics such as real-time stability monitoring to provide continuous protection of power system integrity, as well as coordinated security assessment and dynamic security assessment. An interoperable data model from an energy holistic point of view is essential to enable interactions between system operators, consumers, prosumers, etc.

Background: Power Grid in Transition

In the past 150 years, electric power systems have increased the prosperity and the quality of life of modern societies, but they have also contributed to significantly increasing the emissions of greenhouse gases (GHG). To decarbonise the energy system and make Europe the first climate-neutral continent by 2050, the EU has launched a number of ambitious policy initiatives such as the European Green Deal in general and the Strategy for Energy System Integration in particular. The new EU approach to climate and energy policies includes the transition from a relatively small number of large, centralised power stations to an increasingly large number of decentralised energy sources which are often closer to the consumption centres, hence radically challenging the traditional composition of power systems into relatively independent generation, transmission and distribution subsystems. This new power grid requires new intelligence and communication means to maintain secure and continuous operations, giving rise to what is known as the Smart Grid.

The stability of the power system was traditionally achieved through centralized controls, such as the security assessment carried out in Control Centres (CC) and Energy Management Systems (EMS). Control Centres were created after the blackouts (involuntary and grid-wide events) of the 1960s to help maintain secure operation of the power system and were initially part of vertically integrated utilities. In Europe, transmission systems are currently managed by independent TSOs in different Member States and provide a centralised control of each area of the system. At the EU level, the European Network of TSOs for Electricity (ENTSO-E) was established in 2009. Recently, the mandates of ENTSO-E were amended and Regional Security Coordinators (RSC) have been

[1] IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces

[2] IEEE Standard for Smart Energy Profile Application Protocol

introduced to closer coordinate TSOs, thus supporting energy system integration. Despite a few major interruptions that can still happen occasionally, the security of supply and the reliability of the power grid have been kept at a very high level in most parts of Europe so far.

In highlighting the main challenges to grid stability, this position statement offers several recommendations for maintaining high level of power grid reliability and security, while integrating more distributed and decentralised energy systems as a result of EU policies.
It is noted that this policy document will not address the continuity of power system operation in the face of unpredictable extreme events, such as natural disasters, which is the subject of a separate resilience analysis. Rather, it aims to assess the effect of new technologies and smart sector integration on power grid stability.

Main Challenges to Grid Stability in the Transition Period

The decarbonization drive has resulted in the introduction of several distributed resources based on new technologies to the power grid, most of which have their own control systems. This can give rise to unexpected dynamic interactions, but they also give the opportunity for better coordinated control when appropriately used. Thus, they constitute both a challenge and an opportunity. The main question is **how to take advantage of a multiplicity of controls, without allowing for adverse interactions**.

Most of the new generating units (mainly wind turbines and solar PV panels, but also tide, wave, geothermal) are widely distributed and are connected through power electronic converters, while centralised generating stations are gradually being replaced. Closing generating stations creates a gap in control functions that need to be replaced. These include frequency and voltage regulation, as well as the provision of fast energy storage in the form of the kinetic energy of synchronous generator rotors. The effect of **reduced inertia** may lead to large unpredictable excursions of system frequency, if not properly addressed.

Apart from decreased system inertia, there are also concerns on whether the stability of the system could be compromised due to **RES variability and intermittency** and **reduced short circuit currents**. Recent system events associated with high penetration of RES demonstrate how disrupting for grid stability the energy transition can be, if proper countermeasures are not taken in time.
Thus, the business-as-usual option is simply not feasible in the new environment. At the same time new technologies in electronic converters, also including DC transmission, create a different, yet more controllable, network structure. It is thus clear that an adequate level of grid stability in the power system of the future has to rely on a **new paradigm of distributed, coordinating controls**.

How to Answer the Grid Stability Challenge

As stated above, the increased penetration of widely distributed RES connected through electronic power converters has changed the dynamics of power systems, creating a potential challenge for grid stability. At the same time, converters of RES units have unprecedented capabilities to offer flexible controls, including those needed to maintain grid stability. The integration of RES, **electricity storage** and the widespread connection of electric vehicles as a result of e-mobility, provide not only challenges, but also new opportunities in terms of ability to control the system. The new forms of generation, storage and flexible loads providing demand response can participate in a decentralised, carefully coordinated new control paradigm. **Coordination of distributed controls** with the help of increased communication resources can be equally, or even more, efficient in maintaining an acceptable level of grid stability and security. In this respect, recommendations 1.1, 1.2, 2.1, and 2.2 are key factors to timely address this challenge.

Since most of the new controls lie within the distribution network, a **closer cooperation and tighter interaction between** TSOs and DSOs is of paramount importance to coordinate stability and security support services as per recommendation 1.2. In particular, the distinct role of DSOs should be upgraded to promote the concept of Active Distribution Grids, i.e., distribution grids with control capabilities and the ability to offer ancillary services to transmission. The power system of the future will incorporate several levels of distributed controls, which shall be harmonised in a consistent manner from R&D to standardisation and implementation. One other important point is that the pan-European electrical grid is composed of multiple synchronously grids connected to each other asynchronously via HVDC links. This whole pan-European power system needs to be much more closely monitored and controlled, as individual TSO control areas (usually, but not necessarily, corresponding to country borders) need to be supervised and coordinated to offer mutual assistance in cases of need and to homogenise the necessary actions to smoothly integrate distributed control.

Commission Regulation (EU) 2017/1485 establishing a guideline on electricity transmission system operation refers to stability as an inclusive term for rotor angle stability, frequency stability and voltage stability. It requires stability monitoring, assessment and management. It also requires development of a methodology for the definition of minimum inertia required to maintain operational security and to prevent violation of stability limits. A more **detailed methodology covering not only inertia related issues, but also the aspects of coordinated stability as well as other dynamic interactions** is necessary (Recommendation 1.3). This needs to be handled in a holistic approach in line with the role of RSC and other entities within the existing structure to enhance cross-border cooperation in dealing with system regulation and grid stability.

At the same time, ICT should be used to enhance interactions and exchange of information to coordinate controls and provide security support services at the different grid voltage levels and operating conditions, as well as planning storage and flexibility options (recommendation 1.4).

Another challenge is the reduced short-circuit currents, which force the **design of a radically different protection system** (recommendation 1.5). In terms of system integrity protection in the event of an imminent instability, load participation and energy storage-based solutions should be encouraged to minimise the involuntary load shedding and/or rotating blackouts which are at present the ultimate solution to maintain stability when everything else fails. A recommended way to act correctively is through **voluntary participation of customers** willing to reduce consumption (i.e., demand response) rather than arbitrary disconnection of prespecified consumers.

In light of these changes, maintaining stability in a power grid dominated by RES and other alternative sources can be seen not only as a need, but also as an opportunity to redesign and, where needed, rebuild traditional power system controls. To achieve seamless interoperability, both standards and business processes should be harmonised in a manner that conformity assessment can be tested and certified (recommendation 1.5, 3.1 and 3.2). All this is directly related to ensuring the reliability and stability of the evolving European power system. The information exchange is all around us and it shall be taken seriously in conjunction with the development of coordinated security assessment, dynamic security assessment and other important tasks.

Since many interconnected devices are involved in grid control, it is imperative that all devices have common interconnection and communication standards. In this respect, the **IEEE Std 1547-2018** for Interconnection and

Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces, as mentioned in recommendation 3.1, can provide a useful basis.

Advanced technologies, such as phasor measurement units (PMU) and wide area monitoring systems (WAMS), make it possible to design new **stability monitoring systems** that give advance warning in the event of an approaching or on-going instability, hence allowing emergency protection measures to maintain system integrity and avoid blackouts. Use of data-driven approaches for real-time grid stability monitoring should be encouraged, to provide continuous protection of power system integrity (recommendations 2.2 and 3.2).

All of the above changes do not constitute just a purely technical challenge to be addressed by the engineering community, but they also require new policy and regulatory approaches aimed at incentivising the participation of consumers and at promoting coordination and supervision. The introduction of flexibility markets where distributed resources can provide ancillary services actively and in an efficient and coordinated way should be encouraged.

Enabling the energy transition while maintaining grid stability will also require increased **investments in research and development**, as per recommendations 2.1 and 2.2. There is an urgent need for funding research on new solutions enhancing dynamic performance and securing grid stability based on power-electronic-converter connected resources to better understand the interplay between grid needs and possibilities offered, as well as limitations imposed by the new technologies. The control interaction between AC and DC part of the grids, as well as the modelling aspects and the way in which they shall be considered in the operational planning for example day ahead activities is a topic that needs studies in detail. The decarbonization of the energy system and the achievement of the energy sector integration goals will need to proceed in tandem with plans to maintain and enhance the stability, security and continuity of service of electrical grids during the transition of the global energy sector from fossil-based to zero-carbon by the second half of this century.

This statement was developed by the IEEE European Public Policy Committee (EPPC) Working Group on Energy and represents the considered judgment of a broad group of European IEEE members with expertise in the subject field. IEEE has nearly 60,000 members in Europe. The positions taken in this statement do not necessarily reflect the views of IEEE or its other organizational units.

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