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Reliable Sustainable Connected

Network Code "Requirements for Generators" in view of the future European electricity system and the Third Package network codes

1. Introduction and purpose

The NC RfG is only one code in a suite identified in the EC/ACER/ENTSO-E 3-year plan in accordance to the Third Package legislation that will establish the Internal Electricity Market, contribute to security of supply and facilitate the integration of RES in achieving the EU's 2020 targets and 2050[1] aspirations. The other codes cover both system and market design and operation in addition to system design and are being developed to different timelines by different drafting teams but clearly interact.

The purpose of this paper is therefore fourfold:

1. Provide an insight into the challenges for future electric power system operation in meeting EU energy policy (in particular high levels of RES penetration) and how this drives the technical requirements placed on future generation detailed in the RfG code.
2. Detail the proposal to set some RfG NC requirements at National rather than at Community level.
3. Give an explanation as to why we believe that market incentives would be unlikely to deliver the RfG technical requirements necessary for the secure operation of the future power system.
4. Explain how the Codes covering the System Operation, Markets and System Development interact and how consistency will be ensured.

2. Insight into the challenges of future power system operation in meeting EU Energy and Climate Policies

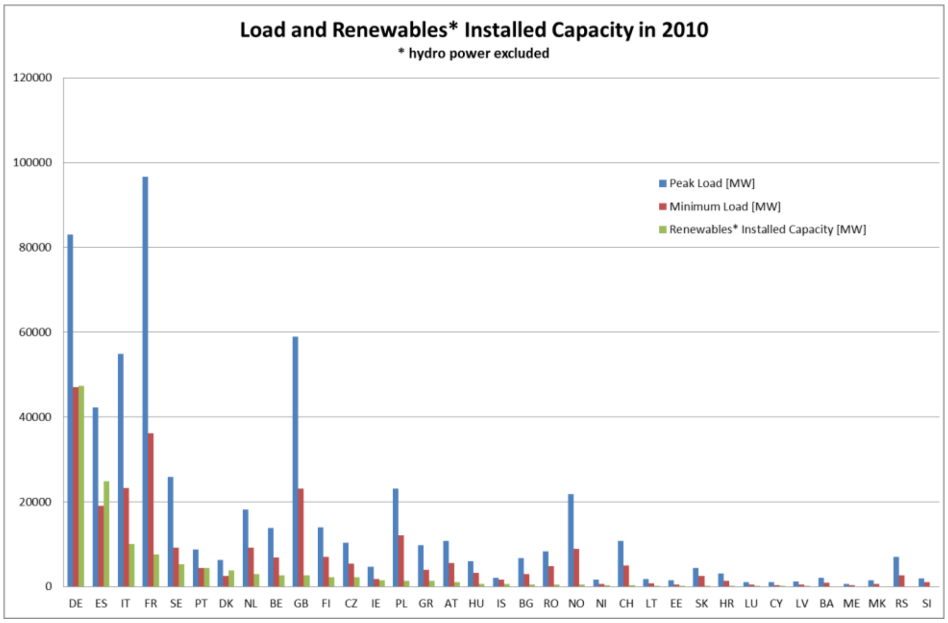
The transmission system is the cornerstone and key facilitator for the low-carbon energy future of Europe, and all stakeholders in the energy sector agree that changes of an unprecedented scale in the electricity system within this decade are crucial for a successful implementation of the political targets on RES integration.

Much of the present electricity system was primarily designed to supply electricity from large dispatchable and synchronous generation units with abilities to both balance the active power and supply the necessary ancillary services to ensure system stability. The future generation system will however be based on a vast number of distributed and power electronics based generators with a variable and only partly dispatchable generation based on RES. This shift will result in massive varying transit flows resulting in a major need for reinforcements of the transmission grids, new technical requirements for all users and generators connected to the grid, and new procedures for the future system operation. As a consequence, it is important to recognise that the transition to the future system operation is not a matter of minor adjustments to the existing system, but a de facto change of paradigm.

Today RES usually provides even at peak generation less than 30 % of the power and most of the time much less but this will increase significantly in meeting the EC 2050 goal of CO_2 emissions reduction of 80% - 95% below 1990 levels[1]. It should be noted that the EU 2020 target of 20% demand supplied by RES generation is an average target for a year and that over a year real-time RES production as a percentage of the total demand at any time is highly variable, typically with the

[1] European Council 29-30 October 2009– Presidency Conclusions

highest percentage about 5 times larger than the average. The reality of this large ratio has been illustrated by the case of Denmark, the country in EU with highest penetration of wind. A few years ago Western Denmark (Jutland, connected to Continental Europe) experienced for the first time peak wind generation exceeding 100 % of demand although the average wind energy compared to the total Danish electricity demand over the year was still "only" about 20 %. This example illustrates the urgent need to develop the capabilities of the system further as more and more countries will increase RES generation to comparable levels. Another set of system challenges, such as regulating the frequency, will have to be faced when complete synchronous areas, such as Ireland and GB, reach similar high levels of wind (with non-synchronous generation), as planned in context of meeting the 2020 RES targets.



PEAK LOAD AND MINIMUM LOAD VERSUS INSTALLED RES GENERATION IN 2010

Operating conditions with the highest real time RES penetration (typically in windy / sunny conditions with moderate demand) present major system challenges for the Network Operators. Operational experience in Ireland, the European *synchronous area* with the highest RES (wind dominated) penetration of non-synchronous generation plants clearly illustrates these challenges:

- The characteristics of variability and also uncertainty (forecast accuracy) until close to real time of RES generation, introduces further complexity in maintaining system security, leading to increased frequency of alert state operation. To ensure the system risk is minimised with normal operating conditions established in a timely manner greater controllability and the flexibility of all power system elements is required together with a reliable market design that facilitates the necessary activities to ensure SOS.
- Renewable generating units are predominantly non-synchronously connected leading to significantly reduced levels of system inertia. In the absence of any compensation, at times of high levels of RES generation, the frequency sensitivity of the power system to energy imbalance increases leading to unacceptable frequency control performance, compromising system security.

- Large RES generation is usually connected away from the demand centres in rural areas or off-shore. This drives the need for significant grid development to transmit the RES energy to the load centres and if this is not developed at a pace that matches RES construction system security will be compromised[2].
- RES is to a significant extent connected to the distribution network. As a consequence the DSOs have to increase their role in facilitating the connection and integration of RES while at the same time they have to guarantee their customers a high level of power quality.

Clearly, the electricity power system as it is designed and operated today will not be able to cope with the expected amount of RES generation without significant changes. To achieve Europe's political and environmental goals it has to be decided how best to deliver the new system requirements necessary to cope with each of the technical challenges. In addition new players in the future will need to deliver all the technical functions necessary for stable system operation that are today provided by large conventional generators.

Three major means for addressing those challenges, while ensuring the continued security of supply, market functioning and RES integration are identified:

- a stronger and more robust transmission grid[3], including a market design that leads to an efficient use of this flexibility
- increased flexibility in both generation and demand,
- a more intelligent control system to facilitate optimal utilisation of all assets in the system.

The RES challenge does not allow room for a choice between the different means, but compel the responsible TSOs to pursue them all in a proportionate and efficient way.

TSOs are investing heavily in the development of the transmission grid – around €100bn of 'European Significant' investments are detailed in the TYNDP 2012 but this is only a small fraction of the total system reinforcements under development.

To make better use of the existing assets more advanced and coordinated day-ahead and intraday operational planning procedures are being implemented by TSOs via platforms such as CECRE, CORESO, TSC and SSC. TSOs are also developing coordinated remedial actions where system issues exist (e.g. PSEO-50Hertz, in the management of RES initiated loop flows) and enhancing real time data exchange (e.g. ENTSO-E Awareness System). However, even in an optimistic scenario, with all the planned reinforcements of the transmission grid implemented in time and operational tools in place, the electricity system would have to be operated much closer to its technical limits than today.

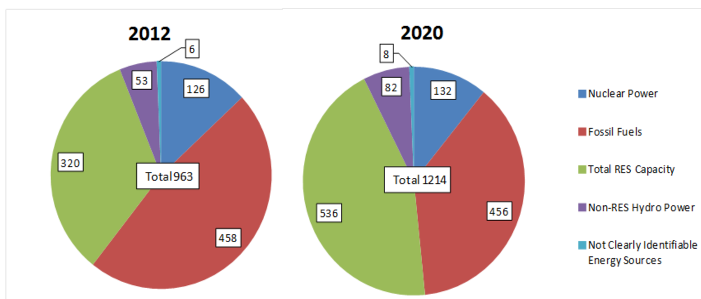
[2]Already today the safe operation of the continental electricity system is challenged by large, varying electricity flows from RES in Northern Europe towards the South.

[3] The TYNDP 2012 reference scenario, based on the European 20-20-20 targets and the National Renewable Energy Action Plans (NREAP), identifies 220GW of RES generation mainly wind and solar by 2020 (reflecting 44 % of the total installed generating capacity). To facilitate this over 100 transmission projects of pan-European significance have been identified corresponding to more than 50.000 km upgraded or new transmissions lines equivalent to 16% of the existing grid and an investment of over € 100 billion in the coming decade.

2.1 NC RfG requirements to address the challenges of RES integration

The NC RfG is drafted on the basis of experience gained throughout decades of system operation with the aim to meet the future challenges in a cost efficient and well prepared manner in order to avoid over-investments in infrastructure, proprietary solutions and ultimately black-outs and other system disturbances. The NC RfG is seen as one of the main drivers for creating harmonized solutions and products necessary for an efficient pan-European (and global) market in generator technology.

The requirements are fundamentally based on generator specific technical capabilities combined with heuristic methodologies and analysis of significant system incidents. In many cases justification of the requirements are complex and not necessarily aligning to a traditional business case analysis. However, system performance across the ENTSO-E area demonstrates that the current requirements on conventional power plants are appropriate for operating a stable electrical network - incidences of alert state operation seldom progress to an emergency state and black outs and other significant disturbances are extremely rare.. The long term experience is built into the NC RfG by inheriting the conventional power plant requirements to the distributed generation and taking the attributes /characteristics /benefits of the distributed generators into consideration.



Today approximately 80% of the installed capacity in Europe consists of large scale generators connected at EHV level falling into the so-called type D category of the NC RfG as explained later in this document and provides the majority of the necessary ancillary services required for secure system operation; however it must be strongly stressed that other factors such as location of generation and technology have predominant impact on system security. The move towards a more RES dominated system as depicted in the adjacent picture (TYNDP 2012 data) implies a gradual diminution of the Type D generation and this will be further compounded by this generation having much reduced running hours compared to today's levels particularly at times of favourable RES generation conditions. A strongly interconnected grid system and enhanced operational tools mitigate the need to apply Type D requirements to all generation in the future system to address the consequences of this move. Considering this, the NC RfG puts forward a novel approach to spread the requirements into four categories[4], considering the size and connection voltage level of generators. In developing the requirements both the expected generation mix (and location) and the relevant additional generator investment costs have been considered and therefore the overall NC RfG structure and specific requirements are based on the extensive experience from conventional power plants and stakeholders input on the cost elements (without insofar having precise

[4] Type A requirements are the basic level requirements, necessary to ensure capability of generation over operational ranges with limited automated response and minimal system operator control of generation. For new installations, there is normally little or no additional cost in complying with these requirements once introduced as part of the standard product.

Type B requirements provide a wider level of automated dynamic response with higher resilience to more specific operational events to ensure use of this higher dynamic response and a higher level system operator control and information to utilise these capabilities.

Type C requirements provide refined, stable and highly controllable (real time) dynamic response to provide principle balancing services to ensure security of supply. These requirements cover all operational network states with consequential detailed specification of interactions of requirements, functions, control and information to utilise these capabilities. They provide sufficient generation functionality to respond to both intact and system disturbed situations, and the need for information and control necessary to utilise this generation over this diversity of situations.

Type D requirements cover a wide area of control and range of operation They ensure specific needs for higher voltage (equal to or greater than 110kV) networks and their operation and stability over wide areas, allowing the use of balancing services from generation Europe wide.

commercially confidential data). The outcome is a proportional allocation of the requirements for future generators throughout Europe on a level playing field.

New installed generation facilities are foreseen to have a life time of decades, and this is a primary motivator for releasing a set of requirement for modern generation (e.g. Smart Grid compliant) as given in the NC RfG. Retrofitting at a later stage will introduce additional barriers and costs.

The following key issues, arising from the increasing levels of non-synchronous RES generation being connected to the European power system(s), are addressed in the NC RfG:

Fault Ride Through (FRT) Small levels of RES generation (geographically dispersed) are unlikely to significantly impact the secure operation of the system should they shut down simultaneously. However, as the levels of RES increase it is of increasing importance that a single system event should not result in the large scale shut down generation. RES generation needs to be resilient to system faults staying connected (and generating) during the initial voltage transients (as conventional generation does today). Since a cost efficient FRT functionality is embedded deeply in the power electronics of generation units, with a long development period, that capability has to be identified today to meet future operational requirements

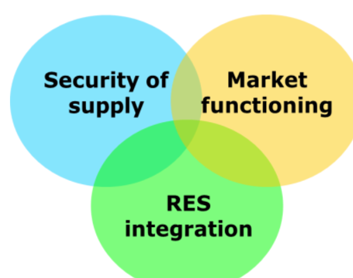
Frequency Stability is significantly impacted by the rapid increase of RES generation both through the variability of generation patterns (driven by wind speed and solar irradiation) and reduced system inertia as large conventional synchronous generation is replaced by non-synchronous convertor based RES generators. To compensate new response and reserve strategies are required with generation having to be resilient to wider frequency ranges and provided new capabilities (e.g. fast frequency response and system inertia) if system security is not to be compromised.

Voltage stability would be compromised if the increasing levels of generation connected at distribution voltages are unable to provide the necessary reactive power support. There are also economic benefits in providing voltage support at a distribution level (close to the demand) rather than from centralized sources connected to the transmission system. Since reactive compensation capability is embedded in the complete design of a generation unit or generation unit technology the requirements of the future need to be identified today if the long lead times for development are to be met economically.

Remote Control of distributed generation units is a highly relevant requirement in the modern electrical network. In this sense, there already exists a very successful experience in Europe with the Spanish CECRE. The control capability is foreseen to include active as well as reactive power regulation in order to support grid stability as well as online reconfiguration. Functionality like on the fly reconfiguration is foreseen to be essential for implementation of Smart Grid solutions in the near future, an added enabler for further RES integration.

3. Proposal for some NC RfG Requirements to be set at a National level.

Regulation (EC) 714/2009 Article 8(7) defines that "... the network codes shall be developed for cross-border network issues and market integration issues ..." The ACER FWGL further specifies that the NC RfG will be evaluated by ACER, taking into account their degree of compliance with the FWGL and the fulfilment of the following objectives: maintaining security of supply, supporting the completion and functioning of the internal market in electricity and cross-border trade, including delivering benefits to the customers and facilitating EU's targets for penetration of renewable generation.

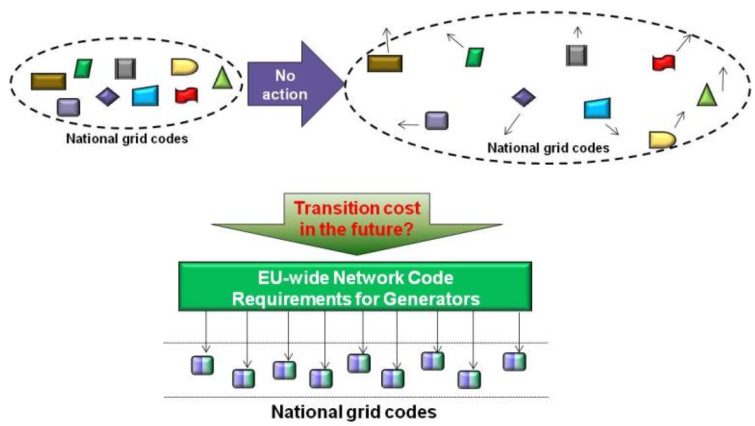


All the issues dealt with in the NC RfG are important to security of supply, market functioning and RES integration, which as illustrated in the adjacent picture are heavily interrelated and cannot be handled independently of each other.

The question whether the NC RfG should go into detailed requirements or be limited to more general – or high level - principles has been addressed by ENTSO-E in consultation with stakeholders and ERGEG (in its role as a preparatory entity for ACER in the context of this NC). On issues, that necessarily have to be harmonised on a pan-European level to ensure the fulfilment of the three objectives, the NC RfG has to specify all details and parameters of importance for this. On all other issues the NC RfG only sets the principles and refers to further specification at National level in compliance with the principles of subsidiarity and proportionality.

ENTSO-E therefore divides the requirements of the NC RfG into the two categories:

- Category-1-requirements (exhaustively described by NC RfG) include:
  - Frequency ranges, including limited frequency sensitive mode
  - Voltage ranges
- Category-2-requirements (not exhaustively described by NC RfG) include among others:
  - Reactive Power
  - Fault-ride-through



A logical consequence of this split is that a detailed justification of the impact of these requirements is possible only with regard to the first category at this stage, as the second group of requirements can only be assessed when specified at National level. The benefits however of including these non-exhaustive requirements are important: as they provide a framework of definitions and processes that ensure a homogeneous evolution of national practices. When considering ranges, wherever provided, they effectively limit the possible future scenarios for the development of national grid codes limiting the uncertainty on requirements from generators and the potential cost of future harmonisation efforts. Finally, they provide adequate flexibility at a national level in order not to create large deviations from current practices when not needed (indeed, the provided ranges cover most current European settings today).

The specific requirements in the NC RfG are primarily based on extensive experience gained by TSOs through many years of system planning, development and operation. It is also based on the TSO forecasts for the future generation mix (see ENTSO-E TYNDP 2012 report on www.entsoe.eu). The NC RfG makes up a coherent set of requirements justified rather through coherent qualitative assessments than individual quantitative assessments. The application of quantitative and meaningful CBA-methodologies on individual requirements represents a significant challenge. Planning scenarios such as those in the TYNDP are just the starting point for this assessment; in-depth analyses can only be carried out by each TSO, taking into account the worst and/or most probable configurations of the power system in terms of generation mix, as a result of market forces and national policies, the location of the new generation, its characteristics, the impact on operations, potential alternative actions, etc.. Consequence of not complying with the requirements can be anything in the range from poorer market functioning, increased curtailment of wind power to more frequent black-outs. Delayed corrective action to avoid these consequences would lead to a massively higher cost for both system users and market actors. Quantitative assessments of these consequences will in any case have to be based on present experiences with system operation, and results will be found within a large range and combined with considerable uncertainties. An individual-based cost-benefit analysis approach is not applicable when considering that the idea/purpose of the NC codes is to bring forward a set of coherent requirements in order to meet the challenges of the future.

4. Market Incentives for delivering the NC Requirements

Network industries such as electricity, but also air-travel, telecommunications, railways, etc. all address the issue of their regulated, partly (natural) monopoly part (the network infrastructure) being secure whilst facilitating competition amongst its users. For example, Air Traffic Control maintains separation between airplanes; however airlines need also to contribute to this in the case that system breaks down due to unforeseen conditions. Collision Avoidance Systems (TCAS or ACAS) are indispensable (and expensive) tools that prevent planes getting too close and instruct pilots for avoidance manoeuvres. However, this system works only if all planes are equipped with it (or at least the two that get too close). EU therefore imposes this requirement despite its costs to all commercial planes flying through its airspace as the alternative ("see and avoid") is inadequate due to the increased traffic and speed of planes (interestingly, this is imposed only to planes that carry more than 19 passengers – significant users). A progressive installation of these tools on planes would be of no benefit until all are equipped and in today's context of fierce competition and the relevant risk appetite of operators makes this unrealistic for achieving a level playing field in Europe.

Similarly, the electricity system security requires that all generators contribute in the same manner to its needs according to their capacities. There are significant and costly externalities: a small PV installation by itself would have no impact on frequency stability, however the sum of all installed PVs has a dramatic effect.

The capabilities identified in the NC RfG are those necessary to ensure the long term viability of the European power system(s); maintaining security of supply, allowing the IEM to function effectively and enabling the EU CO_2 reduction targets to be met through the decarbonisation of electricity generation. The consequences of future generators being constructed without these capabilities are therefore severe and it is difficult to justify the reliance on unproven market based mechanisms to deliver these, particularly when considering the design life of generators (decades) and the costs of a retrofit programme. However, one must note here an important distinction: the NC RfG does not dictate how the ancillary services are to be procured or remunerated. Instead, it defines what generators should be capable of delivering. The delivery of these services will be done generally in a market based context as, for example, in the forthcoming Balancing Network Code.

ENTSO-E designed the NC RfG considering that in the absence of such a market framework with sufficient forward looking scope and the speed by which the system is changing any delay in imposing these requirements to new generators is an unacceptable risk – a risk that is born at European level. ENTSO-E's strategic objective with this NC is to prepare the system of tomorrow in order to be able to participate on an equal basis to markets for the procurement of ancillary services.

ENTSO-E and the TSOs occupy a central position with respect to both responsibilities and competences for defining the technical requirements for ensuring the security of supply in a socio-economic efficient way. At the end of the day end-consumers will get the benefit of a low carbon energy system and a secure system while they have to pay the costs associated with strengthened requirements, and it is a regulatory issue whether the costs should be allocated to ancillary services and collected via grid tariffs or internalised in market prices for electricity. Given the appropriate regulatory framework for cost allocation, TSOs do not have any incentives to impose unnecessary costs on other parties.

5. Interaction and between the Codes covering the System Operation, Markets and System Development

The NC RfG contains 53 requirements of which 44 are of mandatory nature. The 9 non-mandatory requirements, such as the provision of synthetic inertia for power park modules or black start capabilities are those for which, at this point, a European harmonisation is not sought, however their importance to system security is such (especially for smaller, RES dominated synchronous areas when considering for example synthetic inertia or black start capability) that they are defined at European level and the possibility for coordinated action in national grid codes is highlighted. The existence of a common definition for these non-mandatory requirements and in some cases the framework for potentially introducing them into national codes is a significant added benefit to ensure further harmonisation of national practices and to better prepare future generation investments. Of the remaining 44, 12 are defined exhaustively in the NC in the sense that the definition and description of each requirement is complemented when applicable by a parameterization that is to be applied as such to all national arrangements. These requirements form the core of the NC and are central to its objectives; they are focused mainly on frequency and voltage stability and are the minimum harmonised set of requirements needed. The final 36 requirements are defined and further a range of possible implementations is provided in the NC and need to be specified at national level. Such ranges achieve two objectives: first, at synchronous level the behaviour of the system is framed in a way that security is provided for. Second, and looking into the future, national codes, based on the same requirements definitions, do not deviate from the European (synchronous area) ranges and thus avoid further diversity and drive convergence bringing down future costs of potential corrective actions if the system develops even more drastically than anticipated.

The above logic is more evident when one thinks of the other NCs that are to be delivered according to the 3-year plan jointly elaborated by EC, ACER and ENTSO-E. Indeed, the Operational Security NC and the Balancing NC that are to be delivered after the NC RfG is finalised have strong interactions with the latter and to a degree this holds true to all NCs that are to be developed. The impossibility of elaborating all codes at the same time is no reason for inaction. A real iteration between the development of the codes is also unrealistic due to the heavy update procedure of each one and the very limited time allotted to ENTSO-E and ACER to develop the NCs and the FWGLs (12 and 6 months respectively). Therefore, the NC RfG that has been prioritised with the endorsement of the Florence Forum in 2009 needs be the starting and not the blocking point for all codes.

Therefore, the Operational Security NC (as the umbrella for the Load-Frequency Control and Reserves NC and for Operational Planning and Scheduling NC) builds primarily on the 12 exhaustive requirements as a basis for the future picture of the system that is envisaged (what generators can provide). The definition of these requirements can be seen as the first step in the development of this code. Building on those requirements, as well as a definition of the operational security principles the Operational Security NC (as well as the Load-Frequency Control and Reserves NC and for Operational Planning and Scheduling NC) proposes new measures for coordinating system operations and complements the overall picture provided by the NC RfG. As mentioned above, the operational codes are looking into the medium term only as operational tools need be adapted continuously to address rising challenges. However, the added information guides the coordination of national systems by driving the specification of the 36 generator requirements that are not exhaustively defined in the NC as well as the 9 non-mandatory ones. This way, an efficient loop between the two codes is achieved. The same reasoning shall apply for the Balancing NC who designs balancing markets with a view on system security and socio-economic welfare maximisation based on the exhaustive NC requirements (and the operational security principles of the operational NC) and in turn also drives national implementations. Only when this flexibility is exhausted the NCs need to go through a potentially lengthy update process that remains to be defined by ACER as foreseen in Reg. (EC) 714/2009.

6 Conclusions

The changes in the electricity sector driven by EU Energy and Climate policies are not new, however they are taking place in an unprecedented speed for which neither the legal frameworks around Europe nor the power system itself are ready for.

The integration of non-synchronously connected RES combined with a move towards smaller and less centralised generation poses a significant challenge to TSOs and if no action is taken today the power system shall be unacceptably close to its operational limits facing security risks. The impact of this risk is immediate to the EU economies, the well-being of its citizens and the prospect of a greener energy industry.

European citizens are already investing via the TSOs in significant grid reinforcements as demonstrated by the ENTSO-E TYNDP. Within countries, costly measures for addressing system security are commonplace such as redispatch of generation, installation of FACTS, etc. New market designs for more efficient and liquid trading as well as an increased cooperation between TSOs for operational planning or real-time coordination are also parts of the solution. However, the transmission network is only part of the power system; generators and demand are inseparable elements of the system and their contribution to system security has been and must continue to be present.

The NC RfG is the first truly EU action to address the issue of how generators should be equipped to facilitate secure system operation. It aims at creating a level-playing field around Europe by proposing the minimum requirements needed from generators in a technology-neutral manner in order, first to ensure system security, and second to create the conditions for a convergence of national network codes with direct benefits to standardization. All in all, it is the best way to prepare the power system of tomorrow today in order to tackle successfully the challenges ahead, and this in a socio-economically optimal way when considering the risks associated with any other approach related to non-existent legal frameworks or mature markets.

Inaction is not an alternative to this NC; continuing business as usual would certainly lead to either more frequent disturbances like the 4/11/2006 in the heart of Europe, or to overly costly and sometimes insufficient generator design adaptations like the PV frequency settings in Germany and Italy. A less prescriptive network code relying exclusively on national implementations or driven by market forces is also no alternative; the risk of relying on immature and short-term focused markets for delivering the investment incentives needed today for generator design adaptations is high and - making the parallel to the shortage of active power investments - has not proven always successful.

The time is now for this NC to be implemented and the support of policy makers is needed. Any delay, given the speed of system change, could make the NC less effective and it is not predictable what type of adaptations and at which cost could be needed.