Regional coordination of power system operations

Regional cooperation – a cornerstone to guaranty security of supply and efficient use of the electricity grid in the future green, interconnected power systems.

Jens Møller Birkebæk
Nordic RSC
Copenhagen, Denmark
jmb@nordic-rsc.net

Enrico Maria Carlini
Grid Planning and Interconnection
l Terna, Rete Elettrica Nazionale S.p.A.
Rome, Italy
enricomaria.carlini@terna.it

***Abstract* – The general development towards de-carbonization and decentralization of generation in the power system and the implementation of liberalized energy markets across continents have had significant impact on the secure operation of the power systems for several years. However, the recently decided significantly increased pace in this power system transition towards renewable generation and the parallel implementation of continent wide, open electricity markets without a co-current development of the electricity grid now drives the TSO´s to operate the grid at or even beyond its safe limits and sets the security of supply under pressure**

An enhanced regional operational cooperation between TSO´s is seen as a prerequisite to ensure the continued high level of security of supply in the increasingly interconnected power systems.

Previous papers[1,2,3] have described some serious regional disturbances, the analysis of these and the initial implementation of voluntary Regional Security Coordination Initiatives (RSCI)[4].

This paper describes how the voluntary initiatives amongst European TSO´s has evolved into Regional Security Coordination (RSC), partly based on binding TSO agreements and partly through legal requirements in the European Network Guidelines.

The regional coordination creates the first significant step in the digitalization of the Pan-European electricity transmission system through common access to standardized data for the entire European Power System and the standardized use of data for operational security calculation and operational planning. Such access to extensive, reliable, common and shared power system data for several timeframes is a key condition for the regional coordination.

The paper describes how this condition is fulfilled through the development of standardized datasets from all TSO´s, Individual Grid Models (IGM), based on a common standard, Common Grid Model Exchange Standard (CGMES), how the IGM´s are merged to Common Grid Models (CGM) for the entire Power System and further how the RSC´s through standardized regional business processes supports the TSO´s to operate the European transmission grid safely and to its limits.

The importance of the regional coordination and the essential split of responsibilities between planning phases (RSC) and real-time (TSO) to deliver security of supply are discussed based on examples of critical grid situations that were coordinated and operated successfully preventing adverse effect on electricity supply.

Finally the paper discusses the further outlook and the expectations for enhancement of RSC activities towards 2025 including the possibilities for digital innovation based on the availability of big data from the power system

Keywords - Regional Security Coordinator (RSC), Digitalisation, Individual Grid Model, Common grid Model, Coordinated Security analysis, Coordinated Capacity calculation, Outage Planning Coordination, Short and Medium term Adequacy, Critical grid situations, Emergency preparedness, System operator Training, digital innovation.

I. INTRODUCTION

The safe operation of the interconnected European transmission system is the responsibility of the national or sub-national Transmission System operators (TSO).

TSO´s across Europe have through history managed to operate the European Power System efficiently and secure. The TSO´s have a long tradition for developing the necessary common operational procedures and standards for the interconnected systems and for smooth and efficient bi- or multilateral cooperation across borders.

The Power system has during the latter 10-15 years undergone significant changes characterized by large scale implementation of renewable electricity generation from fluctuating resources (wind and solar) and a parallel reduction in the operation of conventional power generation. But despite the serious challenges this has incurred to the secure operation of the power system, the TSO´s have managed to operate the system with a very high level of Security of Supply. One reason for this is the gradually increased regional coordination amongst TSO´s.

The renewable electricity generation typically takes place far from electrical load centers or is highly decentralized. To avoid adverse effect on the secure operation of the electricity grid such changes should be compensated by significant development and enforcement of the electricity grid. However, such development has taken place to a limited extend only, often due to public opposition against the building of power lines.

As a consequence of the above, overloading of power lines, un-controlled loop flows across borders, increased difficulties in voltage control and even dynamic issues like power oscillations occurs more and more frequently.

On this basis it seems obvious, that the further planned increase in renewable generation towards the renewable targets for 2020 and 2030 requires even closer regional coordination and more innovative interpretation of all available data to ensure the secure operation of the interconnected power system

II. Common Standardised Datasets for the European Power System (Common Grid Models, CGM)

A. The legal background and the methodology for CGM

The "Third legislative Package"[5] generalizes efforts to develop further coordination between TSOs. As a consequence of this, and to facilitate the harmonization of markets, common rules (Network Guidelines) were developed during the period 2009-2016. These rules have been turned into binding EU regulation that entered into force in 2016-2017 and are subject to full implementation during 2018-2020.

The creation of standardized datasets for the European power system (CGM) is a major and extremely complex project for the European TSO´s and IT solution vendors. It is, however, absolutely essential for the implementation of requirements in the network guidelines. The CGM contains vast amounts of data and provides a solid basis for statistical and probabilistic analysis and decision making in the future power system. It can therefore be regarded as a first step in the digitalization of the operation of the power system.

To ensure a full uniform understanding of the processes and data to be included, ENTSO-E TSO´s have agreed on a detailed common methodology[6] (CGMM) for the development of Individual TSO Grid Models (IGM) and the CGM. The CGMM covers all aspects related to the data, quality requirements and process timelines for TSO´s and RSC´s and shall be approved by NRA´s. The TSO´s will provide the standardized IGM´s to the ENTSO-E Operational Planning Data Environment (OPDE) for the timeframes in fig.1. All TSO´s and RSC´s will have access to the data in the OPDE.

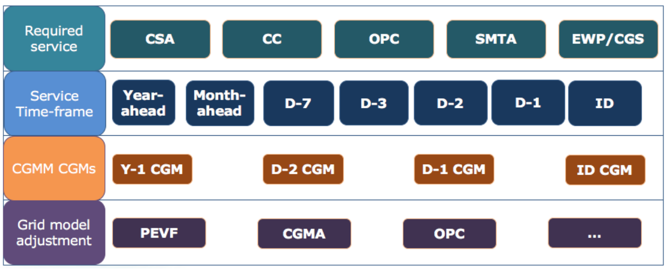

Fig. 1: Datasets from different timeframes provide the basis for different services. (Source: ENTSO-E)

B. Forecasts are an essential part of the datasets for future power system operation

The TSO´s always strive to provide the highest transmission capacities to the market within the secure limits of the system capability. This is a great challenge when a major part of the power originates from renewable and fluctuating generation.
Without reliable forecasts for generation and demand the TSO´s would have to cope with a huge uncertainty by relying on a "reference scenario". This uncertainty could only be mitigated by keeping a large grid capacity reserve (Reliability Margin), otherwise the safe system operation would be at stake.
The operation of the Nordic Power System is highly influenced by fluctuating generation. This is due to the nature of the Nordic Power System (large volumes of installed windpower, high HVDC interconnector capacity to the Continent and a sizeable, flexible hydropower based generation). It is therefore of utmost importance for the efficient and secure operation of the Nordic Power System, that very high quality forecasting solutions are in place.
To be able to create a high quality D-2 CGM for the use in grid capacity calculation, the Nordic RSC has developed a solution "Net Demand Similarity" that is accurately forecasting the power flows across the Nordic TSO´s and bidding zones. This allows the Nordic RSC to minimize the reliability margin and thereby allow the TSO´s to provide a higher capacity to the market.

The "Net Demand Similarity" approach is based on forecast of demand and of non-dispatchable generation for the target hour on the production day. Non-dispatchable generation includes until now wind and nuclear power, but e.g. non-storable hydro and solar will be added in the future. Nuclear power is of course dispatchable, but is normally not influenced by prices in the short run. Wind, solar and non-storable hydro are driven by weather and not prices. "Net Demand" is the difference between forecasted demand and non-dispatchable generation. The algorithm searches for historical hours on similar days (f.ex. week-day, Sunday or holiday) with "similar" net demand in all bidding zones. This solution has resulted in an improvement of the mean average errors between 30 and 60 % depending on the amount of fluctuating generation.
The improved forecasting provided by Nordic RSC allows the TSO´s to increase the availability of the grid to the market without sacrificing operational security.

III. Business Processes to be Implemented in the RSC´s

As described in previous papers the European TSO´s established the first initiatives on Regional Security Calculation units (RSC) already in 2008 (TSCNET and Coreso). The RSC´s has proven their value in daily operation through the support to operational planning of the European Power system and through the coordinated regional calculation of system security preventing dangerous overloading of the system.

The TSO´s and RSC´s will during 2018 and 2019 gradually develop the regional coordination in all European regions. This is in line with the Common Network Guidelines and with the purpose to support the implementation of the internal European electricity markets and the renewable transmission without sacrificing security of supply. The TSO´s and RSC´s will for that purpose implement the following joint business processes:

1. Coordinated Capacity calculation (CCC)
2. Coordinated Security Calculation (CSA)
3. Outage Planning coordination (OPC)
4. Short and medium term adequacy (SMTA)

All based on the use of the common grid models

Fig. 2: Mandatory services to be procured by a TSO from a RSC[7].

The implementation of these business processes will facilitate a seamless and secure transition to the renewable energy system and ensure that the maximal transmission capacity is provided to the electricity market.

IV. RESENT EXAMPLES OF STRONG REGIONAL COORDINATION IN CRITICAL SITUATIONS

Due to the highly interconnected European power system regional coordination has proven extremely valuable. Normal operational conditions today typically results in significant volumes of unscheduled flows (fig 3). RSC´s are providing regional coordinated grid security calculations day-a-head and intraday and are through this, even in the normal situations, supporting the TSO´s to take the optimal measures to guaranty operational security and to ensure the optimal availability of the grid to the markets.

Fig. 3: Average unscheduled flows 2015. (Source: ACER[8])

The importance of regional coordination and coordinated grid analysis and calculations are particularly pronounced in strained or critical situations.

A. *Critical loop flow situations in Central-East Europe during the hot Summer 2015*

The Central-East European Power system experienced during August-September 2015 for several weeks some very critical operational situations due to very large un-scheduled (loop) flows from Germany through Poland and Czech Republic to Austria and further south.
Unless these huge loop flows were counteracted in the operational planning phase, it would have created massive overloading of transmission lines. This subsequently would cause line disconnection with the risk of cascading failures and potentially black-out of major areas.
Counteracting these huge loop flows could not be undertaken on national level only as all available generation was exhausted, and as such required regional coordination of extraordinary remedial actions amongst several TSO´s.
The RSC (TSCNET) made the coordinated security calculations for the region and coordinated the remedial actions between TSO´s.

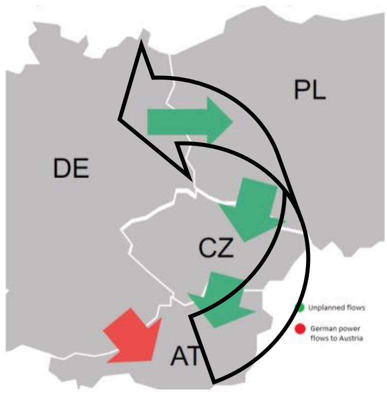

Fig. 3: Critical unplanned flows through Poland and Czech Republic and multilateral re-dispatch

Remedial actions included topology changes, phase shifter control, outage rescheduling and in particular multilateral re-dispatch of generation, in some occasions up to as much as 5 GW of production involving several TSO´s.
With the support from RSC the TSO´s managed to cope with these large loop-flows without impacting the electricity supply in the region.

B. *Critical Adequacy Situations during the Cold Spell in January 2017*

The Southern Europe was during January 2017 hit by a serious cold spell, which combined with massive snow fall, that interrupted several transmission lines threatened the safe supply of electricity in several countries[9,10].

Adequacy forecast in the ENTSO-E Winter Outlook illustrated the need for import in several countries under severe conditions during the Winter 2016-17

Fig. 4: Forecast for generation adequacy map under peak-time at severe winter conditions. (Source: ENTSO-E)

In addition to the very cold weather un-planned outages of transmission lines and interconnectors worsened the adequacy situation particularly in France and some South-East European countries. A critical factor for load forecasting in France is the load/temperature dependency of 2.400 MW/ ^{0}C. During a critical week with very low temperature forecasts it was foreseen, that load shedding would be needed to ensure the secure system operation.
The support from RSC´s (Coreso and TSCNET) through daily regional adequacy calculations and coordination of supportive measures across the region provided the TSO´s in the regions with the relevant information to be able to take the necessary and optimal preventive actions before real-time and thereby avoid any impact on supply throughout the Cold Spell

ENTSO-E and the 5 European RSC´s have, based on the learning from the above examples decided to implement a specific coordination process to be triggered in case a potential Critical Grid Situation is foreseen. The conditions for triggering the process is, that all possible national available preventive measures will be exhausted and extraordinary regional measures are required to ensure the secure supply of electricity.
This coordination process includes coordinated calculations based on regional power system data combined with detailed and task specific investigations of the possible extraordinary measures, and which is particularly important in a critical situation, a coordinated communication process to ensure that all stakeholders and the general public will be systematically informed and up-dated on the potential critical situation. The process responsible is the RSC in which area the Critical Grid Situation is foreseen. The RSC will set-up a dedicated task force together with involved TSO´s and ensure that sufficient expertise is involved to cover all aspects of the situation.

V. Regional operational planning and security analysis versus real time operation.

Operating the European power system is an extremely complex task. For any complex task it is crucial, that roles and responsibilities for involved parties are crystal clear and well defined.
The security of electricity supply is the prime responsibility for TSO´s across Europe. The TSO´s have during many years cooperated closely to ensure this and have developed agreements to document the practices [11,12].

Due to the above described reasons and the development of the power system during the recent years the requirement for regional coordination has increased. The European TSO´s have therefore delegated several tasks/services to RSC´s. These delegated regional services are covering processes during the operational planning phases.
Delegating the tasks related to regional operational planning to RSC´s does not imply delegation of responsibility for security of supply in the areas. This remains solely with the TSO´s

Sharing of near-to-real-time data provides the RSC´s with additional information and a better basis and may enable the RSC to improve the quality of their services. But whilst RSC´s can provide high quality services to TSO´s in operational timeframes up to intraday closing, RSC´s cannot take any responsibility for or in real-time operation, as RSC´s have no access to any direct operation of the power system.
This as a consequence implies that coordination of power system operation in real time involves the TSO´s only and must be organized by direct TSO/TSO contacts.

VI. Future requirements for regional coordination for efficient operation of the interconnected power system

Having realized the significant and valuable impact of regional coordination under the present conditions in the interconnected European Power system, it is now being discussed, how the requirements will develop, when the renewable generation increases towards the fully renewable energy system and the electricity markets gets fully integrated with more market platforms operating closer to real-time

The European Commission presented during 2016 the “Clean energy package” as basis for the Energy Union. Several initiatives are considered for additional regional coordination and a general development of the governance and responsibilities including additional regional coordinative tasks for existing RSC´s are described[13].

Several other studies and discussion papers have been presented in the meantime related to the topics proposed in the "Clean energy package" [14,15,16,17,18].

Stakeholders obviously have different positions and priorities when discussing the requirements for efficient and secure operation of the future sustainable European power system.
There is though a general consensus amongst most stakeholders on the requirement to increase the regional coordination, to develop the existing services and to delegate additional services to regional entities.

The FTI-CL Energy Study propose in their analysis a concept for this development named Enhanced Regional Coordination (ERC)

Fig. 5: Enhanced Regional Coordination and 5 Pillars of the concept[15]

The ERC concept envisions that regional coordination should be developed according to the specific requirements in the different regions and pin-points the need for strong regional cooperation at the political level.
Whilst this approach may seem obvious from a bottom-up perspective (TSO, RSC), it is less obvious from a top-down perspective (EC), where harmonized requirements to all stakeholders across the Energy Union are considered important to prevent distortions to the Pan-European open electricity markets

The regions in Europe are very different from a lot of perspectives, the technical complexity of the grid, the extent of penetration of renewables, the size and regulatory status of TSO´s, the existing level of collaboration amongst TSO´s and the existing level of political cooperation in the region. These differences will prevail in a foreseeable future and underlines, that development in regional coordination shall reflect the regional requirements and opportunities.
Whatever approach will be included in the final directives for the Energy Union it is also extremely important to underline, that the operation of the interconnected European Power system must change through a step-wise evolutionary approach. It cannot or will be connected with unacceptable risks to make revolutionary changes over a short time period.

VII. Discussion

The interconnected European Power system is changing at an unprecedented pace. The simultaneous changes in market design, generation patterns and consumer behavior pose a significant challenge for the TSO´s to maintain the secure operation of the power system.
Major new initiatives are launched by ENTSO-E and the TSO´s to cope with these operational challenges centered around

1. Common European data models (CGM)
2. Extensive Regional coordination (RSC)
3. New common European IT solutions

Each of these initiatives is a huge and very complex project, because they interact with and require significant changes in the business processes and IT solutions, which have been developed across Europe during many decades. Even the first steps in these initiatives involve major change management projects for all parties involved in power system operation.

The availability of huge and standardized data combined with IT solution that are able to analyze and convert these big data into valuable information creates the basis not only for maintaining the security of supply during the transition to a sustainable power system, but it will also allow for efficiency improvements, maximum capacity provision to markets, optimization of reserves in regions and probably also optimization and efficiency improvement in grid development.

The traditional deterministic N-1 principle is and has always been a cornerstone in power system security analysis. However in the future decentralized power system this principle must be developed into probabilistic principles and decision making based on statistical data analysis and calculations.
With the availability of big data for statistical analysis combined with improved forecasting models and methods much more precise and adapted security analysis can be provided using N-k principles (k<1 or k>1 depending on a statistical risk evaluation and even financially determined criteria[19].

Implementation of such new operational principles requires broad acceptance across member states, regulators and stakeholders, which will be a significant challenge, that need the support from policy makers. It should be pursued in those areas/regions where the development in the power system requires new solutions
The above is just one example that underlines the need for different solutions to the different challenges and opportunities in the regions across Europe.

The availability of big data for the individual regions is the precondition for the regions to initiate digital innovation activities. The TSO´s are responsible, but new partners with different competences are important to provide advanced solutions. Solutions that allow the RSC´s to provide more advanced services to the TSO´s at a pace that may be sufficient to match the changes in the Power System, and thereby compliment the traditional solutions like grid development, which in itself has proven to be a slow process.

VIII. CONCLUSIONS

This paper has described how the increased pace in the transition of the power system towards renewable generation and the parallel implementation of continent wide, open electricity markets without a co-current development of the electricity grid drives the TSO´s to operate the grid at or even beyond its secure limits and illustrates that this under critical situations sets the security of supply under pressure.

To cope with these present operational challenges and prepare for the future development ENTSO-E and the TSO´s have launched major new initiatives centered around

1. Common European data models (CGM)
2. Extensive Regional coordination (RSC)
3. New common European IT solutions

This allows implementing extensive regional coordination processes to optimize the operational planning of the power system.
But equally important is, that it establishes the basis for future development and digital innovation to find new advanced IT based solutions for the operation of the power system and thereby complement the traditional grid development solutions.
The regions across Europe are different in many aspects and regionally developed processes that cope with the regional need for coordination must be sought. Provided the sufficient regional policy support this can provide a solid basis for efficient and secure operation of the future green, interconnected power system to the benefit of the society at large.

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