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Future challenges in the control centre due to distributed Generation and Renewables

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Ireland	Switzerland	Spain	Germany	Romania	Netherlands	Italy

SUMMARY

Working group C2.16, in [1], discussed current operational practices with distributed generation (DG) and renewable energy sources (RES). This paper addresses future DG/RES operational challenges, which are categorized under five headings. These are organizational, operations, observability and controllability, technical capabilities and regulation and commercial. Each of these is discussed below.

Organizational: Organizational issues in the integration and control of RES and DG have been handled in different ways in various countries depending on the voltage level and the size of installations, the impact on the management of the power system and the novelty of the phenomenon. Small DG is connected on DNOs' or regional providers' networks and TSOs normally have no direct control of this generation. Different approaches and agreements between TSOs and DNOs for integrated control have been developed. In the case of large installations, TSOs have very often direct control on the power plants. In countries with a high level of renewables and/or high growth trends TSOs and DNOs have realized or are implementing dedicated tools and sometimes dedicated structures to control the RES/DG.

Operations: A number of operational challenges exist, many impacted by the accuracy and availability of forecast information. Changes in bulk power flow and subsequent network congestion is materialising and new management techniques need to be applied. These may include local dispatch and curtailment opportunities. System balancing is becoming more difficult as renewable penetration increases, particularly in off-peak hours. Within the DNO, higher levels of monitoring and control are required compared to previous operations and significant additional resources are required. Particular attention needs to be paid to voltage regulation and control and the determination of appropriate set points.

Observability and Controllability: Since renewable energy has significantly increased its contribution to system generation, real time production telemetry has become essential to ensure system security. Intermittent generation involves new challenges since its management is different from conventional plants. Their variability and uncertainty, their geographical spread, the way they participate in demand coverage, their low participation in voltage control and their behaviour during disturbances, make observability a necessity. Controllability is also required to adapt generation to demand profile, to

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avoid generation reserve exhaustion, to keep balance feasibility, and in general to increase renewable energy sources penetration at the same time as keeping the required level of system security.

Technical Capabilities: There are several key technical capabilities required in the future as renewable energy increases as a percentage of system demand. As the proportion of the system renewable generation increases this may impact on the security criteria and the frequency and inertial responses of the system. Current solutions involve controlling the renewable generation but there are also new system-wide impacts indirectly caused by renewables that may need to be considered. In this section we will identify future technical challenges caused by increased renewable generation on the system.

Regulation and Commercial: The design and implementation of grid codes and energy markets are critical for system operators, when operating and controlling grids with high penetrations of DG/RES. This section will identify a number of the critical issues, in these two areas, for system operators to monitor.

KEYWORDS

System Operation - Control Centre - Distributed - Renewable - Regulation

1. Organizational

1.1 State of the Art

Organizational issues in the integration and control of RES and DG have been handled in recent years in different ways in various countries. These differences are caused by a lot of factors. First of all the different approach in the management of the RES and DG depends on the voltage level and on the ownership of the connection grid.

In some countries the electrical system is still fully integrated, in some others there has been a complete unbundling and there are different operators for production, transmission and distribution of electricity. Often the transmission network is owned by a TSO, in other cases the grid is owned by one or more companies but the network control and dispatching activities are performed by an ISO.

At a European level, in order to deal with the voltage and frequency control challenges presented by such a significant amount of generation, which can jeopardize the security of the whole interconnected grid in the case of severe network events, new standards for connection, protection and control have been defined [2]. These standards are being implemented at country level by national electrical committees and sometimes also with the intervention of national Regulators.

Small DG units are always connected to the distribution grid or regional providers' networks, usually on MV or LV grid and TSOs/ISOs normally don't have direct control of this generation. On the other hand large installations are usually on the HV grid and TSOs/ISOs normally have direct monitoring and control of these power plants.

Nevertheless, in countries where the penetration level of DG is so high so as to have a strong influence on the behaviour of the transmission network, TSOs/ISOs have signed ad hoc agreements with the distribution companies and local grid owners in order to exchange information about these productions.

Dedicated tools and sometimes even structures to control RES/DG have been realized, with a particular focus on forecasts and real-time aggregated production monitoring. For example Spain has implemented a separate renewable control centre, CECRE.

1.2 Future Trends

The growth trends regarding RES/DG installed power suggest that the same issues already present in countries with a high presence of these types of production will ultimately spread worldwide.

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1.2 Future Trends

The growth trends regarding RES/DG installed power suggest that the same issues already present in countries with a high presence of these types of production will ultimately spread worldwide.

One of the main problems to tackle, not only from a technical but also from an organizational point of view, will be the production deviation from schedules and frequency control. Such a high penetration level of RES/DG can have an important impact also on large interconnected systems.

One or more of these different approaches can be taken into account:

- New rules for imbalances: some penalties could be introduced to RES and DG producers in order to induce them to provide a better production forecasts and to respect the schedules declared to markets (e.g. in Italy, where traditional plants are already penalized for imbalances, the Regulator intends to introduce a similar treatment for RES, but is meeting strong resistance from producers).
- New requirements for frequency primary control of DG and RES: Plants should provide themselves the primary frequency control alone or in pre-defined clusters as outlined in the TWENTIES project [3].
- A de-centralized frequency/imbalance control performed in an area with load and production in order to guarantee the respect of a scheduled exchange in the matching points with transmission grid. This solution implies a completely new organization and tools able to perform this task.
- New hierarchical control performed by TSO/ISOs which coordinates actions to be taken by DNOs or generation control centres in order to guarantee power balance. This solution may require a new type of organization in distribution companies and a strong data exchange between them and the grid operators.

Each of the above-mentioned solutions implies a great effort in terms of organizational improvements, new data exchange systems and also in the training of operators at every level of the system, from producer to DNOs and System Operators, so that they cater with new scenarios and new types of behaviour.

2. Operations

2.1 Congestion Handling in TSO-Grids

European transmission systems are highly loaded. The transportation of power from areas with high infeed, both from controllable conventional and stochastic decentralised production, to areas with high demand may lead to local congestions, especially where the tie lines between different control areas are affected. These congestions (in real time operation as well as (N-1) results) have to be handled by the operators in the TSO control centres, until the systems have been strengthened.

In highly meshed systems like Continental Europe (ENTSO-E RGCE) the bulk power flows cover many different countries. So congestions cannot be handled by a single TSO, many TSOs are involved to remove bottlenecks, so coordinated countermeasures are needed. Depending on the grid regions, different tools are available. These include:

- Topological measures are used at almost all TSOs.
- A further common method to control critical power flows is the use of Phase Shifting Transformers. These are used to shift the flows from highly loaded devices to less loaded devices. These actions have to be coordinated carefully, especially when several TSOs are affected.
- The change of generation is the next measure to remove the congestion. This has to comply with countries' individual rules.

In many European countries under undisturbed conditions (Germany / Italy) these congestions cannot be solved by curtailment of DG/RES, due to RES dispatch priority. As a result usually the re-dispatch of conventional generation is the countermeasure.

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As soon as there is no conventional production left, an alternative is needed, e.g. re-dispatch of DG/RES. Here has to be considered, in which operational situation curtailment of DG/RES is the appropriate measure. In Spain, DG/RES curtailment is an appropriate measure to provide (N-1) security on the transmission system.

All re-dispatch measures have to be coordinated: e.g. a chain of several bilateral re-dispatch measures between neighbouring TSOs can be replaced by one re-dispatch between two partners, which are not directly connected. To realize these measures, a deeper cooperation is needed, both operational and contractual.

Critical situations have to be recognized in advance in order to take countermeasures i.e. before congestion occurs. Therefore, the tasks of operational planning and real time operation will further grow together in future. One major task is to realize and solve congestions before they can lead to critical situations. Therefore, in Continental Europe several Security Initiatives were started. In the future TSO control centres both colleagues from the real time world as well as from operational planning will take care of the systems.

2.2 Voltage Control – TSO/DNO Cooperation

With the rising share of DG/RES the number of synchronised conventional synchronous generators decreases, so major possibilities for voltage control are missing. TSOs cannot control the voltage profiles in their systems by giving set points for the generators voltage controllers any more. Voltages are changing much faster, depending on the system load. In high load cases voltages drop significantly, especially in the absence of voltage control devices. In low load cases voltages are often critically high. In continental Europe this is often the case on sunny “holiday-days”.

In the future control centre new approaches for voltage control are required. It is important to state, that reactive power is always a local challenge. These approaches may include:

- Existing devices have to be used more extensively: extend available reactive power band of synchronous generators,
- Allow switching out of lines in high voltage situations. Here the TSO has to ensure, that these measures won't endanger the system security.
- Make use of control capabilities of the DG/RES. Technically modern wind and PV converters can control voltage. But when these converters are connected at the DNO level, the reactive power has to be transported to the TSO grid. This requires intensive cooperation between DNO and TSO. In areas with high / low voltages on the TSO level, the DNO has to give set points to a large number of DG in his system, simultaneously coordinated with tap changer control on transformers from TSO to DNO. This can’t be managed without technical support by the SCADA systems.
- New conventional compensation devices are needed: condenser banks and reactors.
- New power electronic based compensation devices are needed, such as Static Var Compensators (SVC). As these devices replace conventional Q-sources, the provision of short circuit power in case of faults has to be considered.
- Here, a mixture from automatically controlled devices like SVC and manually switchable devices like reactors is needed, to control even extreme changes in the voltage profile.
- Synchronous condensers are an option as well. They can be operated like synchronous generators; additionally they provide short circuit current, in case of faults, and inertia.

HVDC connections are planned to connect big offshore wind parks to the power systems. In Germany for example the overlaying super-grid is planned to transport active power directly from high production areas to high load areas. New converter stations have an impact on voltage control.

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- Conventional thyristor based converters (line commutated) always need reactive power, dependant on the active power. Therefore, automatically switched condenser and filter banks are employed to keep voltages within the allowed range.

- The transistor based converters such as VSC converters can be used for voltage control like SVCs, independent from the active power.

Here, the system wide control of active power flows over the DC connections is directly connected to the local control of reactive power. With the increasing numbers of DG/RES the voltage control mechanisms will change. Operators should know about possibilities and limits of new Q-regulating devices. One major task facing future TSO and DNO control centres is the coordination of the diverse Q-Control-Devices.

3. Observability and Controllability

Since renewable energy has significantly increased its contribution to the demand supply, observability has become essential to ensure system security. Having real time information about the production of all renewable facilities above a certain installed capacity lets the System Operator distinguish between generation and demand, and it means that it is possible to make reliable and accurate renewable production forecasts and to avoid demand forecast errors. Observability also enables modelling of power flow scenarios in order to evaluate the state of the grid under certain constraints.

But that is not enough, controllability is also required to adapt generation to demand profile, to avoid generation reserve exhaustion, to keep balance feasibility, and in general to increase renewable energy sources penetration at the same time as keeping the required level of system security.

The challenge for the TSOs and DNOs is to decide which data is essential to perform their necessary tasks to assure system security within their area of responsibility. The large amount of information that can be received in the control room has to be well filtered in order to help the operator; this fact forces TSOs and DNOs to make the appropriate sizing of their control systems and to invest in new tools and infrastructures.

Depending on the regulatory framework, quick control of the RES production may also be essential. As an example, in a weakly interconnected system such as Spain, based on the current legislation, the system operator receives, through the CECRE (the specific control centre for renewable generation) telemetry for 94.7% of the wind and solar generation installed, of which 84.2% is controllable and is able to adapt its production to a given set point within 15 minutes. The telecommunications deployment to over 2000 renewable facilities spread all around Spain has been achieved as a result of the aggregation of all the distributed resources of more than 10 MW in renewable energy sources control centers (RESCCs) and the connection of them with CECRE. These RESCC will work as the intermediary with the TSO: sending information in real time and executing orders from TSO, guaranteeing system reliability at all moments. This hierarchical structure, together with the applications developed by Red Electrica de España (REE), is used to analyse the maximum wind generation supported by the system.

4. Technical Capabilities

As the penetration of renewable generation technologies, such as wind and PV increases, the technical complexity of the control centre will also increase. The control of both active and reactive power will have to evolve in order to cater for significantly more generators and reactive support devices such as synchronous condensers. The withdrawal of synchronous generators from traditional AC systems may lead to problems, depending on system size, in the areas of inertia and synchronizing torque. The increasing number of power electronic devices may also lead to harmonics problems. Additionally, many systems will have to manage both international and internal HVDC links.

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