THE INTERACTION BETWEEN DSO AND TSO TO INCREASE DG PENETRATION – THE PORTUGUESE EXAMPLE

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ABSTRACT

The operation of transmission networks is made depending on their loads – distribution system. Transmission systems are optimized to ensure loads and generation from EHV, HV and MV. The connection of DG units to distribution networks can impact the planning and operation of transmission systems. When these units are predominantly from renewable sources, given their intermittency or derived from disturbances, they may temporarily disappear causing potential problems on the balance between loads and generation.
This paper addresses the challenges that DG units may cause on distribution and transmission networks and, hence, the need for information exchange between DSO and TSO. An example of a real implementation is detailed and the quantity and type of information valuable for both system operators is explained.

INTRODUCTION

Traditionally, distribution networks have mainly been designed and operated to distribute power passively from the upstream generation and transmission system to the final customers. In this situation, with power flows mainly going mono-directionally from the substations to the consumers, the Distribution System Operators (DSO) do not have the opportunity or the need to take active control of the power flows, unlike the Transmission System Operators (TSO) for the transmission grids.
When the number of distributed generation (DG) units connected to the distribution network increases, power can also be transferred reversely, from the DG units to the distribution and the upstream transmission grid, creating bi-directional power flows.
Depending on the DG penetration levels, several aspects have to be considered regarding the impact of DG on distribution networks: losses, voltage profile, system stability, network capacity and congestions, system balancing and reserve, short-circuit level, protection selectivity, network robustness and power quality.
Planning the integration of DG into electric power systems depends on the technical impact DG may have, not only on the distribution networks, but also on the upstream transmission system. In this respect, different aspects have to be considered – Spinning reserve and unit commitment, reactive power flows, network planning and reinforcement, State Estimation input, short-circuit level, real-time monitoring of DG connected to distribution grid (this being essential when disturbances occur).
In particular, DG connection may lead to the change or distortion of the voltage profiles at transmission nodes. This problem is aggravated in weak networks with long feeders and high penetration levels of DG. Moreover, if no control options are available, voltage profile fluctuation may cause problems on network operation.

DG IMPACT ON DSO NETWORK

DG units connected to distribution networks are directly related to the balance between load and generation and need to be considered when assessing unit commitment, branch congestions or losses analysis. The energy market is already prepared for this and has mechanisms to forecast and allocate an adequate number of slots on the day-ahead bidding system. This also influences the amount of spinning reserve required.
DG units production must be optimized to minimize the time for return of investment. Bi-lateral contracts between the DSO and RES owner enforces the right to inject all produced energy on the network (with the exception of periods of operational restrictions). Moreover, specific contracts can be agreed for the supply of ancillary services.
Therefore, a real-time monitoring of these units is fundamental for the operation of distribution systems. DGs are not only introduced on the SCADA system with telemetered data, status and alarms but also including their model on the network DMS model. This way, impact on power flows can be comprehensively assessed and understood by operators and network planners. This is a major advantage for the operation of distribution systems and DSOs. However, with the proliferation and incentives given by local governments, DG (mostly wind) connection to MV and HV networks has been carefully planned in terms of connection capacity and infrastructure adequacy. However, the promoter or owner of the wind park is not incentivized or enforced to share real-time information with the DSO.
With the proliferation of DG, a higher interaction between energy system operators and DG farms is required for DSOs to distribute incoming energy considering voltage regulation, power flows, losses,

electrical quality and stability [1]. The Portuguese DSO, EDP Distribuição (EDPD) has been facing a lack of information exchange problem with DG units directly connected at the MV, HV or even at the transmission level. Such connections are performed through 404 substations (HV/MV) in EDPD which receive power from 35 wind farms managed by EDP Renováveis (EDPR) and from 60 power injector points managed by the Portuguese TSO.
An interaction increase between the TSO has as main motivation the capability to receive real time information from transmission grid by retrieving active power, reactive power, voltage measurement levels and remote automation device states. Such interaction allows the DSO to perform real-time analysis to retrieved data, which will feed power flow studies determining the best operation and load balance scenario to be applied in the distribution grid, focusing on the increase of distributed generation penetration [2]. This information is extremely important for DMS functions such as optimal power flow, state estimation, network reconfiguration and self-healing strategies to assure data redundancy and accuracy.
The interaction between TSO and DSO is essential to increase the penetration levels of DG and, in order to achieve a full integration with system operation, a direct interaction between DSO and DG units would be required. In this case, a higher control of power flows in the DSO could be performed by exchanging data within substations, which nowadays connect several wind farms avoiding the tripping off all farm production when operational problems occur.

INFORMATION REQUIRED BY THE TSO

One of the main motivations of the TSO to share data with the DSO is the lack of information concerning parts of the distribution grid needed for the State Estimation (SE) and the significant amount of distributed generation on the DSO grid.
The Portuguese TSO faces the problem of lack of visibility of the 132kV network at the north of the country. The topological information of the closed loops at the 60kV network that interconnect adjacent TSO substations is also a requirement for the SE as well as the real-time data of the interconnected DSO lines with Spain. At the TSO substations the 60kV bays are operated by the DSO, but in few cases only the transformers (EHV/HV) are visible to the TSO. Additionally, there is the need to know the status/measurements of the underlying 60kV infrastructure. Therefore, the TSO SCADA/EMS operator can have the same overview over all 60kV network and in case of restoration the open/close status of the load feeders.
A better SE awareness allows to check if the DSO closed loop is secure (contingency analysis due the N-1 of EHV lines), and if it is possible to close/open the loop based on the online security assessment.

The ability of some DG units to provide reactive power support is another issue to be accounted for by both the DSO and the TSO. Not only there are periods of time when reactive power flows can be bi-directional but also some of these DG can participate on the ancillary services support and respond to reactive power set-points when needed. This is currently used by TSOs when they have voltage profile problems on the interface substations' bus-bars. In Portugal, the reactive power supply from the TSO to the DSO is subject to a specific billing system [3].

IMPLEMENTATION EXAMPLE IN PORTUGAL

This paper addresses the Portuguese case where since the 1990's, several companies started deploying small wind farms connected to the distribution grid at 15, 20 and 30kV with rated power output of each wind farm being limited to 10MW. Later, due to the increase in unitary power of wind mills, the limit of the wind farm power output was increased and the voltage level of the connections included 60kV, either at substations managed by the DSO or at substations managed by the TSO.
The DG connected to DSO substations at 60, 30, 20 and 15kV were managed by the DSO´s SCADA/DMS as "negative loads" and were ignored at the TSO´s SCADA/EMS.
The total amount of installed power associated with DG connected to the distribution grid, at the end of 2011 was over 3,000MW.
Most of those wind farms have protection schemes without "fault ride-through capability", meaning that even a small network disturbance on the distribution or transmission networks can trip the wind farms. A temporary trip in a distribution grid substation will also force all the wind farms connected to that substation to trip, meaning that, after network restoration, the load value will be much higher, due to the loss of all "negative loads" connected to that substation.
To face these challenges, an ICCP (Inter Control Centre Protocol) link between the DSO (EDP Distribuição) and the TSO (REN) was implemented by the supplier (EFACEC) of the control centre of the national distribution system. This connection enables the TSO to receive real-time information about DG connected to the distribution network. Besides, large generators (mainly wind and hydro) connected to transmission grid are directly connected using ICCP to the TSO. Therefore, the reverse situation also occurs, allowing the DSO to receive data from large DG units via the TSO system.

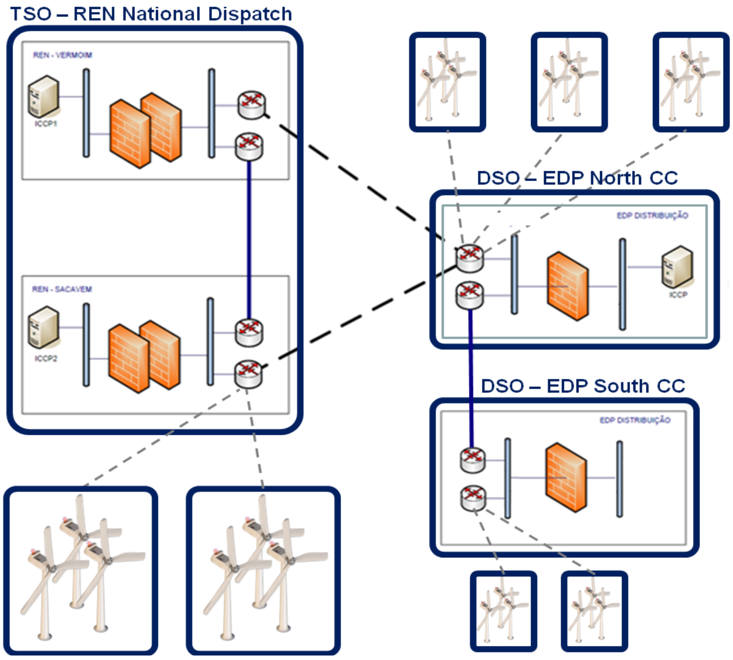

Figure 1 – ICCP system architecture

The architecture of the ICCP system linking the DSO and the TSO (Fig. 1) is redundant at the TSO side. Actually, the TSO operates the overall network using a redundant SCADA/EMS central system. This redundant configuration is spread across two locations, one in the North of the country near Porto (Vermoim site) and the other in the centre of the country near Lisbon (Sacavém site). Each location also hosts an ICCP server, also assuring the needed redundancy. There is a high speed secured link that seamlessly enables the SCADA/EMS performing on a hot-standby scheme.

At the DSO side, there are two redundant SCADA/DMS systems (supplied by EFACEC) splitting the country in half - one serving the north area of the country (Porto site) and the other serving the south area (Lisbon site). Together, both SCADA/DMS systems can backup each other, adding extra redundancy to the system, as they cope with disaster recovery requirements. There is only one ICCP server installed at the Porto site serving the entire DSO needs. In this case there is also another high speed and secured link that seamlessly brings together all data coming from both SCADA/DMS systems.

The DSO's ICCP server manages two links, one with the Vermoim site and another with the Sacavém site, according to the real time status of the redundancy scheme. These links are supported by the SDH networks of the DSO and TSO, operating at 2 Mbps.

INFORMATION EXCHANGE BETWEEN PORTUGUESE DSO AND TSO

The ICCP link between the DSO and the TSO enables the transfer of information between systems, comprising 60 substations from the TSO and 124 substations from the DSO. For adjacency reasons, data is shared between systems taking into consideration the logical coupling of each TSO substation and one or more DSO substations.

The kind of data transferred between systems is presented below:

- 60 kV bus-bar
  - U
- 60 kV bays
  - P, Q, if applicable
  - U, I
  - Circuit breakers' state
  - Switches' state
- 60 kV bus-coupler
  - State, if applicable
- DSO HV substations closing mesh between TSO injector points
- DSO HV substations receiving DG wind generation
- Information regarding substations with international connections
- EHV DSO network (132kV)

Bay analogue values (e.g. P, Q, U, I) are exchanged cyclically, every 30 seconds. State values (circuit breakers and switches) are exchanged by exception. The flow is bidirectional, bridging both the TSO and the DSO systems, as presented below:

- Between north installations:
  - TSO > DSO
    - Over 2.100 digital states of switchgear and circuit breakers
    - Over 1.400 analogues of the relevant bays
  - DSO > TSO

  - Over 4.200 digital states of switchgear and circuit breakers
  - Over 2.900 analogues of the relevant bays
- Between south installations:
  - TSO > DSO
    - Over 750 digital states of switchgear and circuit breakers
    - Over 400 analogues of the relevant bays
  - DSO > TSO
    - Over 1300 digital states of switchgear and circuit breakers

Over 1.100 analogues of the relevant bays For the purpose of serving the TSO and DSO requirements, no remote control or set-point was configured.

Using the ICCP link, the TSO can reach relevant data from the 60 kV network, managed by the DSO, which brings a clearer picture of the power flowing through the DSO network between TSO operated substations, as well as the behaviour of distribution loads and the way they affect the energy balance. Furthermore, the amount of energy being produced by the dispersed generation at the MV level is gathered at substation, by the DSO, being then sent upwards to the TSO, also improving its awareness of the energy balance.

Due to the lack of fault-ride through capability of some DG (depending on technology and regulation at the time of installation), these units will trip in case of a fault. The knowledge of the amount of DG power being fed in each substation, will allow the TSO to better estimate the load evolution in case of a temporary fault.

These features are extremely important for performing State Estimation at the TSO dispatch level and also to have a better estimation of load behaviour, especially under fault conditions.

For the DSO, the knowledge of the TSO network conditions near the interfacing points between transmission and the distribution networks, will allow the DSO to evaluate the need of reconfiguration actions in case of serious failures or contingencies occurring at TSO level.

CONCLUSIONS

DG development and deployment over the network has been incentivized throughout Europe. These connecting vary from MV to HV voltage levels and even at the transmission level. Therefore, both DSOs and TSOs need to integrate these units into operational processes. DMS and EMS applications benefit largely from information about DG units behavior and energy output profile in order to assess and mitigate potential negative consequences on the system. Only including this information on network planning and operation can DSO and TSO implement active control strategies and optimize or defer investment on assets to overcome technical bottlenecks [4].

The information exchange between DSO and TSO concerning DG connected to both distribution and transmission systems must be granted and adequately handled. A real implementation example has been detailed showing the type and amounts of information required by operational processes. Moreover, the presence of third party entities on the operation of wind parks present an increased challenge and similar methodologies must be put in place to establish links between their SCADA systems and DSO SCADA/DMS applications.

Concluding, in terms of increasing the potential for DG penetration, interchanging information between TSO and DSO is essential. In Portugal the wind penetration is very high and to improve the wind forecast, the observability of all wind generation is essential. Since 1/3 of all wind farms are connected at the 60kV network managed by the DSO, this information is critical to increase DG penetration in the distribution system.

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