NEW OPTIONS FOR CONNECTING GENERATION ON DISTRIBUTION NETWORKS AND REQUIRED NETWORK CONTROL PREPARATION

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ABSTRACT

On the French DSO (ERDF) networks, current connection studies are designed to evacuate the full production of Distributed Generation (DG) at any moment (except during incidents and construction works on the network). This leads to adapting the network in order to face a situation of high generation level that only lasts a few hours per year. By adjusting the generation level during these few hours, network reinforcements may be avoided.

As part of Smart Grid Vendée experimentations, ERDF is currently studying new options for the connection of producers as well as subsequent new MV network Control Tools to increase the network hosting capacities and optimize connection costs to prepare for future constrained situations.

On one hand, ERDF searches for technical and financial alternatives with cheaper and/or faster connection, but with limited and partial curtailments. On the other, complementary studies are being performed to prepare the new control functions in Operational Planning and Real Time Operation, along with the best compromise that would allow to optimize the network operation with the alternate DER connection rules.

This paper describes:

- *The contents of the new type of connection study. An example shows how time series for wind and solar generation and consumption help calculate the number of constrained hours.*
- *A probabilistic method is then used to estimate its variability and the volume of yearly curtailment hours.*
- *The required extension of DSO Automation and Control Tools in Real Time Operation and Operational Planning with the necessary anticipation means (load and generation forecasting tools, constraints anticipation tools, etc.) that would allow an optimized anticipated management of the generation curtailment orders.*
- *The necessary reflections on the best trade-off between the new connection rules and their optimal operational settlement...*

INTRODUCTION

The French regulation requires DSOs to provide customers with a connection solution that complies with quality and security regulatory requirements. This particularly means that the new installation should not lead to any new thermal constraints on the network to which it is connected, and also any new voltage constraints for the installation itself or neighboring ones. The *Reference Technical Solution (RTS)* proposed to the customer should be optimized in such a way it complies with the technical requirements but also has the lowest possible cost.

This regulation implies that the DSO should make sure that the thermal and voltage constraint thresholds will not be reached 100% of the time throughout the whole year. When the maximum values of the power flows and voltage are reached just a few hours every year, it would make sense to consider a *Alternative Technical Solution (ATS)* that will not take into account the related periods which represent a limited number of hours every year for network sizing, but will still cover the technical requirement most of the time. Economical analyses show that when the amount of curtailed energy is below 2 to 5%, the ATS may be interesting for the project [1].

Having a lower investment cost, the ATS should require less construction efforts if the length of new cable installation is lower, or even when new primary substation equipment can be avoided. At the same time the ATS would mean putting in place measurement and monitoring equipment to make sure the constraints thresholds are not violated and also a curtailment system that will enable the DSO to request the generation machines to decrease the output power.

Making the ATS a reality on an industrial basis requires addressing its technical, operational, contractual and regulatory challenges. Here are the main issues:

- Form the contractual principles that will enable a feasible operation and control of the generation curtailments. Ex-post verification should also made possible to make sure that both the DSO and generation site have met their commitments.
- Put in place new study tools that are able to identify the right trade-off between investment cost and the amount of generation curtailments. They will need to calculate power flows, voltage levels and also the amount of non-produced energy that will be likely to be requested by the SCADA system.
- Put in place operation and control SCADA tools that are able to monitor potentially constrained network elements, estimate the risk of constraint, and trigger generation curtailments when needed and when the risk of constraint is met.
- Form a new regulatory principle that enables the customer to still be offered the RTS, but also requests

an ATS, if the RTS does not allow the economical viability of the project.

DESCRIPTION OF CUSTOMER REQUEST AND INVESTMENT POSSIBILITIES

Smart Grid Vendee is an experimentation ERDF conducts with other partners on a large scale in the Vendee region (at the Atlantic Ocean coast). As part of the Smart Grid Vendée experimentations, ERDF is currently studying new options for the connection of producers in order to increase the network hosting capacities and optimize connection costs.

The region is facing an important development of both PV and Wind energy on the distribution network, resulting in expensive connection for the new producers which renders attractive the ATS for an actual and significant demand for a new 8 MVA wind farm.

Traditional Connection Solution

The Reference Technical Solution (RTS) proposed to the producer is designed to inject the full production of Distributed Generation (DG) at any moment (except during incidents and construction work on the network). In this case, the 36 MWA transformer of the nearest primary substation already has a 5.4 MW planned or already connected solar installations and a total of 26 MW of wind farms. The load varies between 1.8 and 14 MW, not enough to balance the 8 MW of the new producer. To avoid overvoltage constraints on existing feeder, the producer must have a dedicated feeder. Consequently, the connection solution may require network reinforcements, which means creating a 20 km long cable between the nearest primary substation and the new generation site; or add a new transformer on the substation and only a 7 km long cable.

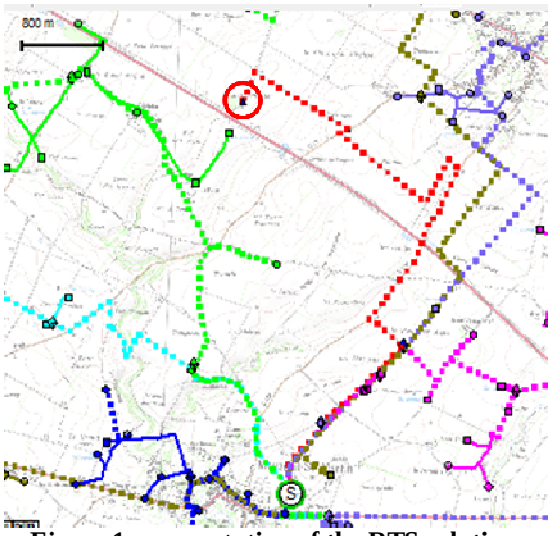

Figure 1 - presentation of the RTS solution

New customer Connexion Solution

Since constraints due to high production may occur only a few hours every year, ATS solution could be tested. The alternative solution would just consist in a 2.3km long cable with curtailments to avoid the voltage constraints on the feeder and the thermal constraints on the HV/MV transformer.

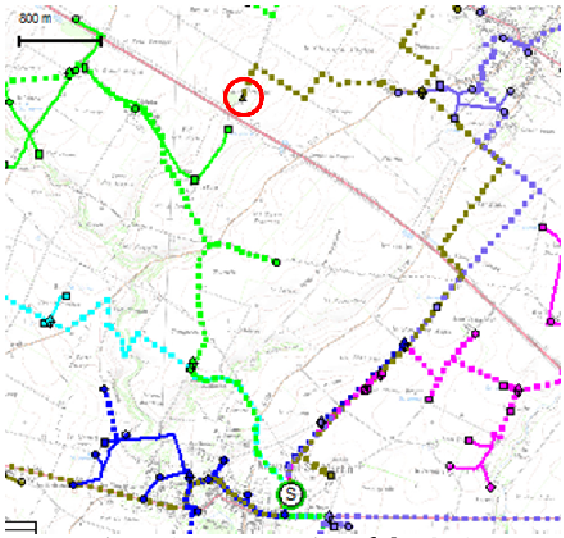

Figure 2 : presentation of the ATS

This new solution will have a lower connection cost and a reduced implementation duration. This solution can be interesting but it must be balanced with the curtailed energy .

Contractual challenges

The producer will have to choose between the following:

- The Reference Technical Solution
- or the Alternative Technical Solution with an energy limitation strategy for the new generation site.

Economical analyses show that when the amount of curtailed energy is below 2 to 5%, the Alternative Technical Solution may be interesting for the project.

Contractual principles must be provided in case power limitations requested by ERDF are not respected by the producer. Indeed, power limitation violations will generate high voltages and thermal constraints which can lead to deteriorations on the network or in customers installations.

On the other hand, contractual principle must be provided in case energy limitations exceed the commitments of ERDF.

CONNEXION STUDY

Traditional connection studies only focus on two sizing situations: one with maximal consumption and no production and another with minimal consumption and all producers at their maximal production level. The RTS

must ensure that in these two situations, no constraint appears on the network.

To offer an ATS, other situations must be simulated and their probability determined in order to guarantee a limited curtailed energy. It requires a new load and generation model and new simulation tools.

New Load and Generation Model

In the ATS, constraints are expected in period of high production. If both solar and wind production are not negligible, a 3D model for PV, wind and consumption and their synchronous behavior is needed.

Since the constraint situations are rare, average long-term forecasts are too smoothened and not accurate enough. Therefore chronicles of local producers of each type of generation, on several years are used instead. Their production is normalized with their maximal power to be applied to other producers of the same type. Since the studied area is quite small (around 30 km), the models consider that two producers of the same type (wind or PV) have a synchronous behavior. For the consumption, the approach is the same with the power measured at the primary substation decreased by the global estimated production.

The result is a synchronous model for wind and PV production and consumption at a 10 min step that can be then used to estimate the number of constrained hours and the amount of curtailed energy.

New Simulation Needs

To estimate the curtailed energy and the associated limitation duration, the studies must detect the situation when constraints appears and simulate the reaction of the control center based on the chronicles and operational constraints (precision of the grid estimator and the production and consumption forecast for example).

To avoid a load flow simulation for each moment of the chronicle, a new method developed by EDF has been used [2]. A number of predefined situations are calculated where the wind and PV production and the consumption varies from 0% to 100% with increments of 10%. At each simulation, if constraints appear, the simulation determines the maximal production of the new generation site. All the results are saved to be applied to a given chronicle.

The chronicles are then processed with these results. Each situation is linked to the closest simulated situation. With this method the calculation time is almost independent of the length of the chronicle.

To consider the precision of short term forecast, each situation of the chronicle is preprocessed: the production at any moment is increased by the incertitude of the production forecast and the consumption is decreased by the incertitude of the load forecast.

Since limitations will be sent every 30 min, the production curtailment can be maintained after the constraints up to 20 min. This leads to double curtailed energy compared to a 10 min order.

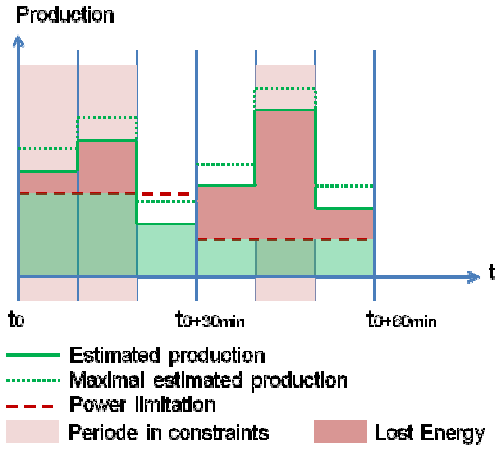

Figure 3 - Dynamic of power limitation

Once the chronicles are processed, the results show that curtailed energy can triple from a year to the other. To cover the risks of this variability a 3 year-commitment on the limitation is considered instead of a yearly one. This thus proves that this new types of simulation needs standard combined chronicles of wind generation, solar generation and temperature. Each one of these variables cannot be independently modeled any more.

THE NEW OPERIONAL PARADIGM AND THE NEED FOR OPERATIONAL PLANNING TOOLS

Once the ATS solution is implemented and since the network is not anymore sized to overcome all constraining situations that may arise due to DER generation, the MV network operational tools shall evolve so as to be able to detect constraints on the network and help to overcome them through an optimized curtailment.

In operation, constraints detection shall focus in priority on current (transit current in transformers and network feeder portions which have the highest potential consequences) and secondarily on voltage limits violation (with a priority associated to high voltage limit violation).

As far as curtailment actions are concerned, the best tradeoff shall be found between informing in advance the producers (period, level), elaborating optimized operation schedules in advance including curtailment, and finding out the way to minimize curtailed energy (with the objective of maximizing DER power injection towards energy necessary de-carbonation).

In this frame, the EDF-ERDF Cired 2015 paper entitled " A comparison of different curtailment strategies for distributed Generation" investigates different operational approaches ranging from a predefined generation limit ("so called P_{base} strategy") to an anticipated alternative ("so called $P_{forecast}$ strategy"). Even if it only examines current "priority constraints", it pinpoints the interest for

ERDF to investigate a *"hybrid strategy that takes advantage of forecast, but also of measurements to minimize the volumes of curtailed energy, whilst ensuring correct and reliable operation of the active distribution network"*

In continuation of what is exposed in the above paper, the present paper discloses the very first reflection outcomes on the operational "*hybrid strategy*», as part of ERDF Operational Planning Project which is shortly described below.

ERDF Operational Planning project

The continuous increase in complexity of network real time management, (mostly induced until now by a higher connection rate of DER but that will be boosted by Smart Grids development), forces utilities to go towards both automation of the network operation and optimized operation through anticipation (i.e. of operation and control actions on the network). The anticipation objective is not only to ensure a more efficient coordination between Network Operators and Producers, it ambitions to help utilities to make the best operational choice (combining technical and financial criteria) for operation optimization (i.e losses reduction, security and reliability enhancement and operational costs reduction) in all operational domains from the maintenance to outages management (non programmed and programmed), works planning, etc.

The ERDF ongoing Operational Planning (OP) Project identified a temporal functional core i.e middle term OP and short term OP, each based on following major functional bricks:

- generation and consumption forecasts
- operational constraints identification on a time frame (constraints detection by anticipation)
- optimization in anticipation of constraints resolution via the elaboration of a merit order of various levers.

While the Use Cases of Middle term OP focus on Works planning optimization (yearly, monthly) and typically rely on statistical and probabilistic forecasts, the short term OP use cases are dedicated to operation optimization in the vicinity of real time, real time in a "looking ahead" perspective.

In other terms, in the OP approach promoted by ERDF, new operation tools fully integrate anticipation functions and real time management.

The validity of this fully new approach for network operation, as well as its IT consequences for the utility is currently under experimentation in the frame of Smart Grid Vendee Project launched and partially financed by the French Agency for Sustainable Development (ADEME).

Focus on Forecasts: status of ERDF research program on this issue

The importance of forecasts for the OP project leads ERDF to strengthen R&D programs on this topic.

The research studies and subsequent development of consumption and generation (Wind and photovoltaic) forecasting models allowed to rapidly reach a rather high level of performance on the short term for local consumption forecasts at the primary substations (5%-7% of mean absolute percentage error (MAPE) on the D-1 to D-4 period). This is hardly the case for generation forecasts which at MV connected site reaches 20-40% of MAPE at D-1. This is really challenging for the project since the upper acceptable limit for forecast precision is around 20% so as to be able to detect constraints with a sufficient confidence level. Moreover, considering that a real increase à the forecasts precision at D-1 was mostly "out of reach", ERDF concentrates from 2015 onwards on:

- the very short term forecasts i.e. 0 to 3h in advance, domain in which the models might be considerably improved,
- Estimation of incertitude on the short term forecasts,
- Elaboration of scenario for the medium term for statistical and probabilistic forecasts.

In the following, we focus on the curtailment technique related to the aforementioned "hybrid strategy".

The curtailment "hybrid strategy" for network operation

This strategy consists in the implementation of following steps:

1. a day before (at D-1) all constraints that may appear on the next Day (D) are analyzed by OP, if among them one constraint is due to a producer with a ATS contract, and might be solved by power curtailment, the producer is informed of the potential power reduction program (starting time, values of power limitation at a 10min time step, end time).
2. On D day, OP constraints computation is launched every 30min, if a constraint is detected within the next 30 min, curtailment program is established
3. In real time, Historical storage of all power limitation orders sent to the producers is performed, complementary levers such as Voltage Centralized Control and real time curtailment could be used if non anticipated constraints appear.

The hybrid strategy presented here corresponds to the status "to date" of ERDF reflection on the subject. It

could still evolve until its implementation scheduled for fall 2016. It is issued from the outcomes on forecasts and short term OP (constraints detection tool) studies.

Regarding the real time functions namely Voltage Centralized Control (VCC) and real time curtailment, they necessitate to improve network observability in real time (via accurate voltage, P and Q sensors for VCC) whose tele-measurements shall feed a state estimator running every 30min on ERDF Control systems infrastructure. In its first version, the real time curtailment will rely on pre-estimated situations generating constraints (elaborated on planning tools)
Finally and in order to keep a sufficient consistency between network development / planning tools and Operational Planning tools, the network development tools shall emulate within their simulation function the capacity of the operational planning tools end associated real time "as a last resort functions" .

CONCLUSION

The facilitation of DER insertion on ERDF network is definitely part of ERDF strategic objectives and participates in the pace towards efficient and sustainable smart grids.

In this frame, and as part of Smart Grid Vendée experimentations launched and financed by ADEME[1], ERDF intends to implement new options for the connection of producers as well as subsequent new MV network Control Tools to increase the network hosting capacities and optimize connection costs to prepare for future constrained situations.
On one hand, ERDF searched for technical and financial alternatives with cheaper and/or faster connection, but with limited and partial curtailments. The methodology to achieve this Goal has been elaborated and implemented in ERDF planning tools. Our investigations showed that this new types of simulation need standard combined chronicles of wind generation, solar generation and temperature. Each one of these variables cannot be independently modeled any more.

It also takes into account incertitude on operational forecasts and emulates the new operational functions to be more realistic whilst offering a good risk coverage.

On the other hand, ERDF performs complementary studies and developments towards a complete renovation of operation functions and tools. These new tools in which the new DER alternate connection with curtailment are properly handled, are based on an anticipation of network operation in the frame of ERDF Operational Planning Project.

This paper also supplements EDF –ERDF paper n° 1026, conclusions [3] regarding the proper operational handling of DER alternate connection with a investigation of an hybrid solution based on both anticipation and real time functions.

1 ADEME is the French Governmental Agency for sustainable development and energy saving

REFERENCES

[1] C. Gaudin, A. Ballanti, E. Lejay, " Evaluation of PV curtailment option to optimize PV integration in distribution Network", Proceedings CIRED Workshop Lisbon 2012, paper 0050.

[2] A. Pagnetti, G. Delille, G. Malarange, A. Minaud, "Probabilistic methods moving towards the field: a tool for DG connection studies featuring the Alternatives to grid Reinforcement", Proceedings CIRED Workshop Rome 2014, paper 188.

[3] A.Pagnetti, J. Fournel, C. Santander, A. Minaud, "A comparison of different curtailment strategies for distributed Generation", Proceedings CIRED Workshop Lyon 2015, paper 1026.