FIELD DEMONSTRATION OF LOCAL VOLTAGE REGULATION ON ERDF MV NETWORK.

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ABSTRACT

Huge increase in the penetration rate of renewable connected to the distribution network has a major impact on the voltage level, and results in voltage constraints that limit its integration or lead to grid investments.

According to the French legislation (order of the 23rd of April 2008), DG (Distributed Generation) reactive power capabilities can be used to ensure that the permissible voltage variation range on the feeder is not exceeded at any conditions. Currently the reactive power demand from DG is constant and doesn't take into consideration the real network conditions.

ERDF investigates DG supplying or absorbing reactive power following a local active regulation characteristic given by the DNO as this has been enabled by the French distribution grid code and pricing policy.

CONTEXT

Due to current energy related framework conditions and technical developments, the penetration of DG in distribution networks increases continuously and it can be expected that this increase will continue in the future. The chart hereafter shows the development of DG connected to ERDF's network (about 92% of the French distribution network): the installed DG capacity has grown by nearly 300% within 11 years, mainly PV and wind farms : from nearly 5 GW in 2001 to more than 14.5 GW at the end of 2012.

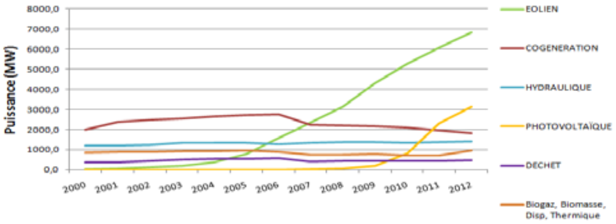

Figure 1: Evolution of DG installed capacity connected to ERDF's network since 2000

The integration of DG is therefore a major issue, leading ERDF to consider alternatives for local voltage regulation.

INTRODUCTION

A working group has been launched in 2010 between ERDF, DG producers and manufacturers to set the new local voltage regulation and its mode of enforcement into ERDF technical guidelines. The regulation developed by EDF and presented in [2] was adapted to the French distributed grid code rules. It is based on reactive power management and maintains voltage at the grid connection point within admissible limits.

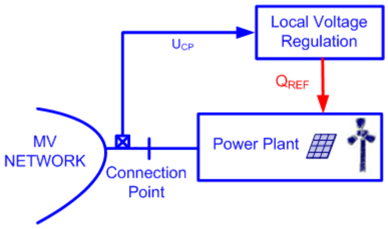

Figure 2: regulation concept
Q_{ref} – reactive power reference; U_{CP} – connection point voltage;

A new local voltage regulation system which consists in a target value set by a reactive power/voltage characteristic Q(U) has been studied last year [1]. In order to better assess the benefits and drawbacks of local voltage regulation, the onsite experimentation has been launched in summer 2012.

The field test considers a wind farm connected to the rural MV grid with low loads in the East of France. It was chosen in order to observe the impact of the local voltage regulation on:

- voltage level in the feeder,
- substation equipments,
- studied DG, in terms of reactive power demand.

Two reactive power management strategies

Two regulation characteristics, chosen by the working group, were tested:

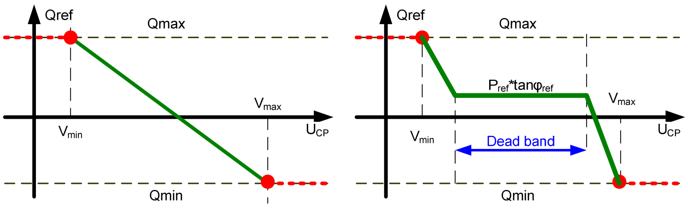

Figure 3: Reactive power management strategies: voltage droop (left) or dead band (right).
Q_{ref} – reactive power reference; U_{CP} – connection point voltage; Q_{max} and Q_{min} – reactive power limits; V_{max} and V_{min} – voltage limits at the connection point; P_{ref} - active power reference; Tanφ_{ref} - constant power factor reference

The main purpose of the regulator is to absorb the reactive power during the periods of high voltage. For other periods, it is recommended to decrease the reactive power flow.

The parameters of those both Q=f(U) strategies are going to be tested in order to define the most appropriates.

Field test grid characteristics

The tests are performed on 20 kV distribution rural grid:

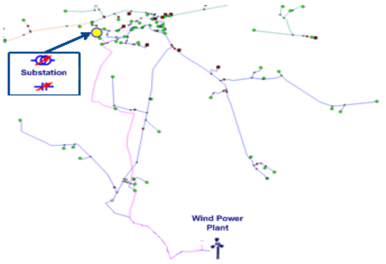

Figure 4: Wind farm connected to the rural MV grid.

The Power Plant consists of 3 wind turbines connected in the end of the feeder reported in Figure 4. Its maximum power (P_{max}) reaches the maximum admissible capacity at the point of connection. With respect to the existing French grid code requirements the wind farm works with constant power factor equal to zero.

The test grid is submitted to high voltage constraints during the period of minimum load and maximum available production. Obviously, the voltage level is preserved within the acceptable limits according to the existing requirements.

FIELD DEMONSTRATION

One month period of measurements with constant power factor was performed at the beginning. Next two periods were performed with different regulators. Furthermore, field tests with the different parameters of regulators will be continued in 2013 to define the most appropriate strategy.

1st phase: business as usual = power factor equal 0.

First measurements were completed with respect to the existing French grid code requirements. They aimed to verify existing voltage constraints and to establish the reference point for further comparisons.

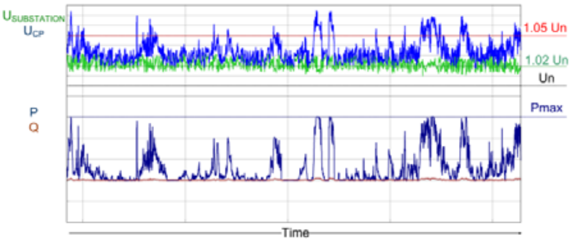

Figure 5: 1st phase of experimentation
$U_{SUBSTATION}$: Substation voltage, U_{CP}: connection point voltage
P, Q : active and reactive power of the wind power plant

On-load tap changer at HV/MV substation keeps the secondary voltage of a substation transformer at 1.02Un level with or without the production at the point of connection. Only, during the periods of high production the voltage reaches 1.08Un at the point of connection. It decreases when production is low. Loads were too low to decrease voltage significantly as the 1st phase of experimentation was performed in the summer.

The parameters of the two regulators were set up to preserve connecting point voltage within the limits 0.95Un and 1.05Un. This choice takes into account network side hypothesis and French Legislation according to the DG reactive power capabilities.

Implementation of the regulator

ERDF requires the behavior at the point of connection while the implementation of the regulator depends on the technical constraints concerning internal installation of a power plant. This part of the demonstration was thus entrusted to the producer.

Two different strategies were employed:

- Integration of the regulation into the internal control system of the power plant
- Using an external regulator that sets up a target value of reactive power and sends it to internal farm control system

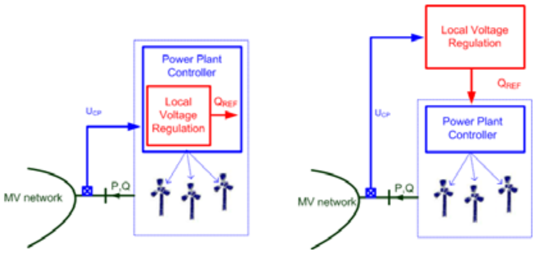

Figure 6: Control strategies employed
U_{CP}: connection point voltage, Qref – reactive power reference
P, Q: active and reactive power of the wind power plant

2nd phase: Q=f(U)

The positive role of voltage regulation was noticed as soon as it has been switched on : voltage remains lower than 1.05Un even in case of maximum power (P_{max}) injected by producer.

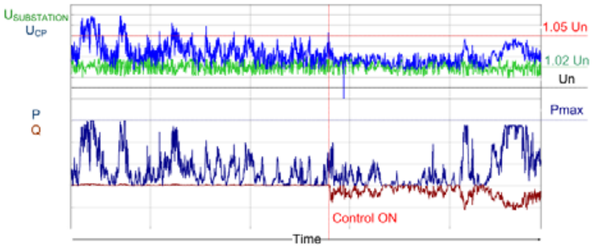

Figure 7: Beginning of the 2nd phase of experimentation
$U_{SUBSTATION}$: Substation voltage, U_{CP}: connection point voltage
P, Q: active and reactive power of the wind power plant

Voltage droop

The “voltage droop” strategy was tested as a first one. It was set up in internal control of the wind farm.

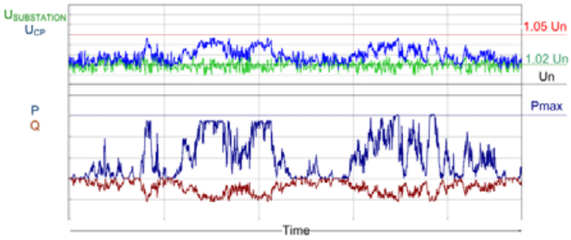

Figure 8: 2nd phase of experimentation: “voltage droop”
$U_{SUBSTATION}$: Substation voltage, U_{CP}: connection point voltage
P, Q: active and reactive power of the wind power plant

Implementation of this regulator allows to lower the voltage at the connecting point of the producer. Nevertheless, an additional capacitor bancs request was noticed because of a weak short circuit power at the substation level. This point will be analyzed during the 3rd phase of experimentation.

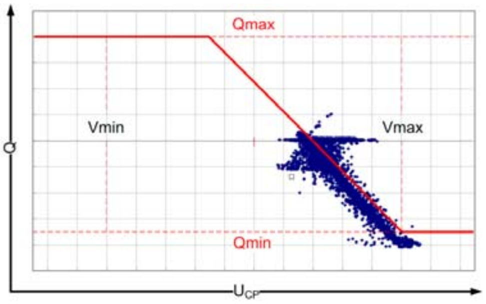

Figure 9: Voltage droop, measurements
where: Q – reactive power of the producer; U_{CP} – connection point voltage; Q_{max} and Q_{min} – reactive power limits; V_{max} and V_{min} – voltage limits at the connection point.

Besides, it was noticed that implemented regulation was not totally in compliance with the specifications given. A change of parameters is thus planned in the 3rd phase.

Dead band

The “dead band” characteristic was set up via an external regulator. As well as “voltage droop” it allows to lower the voltage at the connecting point of the producer.

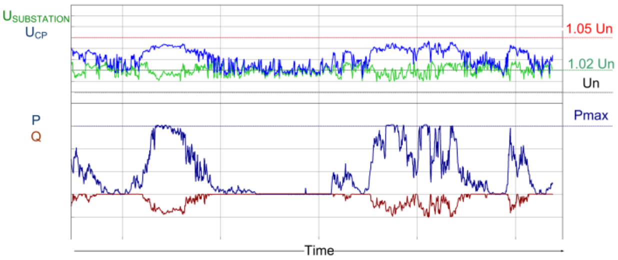

Figure 10: 2nd phase of experimentation: “dead band”
$U_{SUBSTATION}$: Substation voltage, U_{CP}: connection point voltage
P, Q: active and reactive power of the wind power plant

It enables the DG plant to adapt its reactive power demand only while high voltage constraints occur at the point of connection and therefore to optimize local voltage management together with the DG reactive power demand. As shown in Figure 10, low production doesn’t increase the voltage over the dead band limit of the regulator and the local voltage regulation would not demand a contribution in reactive power of the producer in that case. Therefore, the strategy with “dead band” enables a decrease of reactive power demand in comparison with “voltage droop”.

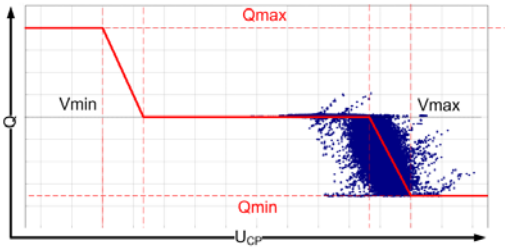

Figure 11: Dead band, measurements
where: Q – reactive power of the producer; U_{CP} – connection point voltage; Q_{max} and Q_{min} – reactive power limits; V_{max} and V_{min} – voltage limits at the connection point.

Nevertheless the producer was in ‘dead band’ range only about 10 % of the time. The hypothesis that the producer may regulate the voltage only when production exceeds 20% of the P_{max} was taken into account to calculate that value.

Besides, an important dispersal of the points of presented U/Q diagram was noticed. The time constant of the regulator as well as the width of ‘dead band’ are going to be tested in order to define their influence and find the most appropriates during the 3rd phase of experimentation.

3rd phase: Q=f(U) with modified parameters

The analysis of the 2nd phase results indicated some interaction between the local voltage regulation and the substation equipment. Otherwise the control strategy and different regulator parameters have to be analysed.

Therefore, to define the most appropriate local voltage regulation the field tests are still performed.

The measurements will be compared with simulation results of the experimentation grid with the dynamic behavior of grid devices, like on-load tap changers and substation capacitor banks included.

IMPACT OF LOCAL VOLTAGE REGULATION ON DG AND THE DISTRIBUTION NETWORK

This paper establishes a first report which describes the implementation and the basic results of the performed field test. This work continues in 2013, including the results of the 3rd phase. Though, only several conclusions corresponding to the technical feasibility and implementation of an operational solution are given below :

Voltage regulation

Using new local voltage regulation at the MV producer’s level allows the preservation of the voltage level in the network within the acceptable limits with both U/Q characteristics employed.

Obviously in presented case, it would be also a case with a constant power factor equal Q_{min}/P_{max} where Q_{min} corresponds to the regulator’s minimal reactive power limit. As a matter of fact, local voltage regulation brings in an active contribution of the producer according to the real time voltage constraints. The participation of the producer depends on voltage constraints at its point of connection and not on active power injection what may optimize local voltage management together with the DG reactive power demand.

Impact on reactive power demand

The strategy with "dead band" enables a decrease of reactive power demand in comparison with "voltage droop". Nevertheless, in presented case, the voltage is in the 'dead band' range only 10% of time. As a matter of fact, the load impact is very low in presented field test. Loads are low and P_{max} of connected power plant exceeds significantly maximal load of the feeder. Therefore, loads don't decrease voltage at the point of connection.

Impact on grid assets

The impact resulting from reactive power modulation on existing grid components was analyzed. Local voltage regulation may indeed affect devices like on-load tap changers and capacitor banks at HV/MV substations. Nevertheless, it is important to note that the producer which regulates the voltage near the point of connection can't replace the DSO for voltage control in the network. Substation equipment behaves to answer to the voltage constraints in presence or not of the local regulation at the producer connecting point. As a matter of fact, local voltage regulation may temporary disturb substation behavior and that's why an appropriate choice of regulation parameters will be performed before implementation of this solution into ERDF technical guidelines.

CONCLUSIONS & PERSPECTIVES

The comprehensive study [1] performed in 2011 has shown that the Q(U) characteristics has the advantage among 'constant power factor', as it enables the DG plant to adapt its reactive power demand in function of actual voltage constraints at the point of connection. Moreover, this regulation is resilient as regard to the network structure and possible evolutions, and the seasonality of the actual approach.

As the implementation of local voltage regulation requires field tests to define the most appropriate solution the onsite experimentation has been launched in 2012.

The first results confirm that using new local voltage regulation at the MV producer's level allows the preservation of the voltage level in the network within the acceptable limits as well as the optimization of the DG reactive power demand. Nevertheless an interaction between the local voltage regulation and the substation equipment was also observed. Therefore, the impact of control strategies and variations of regulator parameters have to be analysed.

Though the field tests on presented grid and wind farm are still performed (2013). In order to better assess the local voltage regulation impact on other DG connected to the MV distribution network and confirm the results of the first demonstration, another onsite experimentation will be launched in summer 2013. Two PV farms connected to the same MV feeder in the South of France are concerned. First of all, the implementation of local voltage regulation will concern the case with one or two power plants connected to the same feeder in order to limit the implementation to what ERDF would have experienced and to limit the impact of producers previously connected with reactive power management through constant power factor.

It is also necessary to complete a full technical-economical analysis of the implementation of local voltage regulation. Indeed, according to the current French DSO technical requirements for network connection, DG is required to operate with a constant power factor without taking into account the real network conditions. Consequently, connection studies should be revised, to determine in which cases the two regulation modes (dynamic regulation and constant power factor) are compatible or not and define applicability cases for the local voltage dynamic regulation (and if need be, the impact on producers already connected with constant power factor).

Whereas the present guidelines require reactive power management only in case of voltage constraints, this local voltage regulation only makes sense when the full reactive power capabilities of DG, as defined in the French distribution code, are installed from the connection of the plant to the distribution network. The fitting of the full reactive power capabilities might have an impact on the cost of the DG plant, but it would also maximize the network capacities. Though the DG producer and manufacturer prepare their analyze to establish a full list of benefits and drawbacks and choose one solution that will be operating and acceptable for all.

Local voltage regulation is one process to implement before centralized voltage management which consists in state estimators calculating optimized voltage target values at the substation. The local regulation managing the DG reactive power solicitation to maintain the voltage between contractual thresholds will be a first step towards an optimized RES integration strategy.

Then combined voltage regulation with local voltage regulation at connection point and centralized voltage regulation at the substation level will be tested.

REFERENCES

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[2] J. DUVAL, G. DELILLE, JL. FRAISSE, X. GUILLAUD, 2009, "Contribution of a local voltage regulation to a better insertion of DG in distribution grids" *CIRED 2009*, paper 0489