POSSIBLE ROADMAPS FOR NEW REQUIREMENTS FOR FRENCH DISTRIBUTION CONTROL AND AUTOMATION

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ABSTRACT

Three main drivers are reshaping the roadmap for new requirements for French Distribution Control: the growing presence of distributed generation (DG) on the Medium Voltage grid, the development of automated metering management (AMM) and the continuing need to optimise operational costs.

Improved observability, control and automation can bring value at the planning and operational levels for all the actors present on the system (generation parties, DSOs). We identified short-term challenges (the limits of the fit and forget approach on the transmission system, the optimisation and forecast of substation loads in the presence of DG, the optimisation of losses, the improvement of post-fault customer restoration) and also long term challenges (coordinated voltage control to lower DG connection costs).

The paper describes the possible roadmaps in terms of distribution automation and the new tools and equipment that will be needed in the control centre, in the substation and at the DG facilities.

INTRODUCTION

The contextual environment of DSOs is evolving and technological innovations have made necessary to reevaluate the roadmap of distribution control and automation. Three main drivers are reshaping the roadmap for new requirements for French Distribution Control:

- The growing presence of DG on the Medium Voltage grid has been treated up to now by fitting the Medium voltage grid and the DG units to guarantee a satisfactory operation of the system at all times. The DSO would operate the grid with very limited knowledge if not no knowledge at all of the real time state of DER units. We are expecting this approach to reach limits in the future.

- The development of automated metering management (AMM). These new technologies provide new data, a communication infrastructure, and will probably trigger some new behaviours of the loads.

- The continuing need to optimise operational costs. The tendency has been to consolidate control centres, operational teams.

Improved observability, distribution automation (DA) and control and automation can bring value at the planning and operational levels for all the actors present on the system (generation parties, DSO).

CONTEXTUAL ISSUES

Metering and Development of a New Market

Automated metering technologies are getting more affordable for utilities and likely to bring value for the DSO metering activities and the energy suppliers. A new metering infrastructure brings a new communication infrastructure and richer customer data. These infrastructure investments are an opportunity for DSOs to have new means of communication for sensors, reclosers, switches. From the present 90 000 remotely readable and controllable points, the AMM infrastructure could offer up to 500 000 new points.

AMM technologies also offer new opportunities of energy optimisation by giving the possibility of adjusting load demand. Customer data is an opportunity to observe better the real time load of MV/LV transformers and therefore to perform local energy optimisation. The ability to communicate with equipment on the customer premises will enable demand side management techniques, allow the reduction of peak demand and bring opportunities to enhance grid operation possibilities.

The Reinforcement of Technical and Economical Constraints on Distribution Grids

Increasing expectations of customers, regulatory bodies, local governments, the aging of assets, the new occurrence of peak loads in summer time will increase the constraints on the distribution grid. The development of DG can release some constraints but can also increase the constraints (voltage constraints at the end of long feeders, powerflow constraints when major loads are not close enough to a generation site). In the long term, the peak load may be increased by new loads like heat pumps, or rechargeable hybrid vehicles. This may lead to new ways for the distribution system to deal with peak demand (send broadcasted or individualized signals to customers about peak time or low load time periods, implementation of different connection contracts depending of the load curve).

Asset Aging and State of the Grid

The development of condition-monitoring techniques will also help to better assess the state of the grid and to better evaluate its limits. This will enable to adapt maintenance, to enrich the observability of the grid in real time operation.

Improvement of the performance of the teams of control engineers

The size of distribution systems that a control centre monitors and controls gets bigger. This usually implies that a single control engineer will have a higher number of substations and circuits to control: he will have a harder time to memorize the specificities of each individual feeder, and in case of multiple simultaneous disturbances it will take him longer to respond and give the right restoration commands. Automated functions can take care of simple and already known situations that happen with a higher frequency.
The development of DA will be an efficient mean to address these constraints by providing more automated post-fault restoration procedures. It will also help better use the flexibility of DGDG in the operation of the grid (coordinated voltage control, power flow optimisation, operation closer to the physical limits) in order to use the grid capacities as much as possible and in a more linear way; this will discussed later.

Deployment of Distributed Generation

DG units installed in the last ten years have mainly been industrial CHP production facilities, and wind energy, knowing that the stability and the security of the grid is still based on centralized generation.
Wind generation reached 1.8 GW installed power in France at the end of 2006. This brings new challenges in terms of powerflow congestion, voltage quality, short circuit power, spinning reserve, stability.
Initially, these generation means were installed by fitting the distribution grid to the presence of generation units in order to ensure normal operation of the distribution grid is safe, but few considerations regarding the sub-transmission or transmission grids are taken into account today. The intermittent and unpredictable nature of these generation means have to be included in the way the whole system (distribution and transmission) are planned and operated.In certain regions of southern France, subtransmission systems may not have sufficient capacity in some N-1 situations. A more economical integration of DER into the grid requires an evolution of the present practices and organisation of the power system. The aggregation of controllable DER will be a way to improve the situation.

FUNCTIONAL NEEDS

Dealing with HV Congestions (63 & 90kV)

The fit and forget approach on the transmission system, and the associated costly investment on HV networks cannot always be justified. In windy regions with scarce loads the power injection can reach peaks that lead to congestions on the HV system; this situation requires limitations of the DG power injection at the MV level.
By adjusting in real time part of the generation and loads, distribution and transmission grid assets would be used better. The traditional grid planning philosophy consisted in installing capacity to meet the demand at the summer and winter peak times. Demand side management techniques open the possibility to build a grid for demand levels that would be lower than the natural peak demand, provided that some loads can respond to congestion or price signals. The sub-transmission systems (63kV and 90kV) and transmission system (225kV) in some regions of southern France are facing congestions in the future years: adjustable generation and load will be an alternative to grid development.

Forecast and Optimisation of Substation Active and Reactive Power Flows

The presence of DG units on the MV system adds uncertainty on the total active and reactive power flows seen on the primary side of HV/MV transformers. Variations in DG active and reactive power output can move the system from its optimal point that is calculated every year in order to prepare the next year contractual values with the TSO. When active and reactive flow exceed contractual levels, EDF Distribution has to pay penalties to the TSO. In order to control the flows between the TSO and our primary substations, it will be necessary to forecast, then monitor closely and control the DG active and reactive power injections.

Towards a Coordinated and more Automated Volt/Var Control

Additional grid automation can provide a finer optimisation of grid losses. Grid configurations are usually optimised using peak demand situations. When connecting DG, the VAR flows are not optimised: a coordinated VAR control of generation and substation would ensure that the generated and consume VARs are optimised. The value of a coordinated VAR control will increase as the presence of DG increases. These systems will involve monitoring and control of capacitor banks and/or voltage regulators on distribution circuits.
We expect this function to reduce the cost of fitting the grid when MV generators are installed on long feeders by around 150 to 300k€ per feeder.

Towards a more automated post-fault restoration

When a fault occurs on an MV feeder, the control engineer downloads data from fault passage indicators, locates the remotely controlled switches that need to be open to isolate the fault and then performs the fault isolation. Usually power can be restored on the healthy segments in the upstream part of the feeder. Downstream from the fault, restoration is usually possible in N-1 conditions. These actions are usually taken within three minutes, thus keeping the number of long interruptions low. When power to a whole busbar or a whole substation is lost, or during storms, restoration is a far more complex operation. The presence of DG makes the evaluation of the restoration more challenging as well if the control engineer wishes to use the DG capacity when backup feeders do not have sufficient capacity. The number of solutions that need to be evaluated can be far greater.

Innovation in DA automatic uploading of fault passage indicators, automatic localization and isolation of faults, automatic restoration of healthy feeder segments, integration of DG capacity in restoration schemes can bring significant value in these situations and specially as the number of substations per control centre increases. By providing a significant help to the control engineer in improving his reaction to faults, the control engineer can handle a bigger number of substation. This is particularly valuable at night or during storms.

The value will eventually be for both customers and DER owners who will benefit from a higher grid reliability. We expect these improvements to reduce the customer minutes lost by 2 to 5 min depending on the region of France.

The challenges for these innovations are mainly in the quality of topological and load data, and also in the quality of the communication with DER units, and the robustness of the optimal solutions proposed when DER units are included in the restoration schemes.

Towards a Control Center fully integrated in the DSO Information System

Real time data available in substations, feeder switches and breakers, fault passage indicators, power quality recorder will be very valuable for many applications across DSO activities. Real-time information can be used to automatically generate power quality reports, and provide data for asset management applications (discussed later). Likewise, data from customer call centers will be valuable for the control centers to improve response time to faults.

Distribution System Real Time State Estimation and Control

The automation functions described above will need to incorporate systems that can process data from monitoring throughout the distribution system to continuously assess the state of the system, identify opportunities for improved efficiency, and implement configurations to minimize the risk of outages. These systems will integrate existing and more advanced metering systems and also real time models of the distribution system. While this type of technology , called state estimation, is used throughout transmission systems, it is not yet applied for distribution systems. Existing Scada systems provide control engineers with the image of the current flows and voltages at the HV/MV substation. Beyond the substation, very little is usually available. Presently, fault indicators, sectionalizers and remote switches data is uploaded at the control centre, and using the MV/LV transformers rated power, and the feeder current flow at the substation, the current flows along the feeders are roughly estimated.

In order to build a real Distribution State Estimation (DSE), additional measurements coming from available or new remote sensors will be needed, such as secondary substation transformer loads (using load profiles), and data coming from DG units (active and reactive data, operational data). There are two mathematical challenges: using both measured and profiled data, and filtering noise, eliminating bad or incoherent data. The DSE will also enable the DSO to optimise the number of sensors and their location.

Advanced Asset Management Systems

State estimation techniques will help building a history of the constraints of transformers, cables breakers, capacitors, regulators, arresters. This will be particularly useful to :

- characterize the condition of equipment on the distribution system,
- provide data to predictive maintenance applications,
- determine remaining lifetime of equipment based on many factors,

Equipment condition information will be incorporated into decision making tools for system configuration and real time grid control.

DISTRIBUTION AUTOMATION ROADMAP

Five-year time frame

In the next five years, innovations in distribution innovation will be based on the philosophy of centralized control with the following goals (see Table 1):

- create as much value as possible by using already available data,
- incorporate DER units in control centre functions (particularly restoration),
- incorporate new possibilities from new AMM equipped customers,

Table 1 : Possible DA Innovations in 5 years time

Context	Distribution Automation Innovation
DER&RES	• Adaptation of fault localization, post-fault restoration and voltage control • Monitor and control DER units • Participation of DER units in critical MV grid situations • Optimisation of load flows and losses taking into account local generation
Grid performance	• Automated post-fault restoration in 80% of the situations • Automated power quality reports • First deployments of more precise fault localization techniques • Integration of the cust. call centre & control centre
AMM	• Improvement of fault localization by automatic uploading of most fault passage indicators

Ten-year Time Frame

As control centres are being consolidated and control centre functions (fault localization and isolation, feeder restoration) are being progressively automated, a new trend will be put into action: the redeployment of the automated control functions in the substation and along the feeders (see Table 2). This will bring:

- new possibilities in terms of optimisation of the flexibilities of load and generation (probably not technically available right away),
- a significant improvement of the robustness of the grid,
- an improvement of the customer minutes lost.

Table 2 : Possible DA Innovations in 10 years time

Context	Distribution Automation Innovation
DER&RES	• Integration of DER units in grid planning in selected circumstances • Significant presence of LV DER units in some areas
Grid performance	• First deployments of local automation functions along the feeders. • New trend : control engineer more focused on anticipation and less on reaction. • High frequency signals, such as BPL, to identify equipment problems and condition • Industrial use of condition monitoring applications • First estimations of life time of grid equipment
AMM	• All meter data available for control functions. • Improvement of load modelling, with a more local detail specially for control engineers • Load demand is part of grid planning. • A significant number of MV switches is now remotely operated.

Twenty to Twenty Five - year Time Frame

In a twenty to twenty-five year time frame, the innovation would likely be a local coordination of load, generation, and demand response for distribution operation (see Table 3).

Table 3 : Possible DA Innovations in 20 to 25 years time

Context	Distribution Automation Innovation
DER&RES	• New trend : new MV grid architectures on grids with a very high penetration of DG. • First MV grids operating in islanding mode.
Grid performance	• Local automation along the feeders widely deployed. • New trend : control engineer more focused on anticipation and less on reaction. • Use of power electronics. • Full integration of MV and HV control functions. • Predictive maintenance applications. • Real-time use of reliability calculations
AMM	Coordinated load adjustment with transmission level applications.

This would involve load and generation optimisation and control to prevent distribution system overload, to optimise circuit restoration or reconfiguration. Dynamic pricing could be a powerful means to achieve these constrained optimizations.

This evolution should happen before large deployments of microgrid techniques that will require affordable small size storage and is more likely to be deployed in 40 to 50 years.

CONCLUSION

DA offers new margins to improve the performance of Distribution operation and control. Improved observability, control and automation can bring value at the planning and operational levels for all the actors present on the system (generation parties, DSO). We identified:

1/ Some short term issues:

- The limits of the fit and forget approach on the transmission and sub-transmission systems. The recent experience shows that the fit and forget approach is not always chosen for HV systems: in windy regions with scarce loads the power injection can reach peaks that lead to congestions on the HV system in certain conditions; this limitations reduce DG output.
- Optimisation and forecast of substation loads. The presence of DG units on the MV system adds uncertainty on the total load seen at the substation busbars, and can lead to penalties.
- Optimisation of losses. The presence of DG units also has an impact on the active and reactive loads that moves the system from its optimal point.
- Improvement of restoration of MV and LV customers. Improved observation will enable to take faster action (remote or not).

2/ And long term issues:

- Fit and forget approach on the MV grid will reach a limitation in the future particularly for the voltage levels along the feeders.

We identified a possible roadmaps that address these issues. On the long term we can expect:

- A more local treatment of distribution control functions. The control engineer would focus more on anticipation and less on reaction. On the contrary, substation and switches IEDs would take the responsibility of reaction “reflexes”.
- A more integrated optimisation of load and generation flexibilities at the local level.

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