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Technology unveiled

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Distribution substation instrumentation and control system

An essential component that sits at the heart of a smart grid

The European Union's 2020 *climate and energy package* (20% of EU energy from renewables, 20% improvement in energy efficiency and 20% cut in greenhouse gas emissions) led to the rapid development of electricity production from intermittent sources (wind, solar photovoltaic), which is undoubtedly the biggest change to have affected power systems over the past five years. In France, installed wind power capacity rose from 3.5 GW at the beginning of 2009 to almost 8 GW at the end of 2013. Over the same period, installed photovoltaic energy capacity increased by a factor of 50 (4.5 GW in 2013).

The emergence of renewable energy sources, as well as new uses of electricity (heat pumps, electric vehicles), the management of consumption peaks and the desire to constantly improve service quality led to the development of new smart systems, particularly within the distribution grids.

This resulted in the emergence of the 'advanced management of distribution networks', which is an essential part of a smart grid and concerns both real-time operations as well as the anticipation of critical situations.

The advanced management of distribution grids

WHEN DISTRIBUTION GRIDS ADAPT IN REAL TIME TO DISTRIBUTED GENERATION AND EMERGENCY SITUATIONS

Whether in France or any other country in the world, the advanced management of electric distribution networks aims, in particular, to:

- reduce the length of power cuts by reconnecting the supply of power to as many customers as possible and as quickly as possible following an incident;
- increase the capacity of networks to accept electricity produced from renewables, while maintaining the supply voltage within its regulatory range.

While the first aim is clear, the second requires further explanation. The production of electricity from renewable energy sources has two major characteristics: on the one hand, it varies in accordance with the weather and, on the other, it is scattered throughout the country and mostly connected to medium voltage ('MV' - 20,000 V) and low voltage ('LV' - 230 V) distribution networks. Furthermore, historically, the power grid was designed to receive electricity production further upstream, on the transmission network. However, any form of electricity production increases network voltage at the place where incoming power is connected. If ignored, this would lead to unacceptable fluctuations in the voltage supplied to customers and even power cuts. Voltage management has therefore become a key challenge for the distribution networks.

Networks that are already smart!

In France, ERDF automated the management of MV networks in 2009 to reduce the length of power cuts following an incident. Work continues: the EDF Group is one step ahead thanks to its smart-grid research and platforms. The Group also plays an active role in life-size smart-grid demonstrators, whose purpose is to test new advanced systems that facilitate the integration of distributed generation.

Olivier Devaux, Networks programme project manager, EDF R&D, RISEGrid Research Institute deputy manager.

THE PRINCIPLES BEHIND THE ADVANCED MANAGEMENT OF DISTRIBUTION NETWORKS

Increasingly smart power grids

LIKE RAILWAYMEN WHO OPERATE SIGNAL BOXES, DISTRIBUTION NETWORK OPERATORS MONITOR AND MANAGE THE POWER GRID

Reducing the length of power cuts following an incident

MV distribution networks are made up of numerous bundles of overhead power lines and buried cables ('outgoing feeders') which leave primary substations and are intersected by secondary substations and switches. Distribution network operators, like railwaymen who operate signal boxes, manage the network's switches to alter electricity supply routes. To supply power to a secondary substation and its LV networks, there are several possible routes. In the event of a fault on the MV network (for example, a short-circuit), power may be re-established for a large share of customers by activating these switches. The automation of the search for the best routes - known as optimal reconfiguration - (while complying with multiple constraints such as protective devices and maximum line or cable current load) and the actions necessary to establish these routes is quite a recent technique that has significantly reduced the length of power cuts and allowed operators to respond more effectively to storms when incidents last several hours and affect a large area. Optimal reconfiguration still offers important development opportunities, such as the search for the best supply routes while considering distributed generation, or the optimisation of the power flow between distribution and transmission networks.

Managing voltage to increase distributed generation hosting capacity

The connection of an energy production site increases network voltage at a local level. In order not to exceed contractual voltage levels, the connection of a MV producer may require the creation of an additional outgoing feeder - known as a dedicated feeder - which leaves the primary substation. However, depending on the remoteness of the site, the cost of the operation can be quite high. Nevertheless, it may be inevitable if the existing feeders do not have enough capacity to cope with excessive production.

Among the wide range of smart grid functions, advanced voltage management offers an interesting alternative solution by increasing the capacity of existing outgoing feeders that are already supplying power to other customers. To manage the voltage, the operator has a smart and centralised system that has various levers:

- lower the voltage of the primary substation to offset the voltage increase due to generation; however, this affects the voltage of all of the other feeders (action A in the diagram);
- ask the producer to absorb some reactive power; this action lowers the voltage at the local connection point. However, it increases electrical losses on the network (action B in the diagram);

KEY POINTS

1960s: Water heaters are subject to off-peak pricing signals sent via the power grid: a first step towards smart grids.

2010: ERDF rolls out Advanced management functions ('FAC'), which automate the re-establishment of customer power supplies following a fault.

2012: launch of the Flexible Plug and Play demonstrator in the UK.

2013: launch of the VENTEEA demonstrator in the Aube département (France).

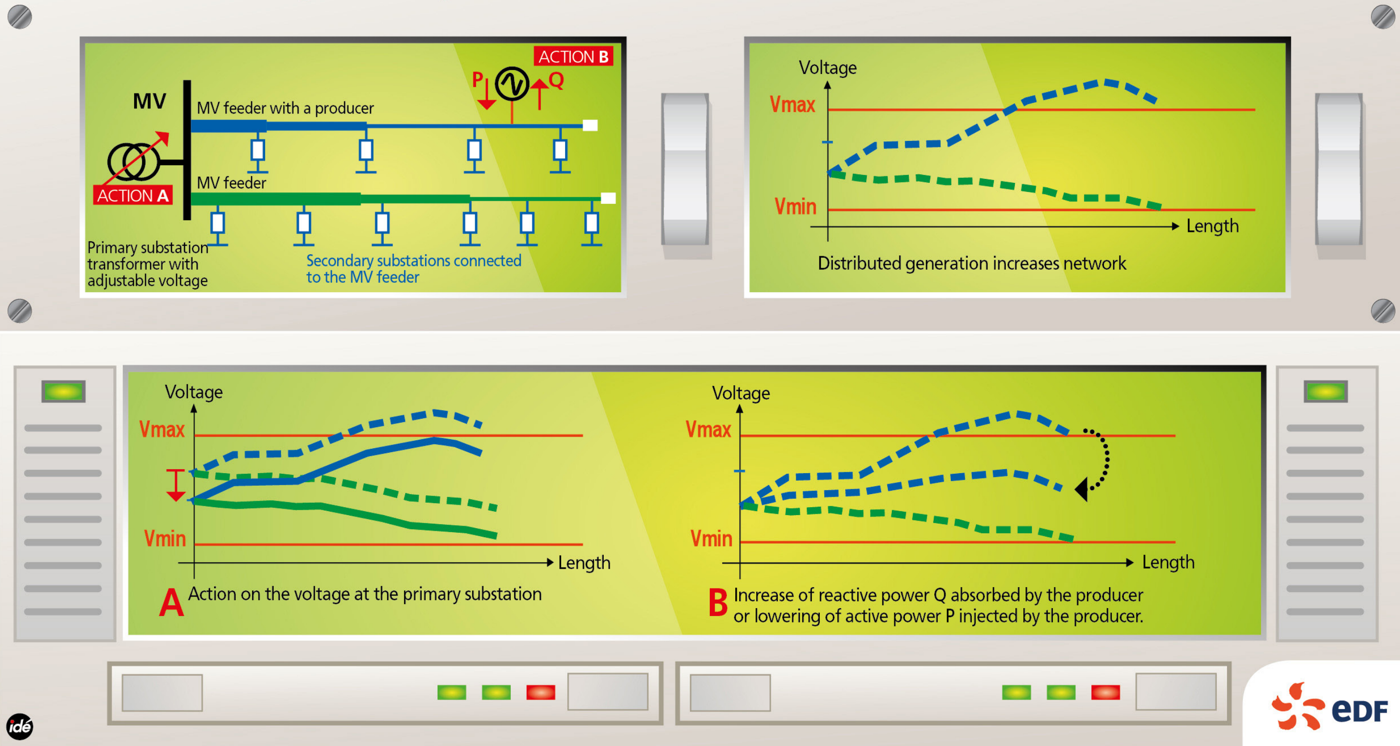
ERDF'S POINT OF VIEW

The implementation of the optimal reconfiguration system has transformed the management of MV distribution networks. Work continues: within the VENTEEA demonstrator coordinated by ERDF, we are testing centralised voltage management processes to facilitate the integration of renewable energy sources. In the future, forecast management, which we are developing in certain demonstrators, will respond to changes in use (electric vehicles, load shedding, etc.) and in local energy sources. Linky smart meters also represent a great opportunity for new advanced management and operating tools.

Current and future progress is attributable to our R&D programmes and the ability of our technical teams to undertake innovative projects.

Pierre Mallet, Technical strategy and innovation director at ERDF

Centralised voltage management on MV networks



DID YOU KNOW ?

In France, the total combined length of the country's distribution grid is 1,250,000 km.

On these networks, electricity is supplied by primary substations (connected to the high-voltage power network) at 20,000 V. It is subsequently decreased to three-phase 400 V (namely, 230 V between the two conductors of your socket) to provide LV power from secondary substations.

In France, on 30 September 2013, there were 1,187 wind farms with a total installed capacity of 7,821 MW; most of these sites were connected to MV distribution networks. There were also 309,929 PV production sites (4,478 MW), which were mainly connected to LV networks.

- ask the producer to lower the active power that is being injected; this action also lowers the voltage, but at the expense of the energy produced (action B in the diagram).

Thanks to this new smart function, connection to an existing outgoing feeder is now possible and costs far less than a dedicated feeder. The effectiveness of this function is further enhanced when the producers are involved in the adjustment of the voltage.

To implement this centralised voltage management system and to compute the instructions to be sent to the various levers, voltage sensors have to be installed on the power grid. However, increasing the number of sensors to have a complete view of voltage levels would not be financially viable. To fulfil this role, another advanced function comes to our aid: state estimation.

Distribution network state estimation

This function could be described as a pair of binoculars which allows the operator to examine the voltage level on any point of the network. However, it is more than that: using a small number of sensors, this function is able to produce an overview of the voltage on all of the primary substation's outgoing feeders while taking measurement errors into consideration. Although built on complex mathematical algorithms, EDF R&D has demonstrated the feasibility of this new advanced function on the distribution networks: today, we can estimate the voltage of the entire network fed by one primary substation with a measurement error of less than 1%.

Real-life tests prior to roll-out

To test the smart grid of the future, the EDF Group is involved in several demonstrators. Here, we mention two demonstrators that focus particularly on voltage management and the participation of producers:

- the VENTEEA demonstrator in France, managed by ERDF with the support of ADEME. Installed in the primary substation of Vendeuvre sur Barse (Aube département), it tests state estimation and voltage regulation functions with the participation of a wind energy producer;
- the Flexible Plug & Play demonstrator in Cambridgeshire (UK), with the support of Ofgem. To manage the voltage, it tests the modulation of the active power injected by producers.

The advanced management of smart grids has a bright future

While smart grids are, to a certain extent, already a reality, energy producers and network operators have new smart functions up their sleeve to deal with the challenges posed by intermittent energy sources and the increase in electricity consumption. Over the next few years, the advanced management of distribution networks will adopt new tools:

- forecast management: this solution will stand between the network management systems, which control the network in real time, and planning studies, which prepare long-term changes to the networks (10 to 20 years). Forecast management will allow critical situations to be detected several hours or days in advance and will put forward solutions automatically. It will also facilitate the preparation of works a few weeks or months in advance;
- demand-side management: managing consumption peaks is essential as such peaks dictate the size of the electrical system and its cost to the community. The first demand-side management systems date back to the 1960s, when water heaters became subject to off-peak pricing signals.
- A new and more flexible generation of demand-side management solutions could emerge thanks to Linky, the smart meter. For example, in residential areas where photovoltaic energy production increases the voltage of the LV networks, water heaters could be switched on when solar energy is being produced.
- Finally, the development of the electric vehicle, which has been announced, should further increase demand and constraints on the distribution networks. Management of the various battery-charging methods (fast or slow, scheduled) could therefore also become a new advanced function.
- Management of battery-based storage: still at an early stage, electrochemical storage could play an important role in the networks, particularly on islands. In 2011, EDF launched the Millener demonstrator to test new smart grid functions that combine photovoltaic panels and batteries in Corsica and Réunion. In mainland France, the NiceGrid demonstrator is developing the concept of a smart solar neighbourhood that incorporates electrical energy storage.

> for more information

VENTEEA demonstrator: http://www.venteea.fr
Flexible Plug and Play demonstrator: http://www.flexibleplugandplay.co.uk/
Millener demonstrator: http://www.millenercorse.com
NiceGrid demonstrator: http://www.nicegrid.fr
Concept Grid smart electrical systems laboratory: http://chercheurs.edf.com

Lexicon

Watt (W): International unit of power. Corresponds to the energy consumed or generated in a given time (one joule per second).

Megawatt (MW): 1 million watts. Corresponds to the energy consumption of 100,000 low-energy 10W light bulbs.

Gigawatt (GW): 1 billion watts. Corresponds to the average electrical output of a nuclear reactor.

MV: medium voltage: 20,000 V in France.

LV: low voltage: three-phase 400 V / single-phase 230 V.

Primary substation: a medium-voltage electrical installation made up of transformers that are connected to the transmission network and lower the voltage to 20,000 V to supply power to the medium-voltage networks. There are 2,200 primary substations in France.

Secondary substation: an electrical installation made up of a transformer that is connected to the medium-voltage network and lowers the voltage to supply power to the LV networks. There are 750,000 in France.

Network interrupter: A device that cuts off power on medium-voltage networks. In France, there are 105,000 that are remotely controlled by management operators.

Active power: in alternating current, it is the electrical power that can be used (for example, it can be converted into mechanical energy). It corresponds to the alternating current component in phase with the voltage, multiplied by the latter.

Reactive power: Reactive power is 'fictitious'. It corresponds to the alternating current component in quadrature with the voltage, multiplied by the latter. The injection or consumption of reactive power tends to increase or decrease the voltage.

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