CONCEPT GRID: A NEW TEST PLATFORM FOR SMART GRID SYSTEMS GENERAL PRESENTATION & EXPERIMENTS

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ABSTRACT

Concept Grid is a new laboratory dedicated to the test and validation of smart grid equipment, systems and functions. It has been set-up by EDF R&D and has now been in operation for more than one year.
New challenges must be overcome to integrate fast-growing photovoltaic and wind turbine generation as well as new uses such as electric vehicles and heat pumps. The move towards smart grids is directed to make electrical systems more flexible, while maintaining a sustainable, cost-effective and safe electricity supply.
In this context, EDF is committed to these developments and conducts various experiments both in laboratories and under real conditions on the grid. This paper shows a few experiments that have been performed on Concept Grid, completing unit-tests and preparing new solutions to the real grid.

INTRODUCTION

EDF has built Concept Grid, a brand new laboratory dedicated to the test and validation of smart grid equipment, systems and functions. It is located on Les Renardières site, south of Paris. It has been developed to study and accompany the integration of renewable energy resources in the electric system, as well as storage and new uses such as electric vehicles or heat pumps.
Moreover, Concept Grid is designed to take place mid-way between laboratory tests and experiments in the field. It is then possible to conduct, in complete safety, complex testing campaigns that would be impossible to perform on a real system.
This paper aims to describe Concept Grid and some experiments that have been already performed on this platform. This open environment has been designed for many types of tests, becoming a privileged place for different stakeholders, from universities to equipment suppliers or network operators.

GENERAL PRESENTATION OF CONCEPT GRID

A representative testing facility

One of the first goals for Concept Grid is to reproduce the real conditions of operation of an electric system. For that purpose, it offers a wide range of equipments, from the primary substation to the customer.
Fed by a fully dedicated 63/20 kV transformer, Concept Grid includes 3 km of MV network (overhead lines, underground cables) supplying 7 km of LV network. The representativeness wouldn't be effective in Medium Voltage without additional network. To correct this, RLC cells have been added to make the equivalent of 120 additional kilometres. Chosen values perform a mix between overhead lines (two thirds) and underground cables (one third). This 50 Hz modelling fits with reality, especially when performing short-circuits.
Representativeness is also brought by a residential neighbourhood of five 20 m² houses, fitted with up-to-date equipments: smart meters, remote controlled household appliances, micro wind turbine, reversible heat pumps, PV panels, terminal for electric vehicles, storage systems, etc. This residential neighborhood of sample homes brings together new technologies in respect of renewable energies, storage and electric mobility.

Fig. 1: Concept Grid neighborhood

Concept Grid can also be connected to other unit-test laboratories of Les Renardières site for specific questions regarding:

- Electric vehicles;
- Heat pumps (industrial, geothermal...);
- Home automation with a real detached house representative of French constructions ;
- PV panels.

Information system for smart grid issues

The electrical network is doubled up with a telecommunication network using optic fibers, radio and power line carriers (PLC) as well as an information system that includes of smart grid-type features.
A part of this network provides I&C for Concept Grid from the control station with:

- the feedback of information;

- the flow of commands;
- the automation of the protective device coordination.

The other part of the network is dedicated to the transmission of experimental data and to the remote control of equipment located in the houses using networked meters.
Linking the information system and the telecommunications network to the medium and low voltage network allows Concept Grid to perform tests on *smart-grid ready* equipment.

Cutting-edge equipment

Several devices used on Concept Grid are state-of-the-art equipment that makes the platform unique. We chose to quote here three of them, for the special advantages they can bring in our experiments.

Instrumentation & Control
As explained, some optic fibers are dedicated to the I&C network. This network complies with latest standards (IEC 61850).

Three different grounding systems
Three different neutral point treatments can be selected according to needs: two currently implemented on French networks (resistive and compensated) and a third one, the active neutral, which relies on power electronics.

Power amplifier & Real-time simulation
The power amplifier, combined with the real time simulator, allows scenarios of generation (up to 120 kVA) or power consumption (60 kVA max) to be created, and then to be physically linked to the network of Concept Grid. It is used to virtually extend Concept Grid, to add distributed energy resources or to generate reproducible disturbances.

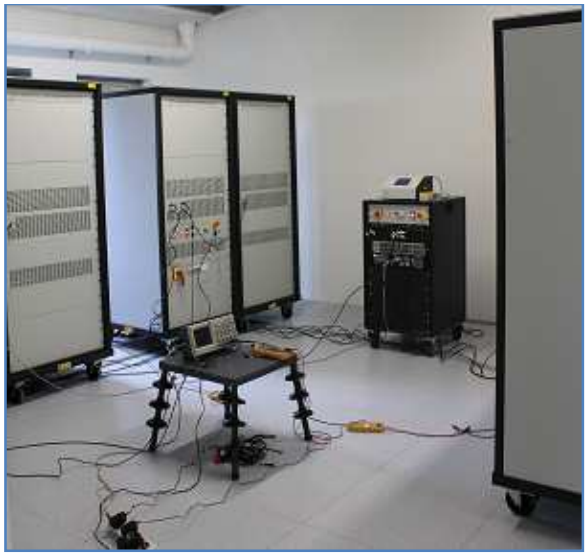

Fig. 2: Power amplifiers

Disturbances performed on Concept Grid

Concept Grid allows installing equipment in order to study their impact on the system. It is also possible to perform disturbances, and study efficiency of these new devices facing difficult conditions.

On the medium voltage network
All types of short circuits can be performed:

- from one to three phase(s);
- on overhead lines or underground cables;
- with different grounding systems;
- direct fault or resistive fault;
- etc.

On the low voltage network
The power amplifier allows disturbances on frequency, voltage, current, harmonics, etc. It injects up to 120 kVA and absorbs up to 60 kVA.
A rotating machine also allows performing disturbances on voltage (22% around nominal voltage) or frequency (from 47 Hz to 53 Hz). This system can work as a load or as a source, up to 50 kVA.

These disturbances are considered from an electrical point of view, but Concept Grid also permits to realize tests on telecommunication protocols, propagation, everything that are studied for smart grids issues.

SOME EXPERIMENTS PERFORMED ON CONCEPT GRID

Automatic ground loop recovering system using IEC 61850

Switchgears are located on either side of the distribution substations that are located on the underground medium voltage loop. The grid is therefore divided into several sections, which can be powered on either side.
Without automated ground loop recovery systems, when a failure occurs, the switching devices secure the grid and cut-off current to a part of the loop.

These operations are performed either remotely or in the field. Residential customers must wait until these operations are complete before recovering their power supply, which may take from a few minutes to an hour. Different systems exist to automatically reconfigure the grid. At the very forefront of new technology, Concept Grid integrates an innovative loop recovery system.
Its originality resides in its simplicity and in its decentralised intelligence.

A dedicated network of fibre optics complying with the latest communication protocols enables the switching devices of the loop to communicate with each other.
In the event of a failure, this enables them to instantly locate the faulty part of the loop and automatically order

the opening of the switching devices nearest to the failure. The section is thus isolated.
The automated recovery system then checks the other sections of the loop before reconfiguring it in order to restore power to the healthy parts. Finally, the failure is detected, analysed and removed in less than 200 ms and power is restored in barely one or two seconds.

This system is installed under real conditions on the Concept Grid to confirm its reliability when interacting with other equipment. The Concept Grid is also used to assess the benefits of this device before its potential integration into existing distribution grids.

Comparison of grounding systems

Thanks to its equipment, Concept Grid can be used to test the two neutral points currently implemented on French Medium-Voltage grids – the resistive neutral and the compensated neutral. It can also test a third innovative system, the active neutral. Studies are being conducted to assess this neutral point and study its feasibility.
To compare and assess the performance levels of these 3 neutral points, we compared them under identical fault configurations. To achieve this, it uses a horns air gap positioned on a secure platform dedicated to the injection of faults. The appearance of a short-circuit between the conductor at 20 kV and the ground leads to a fault current which runs into the ground. The characteristics of this fault current therefore depend on the neutral grounding characteristics.

With the resistive neutral grounding, the intensity of the fault current is relatively high, which also eases its detection. The protections react and very quickly cut off power to the faulty section of the grid.
With the compensated neutral (using a Petersen coil), the fault current to ground is lower than in the previous case, however also more difficult to detect. The effects of the failure are less significant; however the grid must nonetheless be cut off.

For the 3rd experiment, the active neutral grounding is implemented. This neutral point associates the compensation of the neutral as in the previous case, with power electronics and a smart controller.
The controller calculates the grid characteristics in real time. On the one hand, this enables it to precisely compensate the capacitive current of the grid. Its action consists in adding a current to the inductor's compensation current, the former being generated by the power electronics and constantly controlled. On the other hand, the calculations made by the controller provide the high sensitivity required for the detection of failures.
The use of technology such as power electronics reduces the fault current to a negligible value. Under these conditions, the grid remains live, even in the presence of fault, thus guaranteeing continuity of service.

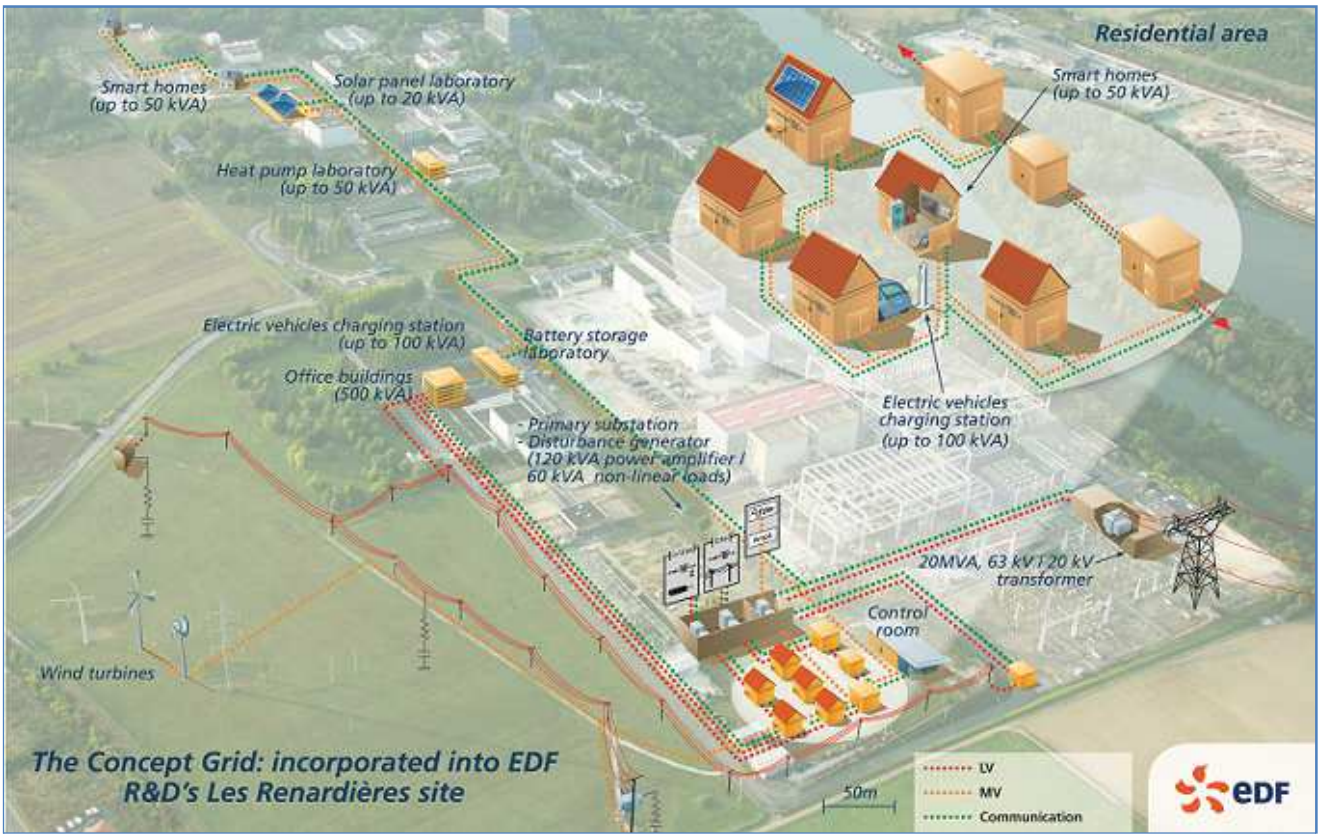

Fig. 3: Overview of Concept Grid

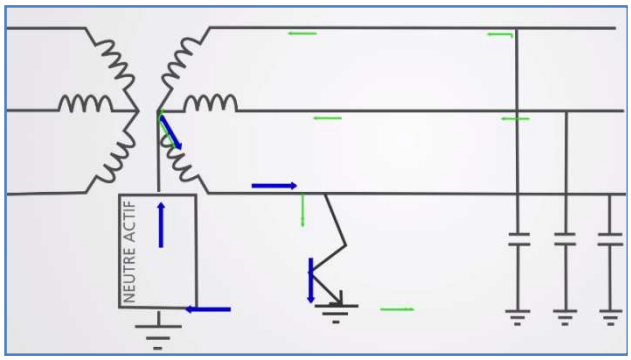

Fig. 4: Current circulation with active grounding system

The presence of three neutral groundings modes on the Concept Grid therefore provides for the possibility of studying the neutral groundings themselves to assess and compare them. It also enables different studies and experiments to be conducted, for example to test new equipment and check their correct operation with these 3 neutral groundings modes. The possibility of creating faults on request also helps to study the reactions of the entire system, especially the overvoltage due to faults.

Demand response

This experiment involves cutting off the heating in a home for a few minutes. The curtailment is sufficiently short in duration for the customer not to feel any loss of comfort.
Conducted across multiple homes in turn, these curtailments result in a significant reduction in the overall electricity consumption on a district-wide scale. Thanks to its residential area equipped with smart meters, Concept Grid allows to test this solution under real conditions on a representative reduced scale electrical system.

Fig.5: Home automation

The demand side management solution is launched. The smart meters placed in each of the houses communicate with a concentrator dedicated to the residential area using Power Line Carriers: information is transmitted by a signal injected over the electric current lines.

The heating system in one household is switched off.
At the exact moment when this heating system is powered again, the heating system of a second household is switched off by the same load shedding program, followed by a third one and so on and so forth. Once the load shedding program of the heating devices has ended in the last house in the district, the curtailment is performed in the first house and thus begins a new cycle. Load shedding therefore takes place from one house to the next, in turns, to form a cycle.
Each house is equipped with a power quality measurement system.

The data is sent to the control centre for analysis. After examination, the load shedding experiment conducted on the Concept Grid confirms a peak shaving of the load in the district, without any noticeable reduction in temperature in the homes. The duration of the load shedding was short and segregated for each house, however when operated on an entire grid, it provides a longer load shedding duration equal to the number of cycles performed, and therefore improves the management of electricity demand.