Medium Voltage Microgrid Islanding

A part of the Nice Smart Valley project

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***Abstract*—SOCOMEC has taken part in the French demo project Nice Smart Valley as the energy storage system manufacturer, as part of the European project INTERFLEX.**

The aim is to demonstrate the feasibility and performance of a medium voltage microgrid, based on several distributed storage systems.

This paper describes the tested use cases such as: Islanding with or without black start, synchro-coupling, voltage/frequency generation in the limits required by the standards, grid stability data monitoring and wireless management of several storage equipment for longer backup. All functionalities have been analyzed by theoretical study, experimental tests in a laboratory and in real conditions on the island.

I. Introduction

INTERFLEX is a European project, piloted by Enedis, which won a European call for projects “Horizon 2020”. The objective of the project is to demonstrate and validate new business models, with distributed energy resources and local flexibilities, integrating new technologies and solutions in the context of an increasing share of renewable energy sources. For this project 6 Demos will take place in Europe, among which one is taking place in south of France: the Nice Smart Valley Project (NSV).

This French demonstrator is led by the Distribution System Operator (DSO) Enedis and developed with five partners: GRDF, EDF, ENGIE, GE and SOCOMEC. Within this project three main use cases will be performed on Local flexibilities, Storage and Islanding.

Medium voltage (MV) islanding with distributed storage systems will be performed by ENEDIS and ENGIE using a solution by SOCOMEC. This paper describes the stakes, the implementation and the result of this innovative demonstrator.

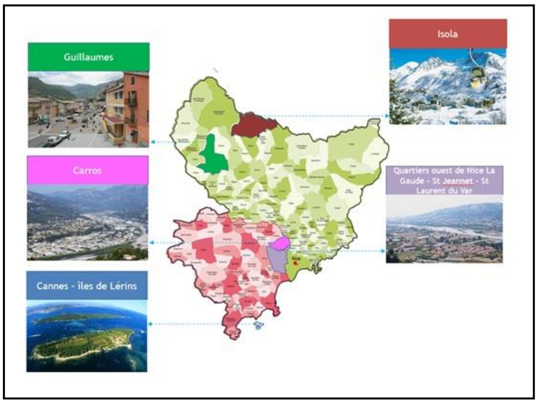

Figure 1. Presentation of the French demonstrator places

II. Project Challenges

A. The resilient Microgrid: a challenge for the future

In Europe, microgrids are defined by the European Commission inside the "Microgrids" projects. They represent a subgroup of electrical distribution systems equipped with distributed local energy sources such as photovoltaic systems and storage systems that are able to generate voltage and frequency (Grid Forming Units) under the control of the grid operator. Microgrids are connected to the distribution network in normal operating mode and can also operate in islanding mode in the event of a fault of the main grid, thereby ensuring power resilience (back-up mode).

As part of the NSV project, the goal is to ensure the electricity supply of the Lerins Islands in an emergency mode in the event of an incident on the single submarine cable without the use of generators. The Nice Grid project has been completed, tested and operated successfully at LV. The next challenge for this new project is to develop the technology to operate in Islanding mode at MV and develop the hardware and system intelligence that will allow the system to be replicated for other applications without requiring large amounts of engineering each time.

When the islands are islanded from the main grid, the goal of the project is to maintain the voltage and the frequency at acceptable level in accordance with the standards. To achieve this all storage assets available on the MV / LV networks, (2 storage systems) will be used simultaneously.

Finally, the last goal is to demonstrate the economic relevance of the use of storage assets to ensure the resilience of a microgrid. Therefore different business models depending on the operating conditions of the network and owners of the assets will be addressed in order to use Storage assets outside of an islanding period. These topics will be described with a specific contribution shared with Enedis, Engie & Socomec partners.

B. Grid Forming Units and Grid Supporting Units

As briefly mentioned above, for Socomec, as an energy storage system (ESS) partner, an important target is to use distributed storage assets to build and control the microgrid voltage and frequency when it is disconnected from the main grid. To make it more relevant, the aim is to be able to use those assets whatever their physical location and whoever their owner.

Therefore in the NSV project this is going to be tested by using two storage assets simultaneously, the first owned by Enedis and the second by Engie. To do this the first system will be used as a Grid Forming Unit (GFU), which means that when disconnected from the main grid it acts as a voltage generator that is the master of the microgrid. The second system will be used as a Grid Supporting Unit (GSU), which operates as a current generator following the requests sent by the GFU.

One of the sequences that will be tested in case of islanding is the blackstart – Fig. 2. Once the main grid is lost, the GFU will start and there will be a soft voltage ramp-up to enable all the power converters (PCS) used in this system to synchronise and avoid the inrush currents, due to the MV/LV transformers. We enable two modes: the synchronization can be done either directly at the nominal voltage or at 80V. In the second mode, by progressively increasing the voltage after the closure of the circuit breaker, we ensure that there are no bad consequences on the loads, mainly on motor type loads. Once the nominal voltage is reached the GSU and the PV inverters can be connected to the microgrid.

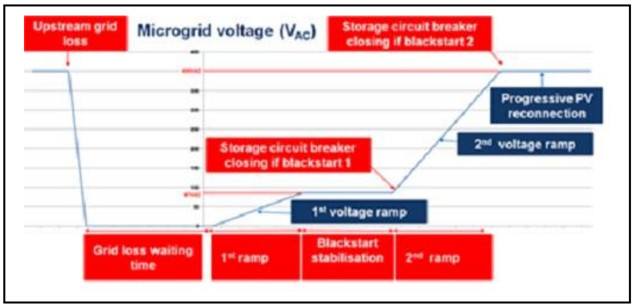

Figure 2 Blackstart process

C. Nice Smart Valley microgrid area description

The islands of Lérins, Fig. 3, were chosen for this project because of their particular grid connection. They are currently fed by a 10 kV submarine distribution network cable of 1500 m placed on a shallow bottom (<10 m). Previously second submarine cable provided a back up to the main power supply, but this has now been abandoned as it is expensive and requires a long term approval process. In case of an incident causing the loss of this connection (removal of the cable by an anchor, for example), the installation of one or more generating sets on the islands of Lérins is necessary.

The MV network, entirely in 10 kV, present on the islands is relatively small: 2.2 km of MV network of variable section, five substations MV/LV for a load peak of 600 kVA and 54 clients among which five have powers included between 36 and 250 kVA (monastery, museum, restaurant etc.).

There is no production of relief on the islands: if the link with the continent breaks, customers are no longer supplied during the time of routing and installation of generators, which can be quite long. In fact, the troubleshooting and repair times are very much linked to the climatic conditions of course but also to the provision of a barge to carry the generators and to repair the cable (which must be hoisted onto the surface to repair). So, returning to a normal mains situation may take several days. To overcome these disadvantages linked to the islands isolation, the installation of a microgrid including local production and storage facilities, driven by a system of local optimisation of energy flows and management of peaks of consumption was proposed within NSV. This installation must be able to allow autonomous operation of the local network in the event of loss of the main power supply while ensuring the maximum self-consumption of the locally produced energy. For this demonstrator, we will rely on the results of Nice Grid where islanding has been successfully tested.

NSV could test a multi-day islanding based on battery storage (or other means) and a renewable local production (mainly PV) to be developed with the partners of the project.

The GFU, connected at the public distribution system – Medium Voltage -, will make it possible to generate a microgrid in case of incidents on the upstream network (connection with the continent). This system will make it possible to balance generation and consumption, and to manage frequency and voltage during the phases of islanding with an optimisation of the loads.

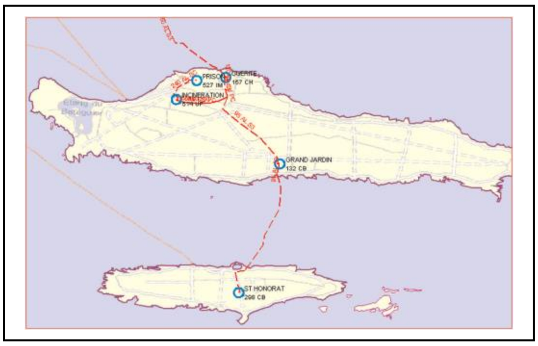

Figure 3 Map of the islands of Lérins

III. KEY ACHIEVEMENTS

Given the degree of innovation in this project, the risks associated with the new functions were validated in three stages.

At first, we worked with the University of Padova in Italy, which helped us to simulate the interactions between the equipment and the grid topology on the islands that could be causing instability. These instabilities can result from the high reactive powers exchanged in the electrical distribution under the influence of capacitive loads due to the cables and inductive loads due to the transformers, Fig. 4.

In a second step, we reproduced an installation identical to the one of the islands of Lérins, at a fourth (25 %) of the real power. This has been done in the research laboratory of EDF R & D, Concept Grid in Moret sur Loing, Fig. 5. Thanks to this installation, the qualification of the new features of our converters has been made and all the risks have been removed, enabling the warranty of the quality of energy supply. During these tests all the use cases detailed after have been validated.

After a successful test programme at Concept Grid, and approval by ENEDIS, the last step was to carry out real tests on the islands of Lérins.

Figure 4 Load profile on the LV network

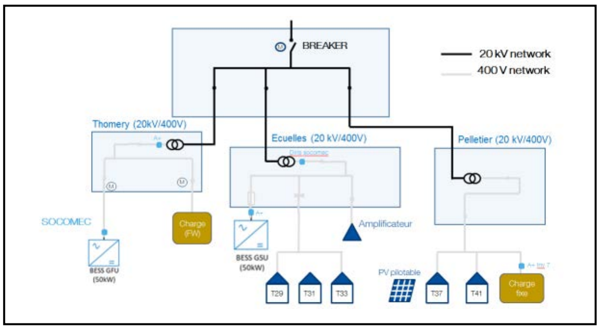

Figure 5 Picture of the islands simulated at Concept Grid

A. *Medium Voltage Islanding*

By definition, islanding is the situation when a part of the grid is disconnected from the main grid but remains energised by the local generation.

In MV islanding, as it is the case for NSV, some additional equipment needed to be put in place. They have to ensure the connection and disconnection from the main grid without disturbances on the load by the synchronization process. Therefore, it is necessary to measure the voltage upstream and downstream of the islanding breaker (CBG), Fig. 6. To do so, MV switchgears measurements (voltage and current) have been adapted in order to be compatible with the islanding controller and with the requested accuracy. This aims to determine the power consumed from the grid in order to compensate it via the ESS. This will enable an islanding without energy exchange, as detailed below.

Two types of modes for islanding are tested in the NSV project:

- The first mode is the so-called scheduled islanding. This type of islanding is planned by the DSO and it isn't noticeable from the customer's side. When the islanding is requested, the power of the PCS will ramp up, thus doing a ramp down of the grid's power, in order to erase the current flow on the grid circuit breaker. Once the current and power are close to 0, the grid breaker is opened, without any disturbances to the load. After the breaker is opened the ESS switches automatically from a slave voltage generator to a master voltage generator. In this situation, the ESS ensures autonomously the balance between the local production & consumption, while the state of charge and the power of the PCS are within the operating ranges. The ESS is able to perform PV production control acting on the standard PV inverter P(f) function. This capability allows the extension of the islanding duration. The power sharing between the PCS is ensured by droop algorithm, without any communication link for robustness. The reconnection to the grid is performed with a synchro-phasor; the phase of the voltage, voltage amplitude and frequency are measured on the main grid. These parameters are entered as an input in the inverter regulation to get the same parameters on the microgrid. When all the parameters are identical, the breaker closes and the islanding stops.
- The second mode is called the unforeseen islanding. It simulates the situation when a fault occurs (loss of the submarine cable) and a breaker opens leaving the distribution grid without energy. The ESS has to create a blackstart, which means that it is able to energise the microgrid starting from no voltage, Fig. 7. The resynchronisation is performed in the same way as for scheduled islanding: without interruption of service.

Finally for NSV project the ambition is also to prepare a third way of islanding: the anticipated islanding. The idea for that is to analyse the network, thanks to several measurement devices that have been put in place, in order to see if some specific grid behavior systematically lead to a loss of the grid. This will stay at an analysis phase for this project.

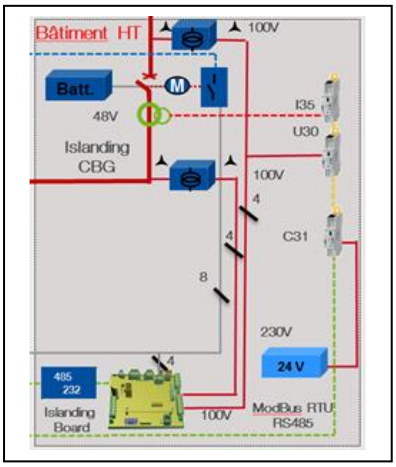

Figure 6 CBG upstream and downstream measures

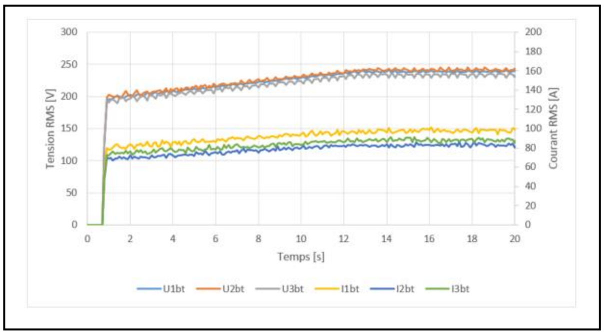

Figure 7 Voltage and current during a blackstart

B. Energy Quality EN 50160

When performing an MV islanding, there are some new challenges compared to the LV islanding that has been done during the Nice Grid project. As already described, there is a risk of instability when powering the islands of Lérins microgrid with the ESS. These instabilities come from a potential resonance between the intrinsic inductances of transformers and of long and capacitive cables (buried and submarine). The goal for the ESS control system is to not interact with these resonances and furthermore to contribute to maintaining the quality of the energy supply, Fig 8 and 9. This quality shall be compliant with the recommendation of the EN 50160 standard, which defines the limits of voltage, frequency and distortion rate.

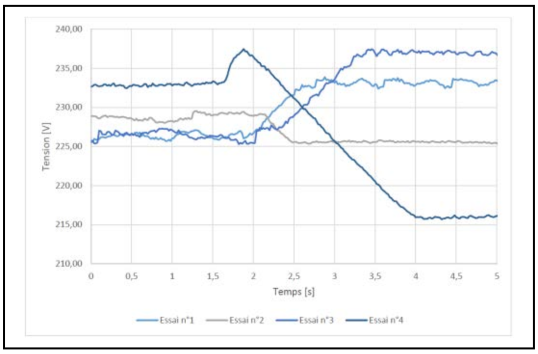

Figure 8 ESS RMS voltage during several islandings

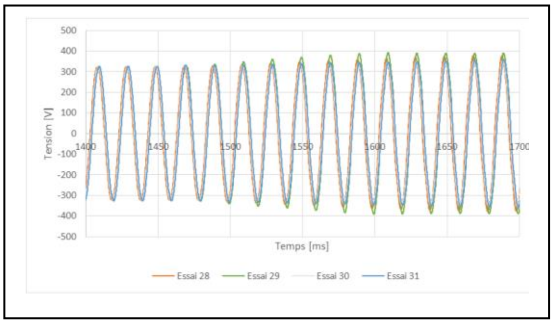

Figure 9 Voltage wave form during several islandings

C. Protection Plan

NSV project also includes a part concerning the setting of medium-voltage network protection devices. Therefore several single-phase and three-phase short circuits were created and the tripping of the network protections and storage converters was tested, Fig. 10.

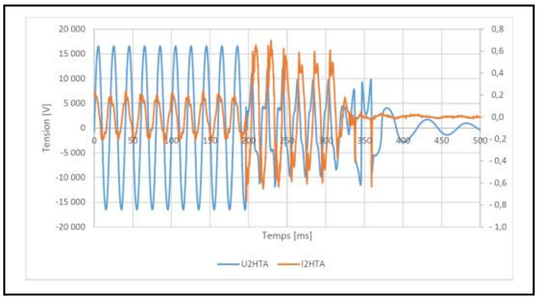

Figure 10 MV Voltage and Current during and after a fault

D. Control of renewable energy sources

One use case of the NSV project is to manage the photovoltaic production. Two main topics are considered here: balance between production and consumption and self-consumption.

Preservation of the balance between production and consumption during islanding phases while maintaining the voltage and frequency within required operating ranges is really important. In this operating mode, the ESS's priority is to regulate voltage and frequency of the micro-grid. This operation is possible for a limited time which varies depending on the state of charge (SOC) of the batteries, the load consumption and the level of local photovoltaic production. To reduce PV generation and thereby avoid the maximum power level or reduce the SOC, the PV invertors' built-in P(f) function is used. This function reduces proportionally the PV power generated according to the frequency, which is controlled by the ESS, Fig. 11. As soon as the frequency of the microgrid exceeds the value of 50.2 Hz, the reduction of P(f) function is activated.

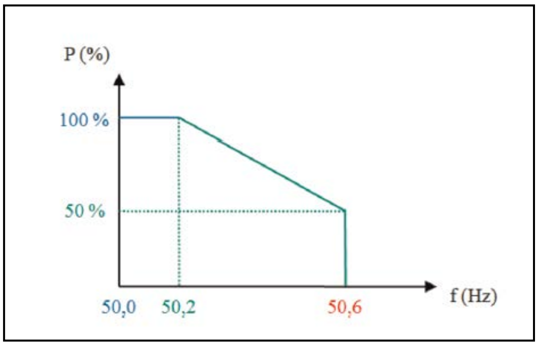

Figure 11 Illustration of one P(f) function

The goal of self-consumption is to charge and discharge batteries according to the ratio between plant consumption and renewables sources production.

It means that self-consumption function can be summarized by, Fig. 12:

- Renewables production > Load consumption ⇨ battery charging
- Renewables production < Load consumption ⇨ battery discharging

Self-consumption has to be based on Grid measurements but renewable generation must also be monitored.

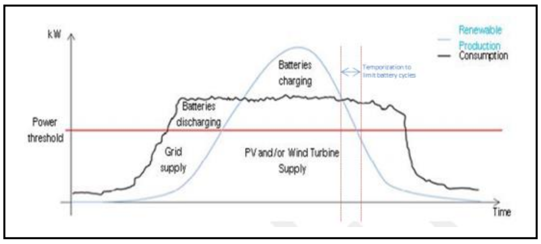

Figure 12 Self-consumption principles

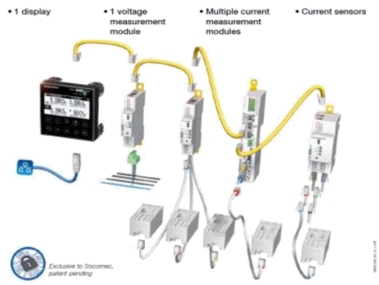

Figure 15 Digiware measurement and monitoring system

E. *Interaction mode between two energy storage systems*

Concept Grid facilities also enabled us to adjust the operation of several voltage sources in a single electrical installation. The interaction between two storage systems, Fig. 13, distant from each other and regularly communicating together for optimum control of the batteries, was tested according to a protocol defined in collaboration with ENEDIS and ENGIE. The strategy is to maximise the use of the master GFU and to consider the GSU as a support when the GFU reaches its defined limits in terms of SOC and power, Fig. 14.

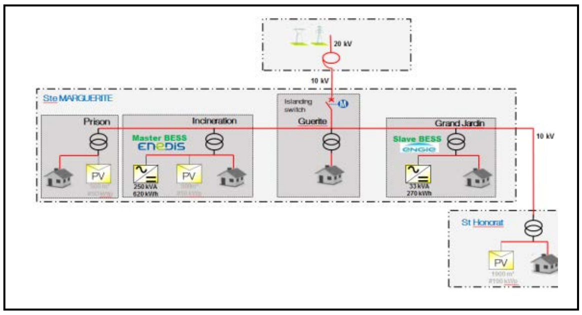

Figure 13 Simplified installation power diagram

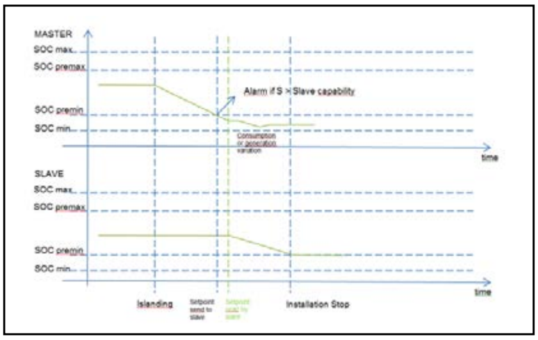

Figure 14 Strategy in discharging mode

F. *Data measurement and monitoring*

To analyse the microgrid behavior, the ESS in NSV include an innovative measurement system for multi-circuit electrical installations, Fig. 15. This system measures several data on the AC network such as frequency, voltages (phase to phase and phase to neutral), currents, powers (active, reactive, apparent), power factor and phases unbalance.

All collected data are transmitted to an Iot platform hosted in the cloud, in order to enable ENEDIS to do a continuous monitoring of the grid evolution.

The main features proposed by this online application, Fig. 16:

- Map and alarms
- Measurement of the last values
- Historical data
- Data export to an excel file
- Alarms for device non-communication

Figure 16 Online application

IV. Conclusion

In the end, our ESS make it possible to secure the power supply of the islands in the event of a main grid fault, but also on demand; to store locally the energy produced by renewable energy sources and to ensure the longest possible supply of energy. This will be made possible thanks to the wireless communication between the two storage systems that we are going to implement.

The different tests will continue during the period between April and December in real situation directly on the islands. The aim is to observe the behavior of the systems and to measure and store a maximum of electrical values of the islands of Lérins. Data recovery is facilitated by the automatic transmission of all measures to our servers, which will allow us and our partners to exploit them optimally.

[1] Behaviour of PV inverters during islanding of a district – CIRED – Thomas Drizard, Giovanny Diquerreau, Sébastien Vilbois, 2017