ISLANDING OF A COMMERCIAL DISTRICT: NICE GRID PROJECT

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ABSTRACT

Islanding is the most innovative use case of the NICE GRID project led by ERDF. It involves the disconnection of a low voltage district for a limited duration and its supply only by energy storage and PV generation. Five hours of islanding have been achieved in October 2015

INTRODUCTION

The research leading to these results has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n°268206. The project is also funded by the French Environmental Agency ADEME.

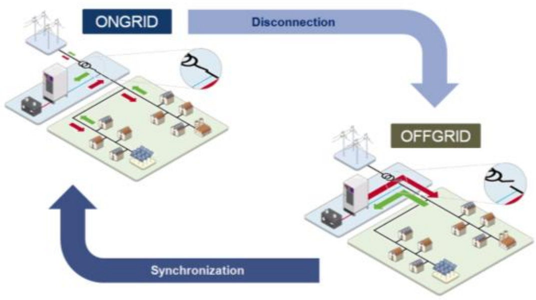
NICE GRID is a smart grid demonstration project led by the French DSO **ERDF** and developed with nine partners: **EDF, GE Grid Solutions, SAFT, RTE, ARMINES, SOCOMEC, NKE, NETSEENERGY** and **DAIKIN**. **Islanding** was developed on **ERDF** grid with a solution (hardware and software) by **SOCOMEC**, relying on **Saft** lithium ion batteries. This paper describes the objectives, the implementation and the technical results of this innovative experimentation.

1. OBJECTIVES AND TECHNICAL REQUIEMENT

Definition

Within the **NICE GRID**, **islanding** of a district is a sequence

- Consecutive to the **disconnection of the district from the main grid** (*manually or automatically, scheduled or unforeseen*)
- During which the district is supplied for **a limited duration of time** by a **storage system** and **local PV generation**
- Involving the maintaining of **frequency** and **voltage** by the storage system
- Ending with the **resynchronization** to the main grid **without any interruption of service** (when the upstream grid is back or at the end of a set period)



- **Figure 1 – Islanding principles**

A specific C&I district

The chosen district is a commercial district located in the industrial area of Carros. This district is supplied by the "Dock Trachel" secondary substation (400 kVA) where are fed:

- 8 commercial clients consuming up to 100 kW the days of high PV generation
- 3 large PV generators representing 430 kWp of installed capacity

Figure 2 - 1st Street district in Carros

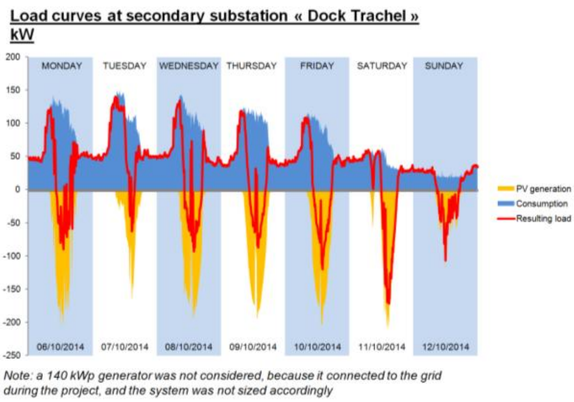


Figure 3 - Load curve from "Dock Trachel" secondary substation in October 2014

This site was selected mainly for its significant backfeeding due to the high concentration of PV generation. Backfeeding is the reverse power flow from the LV to the MV grid that occurs when local PV generation exceeds local consumption.

Islanding use cases

Scheduled islanding

The **scheduled islanding** is ordered by the network energy manager (NEM) as a load-shedding option to completely eliminate any power transfer between the main grid and the microgrid. It can be also use for maintenance purpose on the grid. **Scheduled islanding** is generally of limited duration (several hours) and preparation starts the day before to give the energy storage system time to reach the required charge based on the consumption and generation forecasts for the **scheduled islanding** period. The local LV grid is disconnected and reconnected to the main distribution grid without any outages or disturbances for consumers.

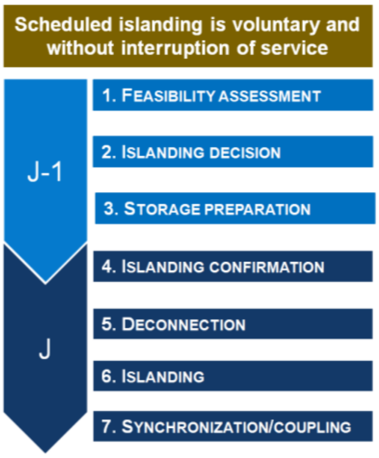


Figure 4 - Scheduled islanding sequence

Unforeseen islanding

Unforeseen islanding provides backup power in the event of unavailability of the main distribution grid upstream from the local area. Once grid failure is detected, a short interruption of supply for customers (three minutes) is allowed during which the network energy manager may attempt to reconfigure the MV feeder loops. After those three minutes, the energy storage system backs up the local grid with support from the PV generators. The duration of unforeseen islanding depends on the grid outage duration, the amount of PV generation, and the state of charge of the energy storage system. Once the main grid is reestablished, the system seamlessly reconnects to the upstream distribution grid **without any interruption of supply or disturbances for customers.**

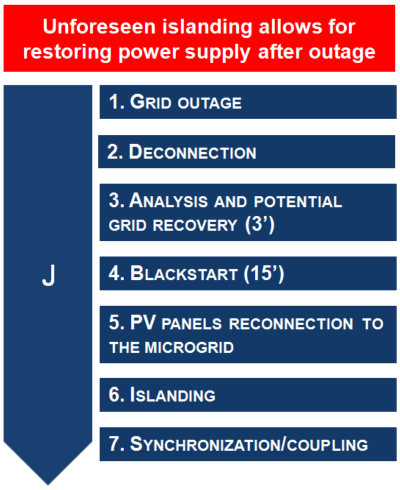


Figure 5 - Unforeseen islanding sequence

2. DEVELOPMENT AND IMPLEMENTATION

Architecture

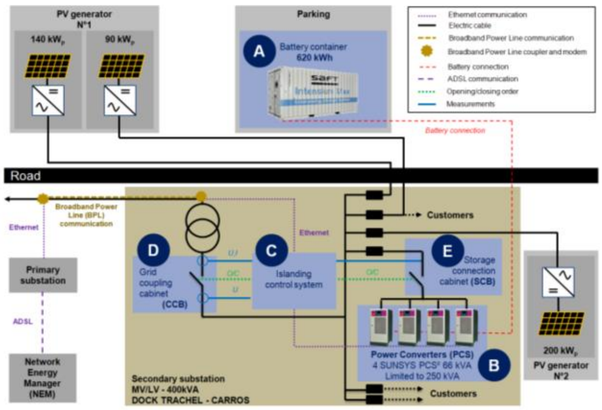


Figure 6 – Architecture of the system

To island the district, a dedicated infrastructure was implemented:

- A **250 kW / 620 kWh storage asset** with 4 power converters from SOCOMEC and a lithium ion battery container from SAFT
- A **local intelligence** to control disconnection, islanding and synchronization phases
- Advanced **measurement devices**
- A **coupling circuit breaker (CCB)** to manage transition phases.

Functions

Black start

The **Black Start** function (to borrow a term usually associated with backup diesel gensets) is used to gradually

reestablish the supply voltage supplying the microgrid during unforeseen islanding so as to prevent excessive inrush effects (on the magnetizing current of the transformer). The Black Start function also makes it possible to place multiple converters in parallel without having to go through a converter synchronization step, which means near-immediate availability.
Power supply can be restored **within 15 seconds.**

Droop control
A system made up of multiple voltage-source converters requires the use of active (P) and reactive (Q) power to avoid current circulation between the converters. The desired equilibrium is accomplished without communication between generators during islanding, via droop control. Conventional droop equations are used, defining P and Q for generators connected to the same line, and showing the direct and proportional relationships between frequency (f) and active power (P), and between voltage (U) and reactive power (Q). **Frequency and voltage can be adjusted by regulating the system's active and reactive power, respectively**. Since the generators are connected to the same line, their voltage and frequency are **interdependent**, meaning that reliable, stable operating points can be selected according to the total power drawn by the load.

Grid protections
Abnormal increases or decreases of nominal electrical parameters (voltage, current, and frequency) are **electrical defaults**. The most frequency ones are: overload, short circuit, over voltage, voltage drop.
Overload and short circuit create an **over current**. In case of a default, the system must supply enough current to eliminate the default: it is always the case when connected to the main grid, because it has an infinite short circuit current. In microgrid operation, the overload and short-circuit currents are limited by the machine: in the case of the SOCOMEC power converters, they have an **overload capacity of 150% during 60s and a short circuit current of 2,5 In (nominal current) during 100ms.**
Short-circuit protection tests were run by causing short circuits at two places on the grid:

- At the site of an individual customer with and without a circuit breaker
- Downstream from the distribution panel of an MV/LV substation

The short-circuit tests **proved the storage system's ability to supply the short-circuit current needed to correctly trigger customer protection responses**. If the PCS has enough current to eliminate the default, the microgrid operation can be sustained. Otherwise, the storage system automatically goes into safe mode and stops feeding power into the microgrid, thereby blacking out the entire area.

Reducing PV generation to extend islanding duration
To reduce PV generation and thereby avoid the maximum power level or reduce the SOC (state of charge), the PV generators' built-in P(f) function is used. This function **proportionally reduces the power generated according to the frequency,** which is controlled by the storage system. As soon as the frequency of the microgrid exceeds the value of 50.2 Hz, the PV generation (Pf) at that specific moment is taken as a reference and the reduction function is activated. As long as the frequency is more than 50.2 Hz and less than 50.6 Hz, PV generation varies according to the gradient that has been set (125%/Hz in our test, i.e. 50% of Pf over 0.4 Hz). Within this frequency range, when the frequency increases, the active power decreases; when the frequency decreases, the active power increases. The frequency is adjusted by the converter system by vertically translating the frequency droop lines of each power converter.

Synchronization and recoupling
At the end of scheduled or unforeseen islanding, to avoid de-energizing the grid, the microgrid is reconnected to the normal distribution grid by **synchronizing the two and then connecting them.** Synchronization consists of **superimposing the voltage sine waves of the two sources**. Since it is impossible to alter the normal distribution grid's settings, this is accomplished by adjusting the voltage (U), frequency (f) and phase difference (φ) of the storage system according to the ΔU, ΔF and Δφ differences measured. Once these values have stabilized within their respective connection windows for a specified period of time to avoid transient phenomena, the order is given **to close the Coupling Circuit Breaker (CCB).** The grid and the microgrid are reconnected, and the storage system goes directly back into active and reactive power control mode.

Lab tests

In June and July 2015, before implementing the islanding system in Carros, two test sessions have been organized at **Concept Grid** (*experimental distribution grid from EDF R&D*)

Figure 7 - Islanding testing system at Concept Grid

Around **150 test sequences** proceeded in order to validate the functionalities, performance and robustness of an islanding system (at reduced scale) at conditions close to the real grid

For more information, see *CIRED Paper 84*: *Islanding tests with Li-ion storage system on the EDF Concept Grid*

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3. TECHNICAL RESULTS

Experimental islanding was tested **successfully** in Carros in October 2015. The system was able to supply power to customers safely and for a **five-hour test period**, which is a world record.
In September 2015, the islanding version of the system has been implemented at the "Dock Trachel" secondary substation in Carros to proceed the **first field validation tests**. The objective was mainly to validate functional sequences as well as the absence of influence of the two PV plants (in their initial configuration) on the storage system behavior. These tests have been done on a weekend, therefore with a moderate load in order to avoid disturbances for the activity of the commercial clients. Several islanding tests have proceeded successfully
In October 2015, a second validation test campaign took place in **real conditions** (PV generation and high consumption) in order to validate definitively the solution and start experimentation. **Duration of 5 hours of scheduled islanding** has been achieved. A cloudy day (6/10/2015) and a sunny day (7/10/2015) have been tested, *as shown in the figure below*.

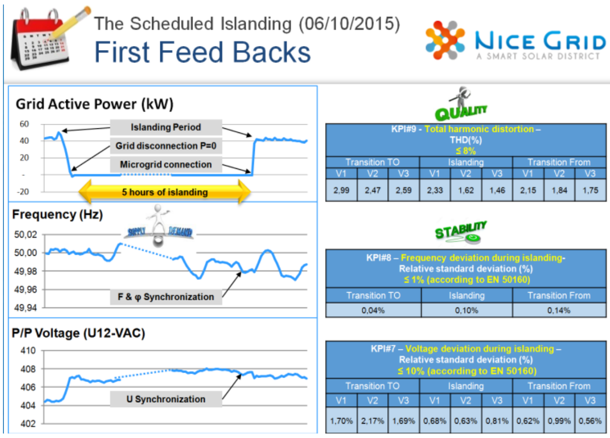

Figure 8 - Results for the scheduled islanding

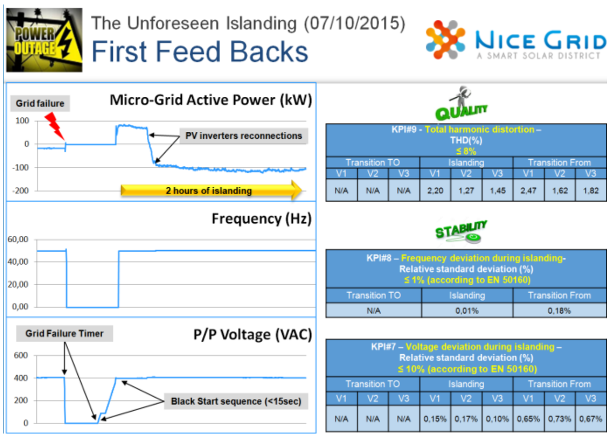

Figure 9 - Results for the unforeseen islanding

CONCLUSION

Islanding tested within NICE GRID is a **world premiere**, with **five hours** of islanding without any rotating machines. Islanding can be extended **beyond five hours.** This solution works without any dump load, and allows for **better taking advantage of the photovoltaic resource**, which must be curtailed or consumed in dump load by low load in case of a diesel genset solution. Unforeseen islanding is **automatic**: the trigger is the upstream grid loss. Therefore, the system restarts automatically after a grid outage, and **synchronizes automatically** when the upstream voltage is back. For scheduled and unforeseen islanding the microgrid recouples **without any interruption of supply** after synchronization. Islanding ensures **stability and quality of power supplied** as shown by the KPI (voltage and frequency deviation, harmonic distortion)
Islanding solution can be seen as an **additional service provided by a storage asset**, beyond the numerous services in "grid connected" mode (renewable integration, voltage support, frequency regulation, load shedding, grid investment deferral…).
Its application is also promising for:

- The back-up of **low reliability distribution grids**. For instance, in some developing countries, we can count up to 5/6 mains failures per day.
- The **C&I critical buildings** in complement, for instance, of a self-consumption management in order to have a solution to secure the power supply availability.
- The **islands not connected to a standard electrical distribution grid** and which may use several types of power supplies: turbines, wind turbines, photovoltaic fields, generating sets and storage systems to form a hybrid plant production.