PREVENTING BLACKOUTS IN A CORSICAN VILLAGE THANKS TO LOCAL BIOMASS GENERATOR

Laure LAMBROT
EDF SEI– France
laure.lambrot@edf.fr

Boris DENEUVILLE
EDF Lab – France
boris.deneuville@edf.fr

Joseph MAIRE
EDF SEI– France
joseph.maire@edf.fr

Az-Eddine KHALFI
EDF Lab – Allemagne
az-eddine.khalfi@edf.fr

ABSTRACT

To prevent local blackout situations, EDF Insular Energy System Division (EDF SEI) is developing an innovative energy system which aims at securing the village in case of snow alerts. This system is based on a local biomass power generator and on a smart grid system enabling isolated operation of the village electrical system. This last system is described in this paper.
It focuses on the main technical problems that have to be solved and describes possible solutions for:

- *dynamic balancing between supply and demand,*
- *respect of quality criteria for the power supplied,*
- *adaptation of the protection plan,*
- *development of a specific controlling process,*
- *islanding and coupling stages.*

Lab test results are presented and it concludes on the next steps and the perspectives opened by this experiment.

INTRODUCTION

In winter time, following big snow storms, small villages in Corsica may be without electricity during several days due to both overhead lines failures and difficulty of access for maintenance and repair crews.
Developing a reliable microgrid solution based on local resources seems to be a solution to avoid the consequences of those blackout situations and to provide the continuity of electricity for the villages' inhabitants when the feeding network is down.
Therefore, the microgrid should be able to operate connected to the main network as well as in an islanded configuration.
Following this observation, EDF SEI, in partnership with the local agency of rural electrification, has found a Corsican village willing to participate to the first life size microgrid islanding experimentation.
This paper details the main choices for the microgrid's components and the microgrid-related technical issues based on lab tests results.

PAESI -MICROGRID PROJECT IN CORSICA

Context

The island of Corsica is located in the Mediterranean Sea, 180 km off the southern coast of France. Having several strengths for tourism activity with splendid mountains flowing down into the sea, Corsica is also a challenging territory in terms of electricity distribution: steep terrain, dotted inhabited areas, winding roads, large forests challenging the reliability of power supply.

In this context, snow storms frequently bring about long power cuts in mountain areas despite of the special means implemented by EDF, just because damaged networks are unattainable until the snow has been cleared from the roads, which takes time.

The PAESI microgrid-project arose from the common will of Corsican authorities, the local agency of rural electrification and EDF SEI which is the network operator, to convert the singular situation of those mountain villages into an opportunity of innovation.
The technical and partnership outlines of the project were conducted with a constant requirement: be innovative but also ensure economic relevance. The islanded operations will be operated only few days a year. That's why the whole solution has to be cheap, robust and reliable.

Scale of the microgrid

The village participating to the islanding experiment is a village of 50 inhabitants located 600 meters above sea level in Corsica, in the mountainous area covered with forest named Castagniccia (chestnut tree in Corsican language). It is shown in the picture below.

Fed by an electrical antenna, the village suffered more than 5000 minutes of power outages between 2010 and 2012, sometimes during several days.

Most of the time, the active power consumption ranges between 10 kW and 60 kW while the reactive power consumption ranges between 0 and 20 kVAr.

As shown in figure 1, consumption is unpredictable with variations within one minute that can reach 50% of the power used.

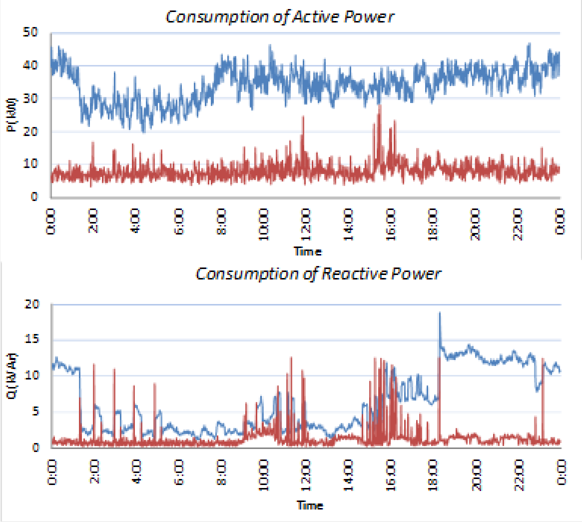

Figure 1 : Consumption of Active and Reactive Power on the 26th February of 2013 (blue = average by one minute, red = gap between min and max measured within one minute)

By 2016, the village will be equipped with a small power plant of 90kW fuelled by gas extracted from biomass, a local and abundant resource. This small power plant will be operated almost permanently (7500h/year) and will be injecting energy on the MV network most of the time. An industrial offer exists for such small power plant but technically optimized for feed in tariff and not stand alone operation.

Using such a device for the PAESI project gives rise to three issues:

- Installed capacity should be sized to cover the active peak consumption of the village and be the only supplier of the microgrid when isolated;
- Gasification process used is unable to modulate its output. Without any gas storage possibility, the active power supply is therefore almost constant. To isolate the village from the grid, a complementary mean has to balance production and village consumption instantaneously;
- To cut the costs, the electrical generator is an asynchronous machine well adapted when the village is connected to the MV network but with no means to supply reactive power when the village is isolated from the grid.

Purpose and principle of islanding experiment

The purpose of the PAESI microgrid project is to improve the continuity of supply when the MV network is out of order. Thus islanded operations will be required only for a few days (on snow alerts concerning Castagniccia) and not permanently.

That's why the whole solution has to be cheap, robust, reliable, as self-sufficient as possible and based on renewable energy.

These criteria have led to exclude storage solutions (too expensive and not so reliable in this case) as well as classic fuel generators.

Microgrid devices

As the biomass power plant is both unable to modulate active power supply and to supply reactive power, complementary devices are needed to ensure the balance between production and consumption when the village is isolated from the main network:

- A Controllable Resistive Load (CRL, see below);
- A Controllable Capacitive Load (CCL, to be designed).

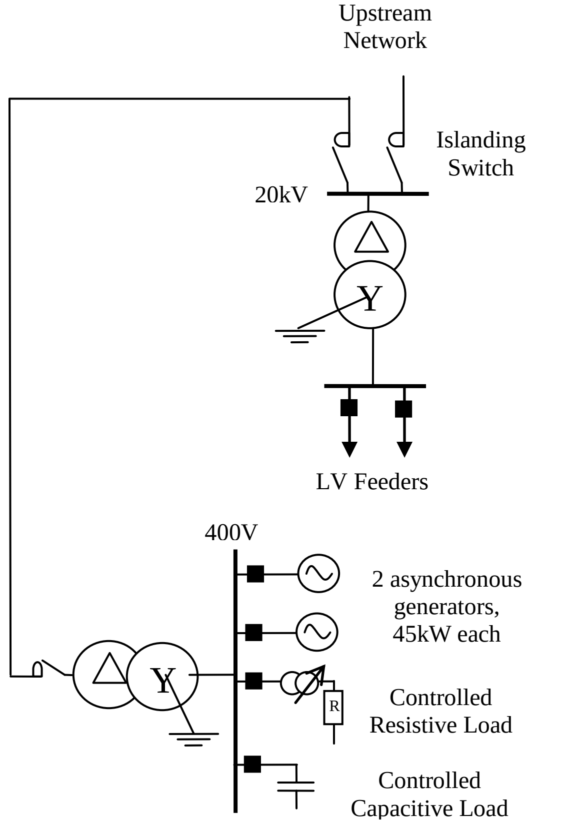

Figure 2 : Microgrid Components for the Islanded Operation Project in Corsica

The controlled resistive load contains a pure resistance connected at the secondary of a LV/LV transformer through 3 different taps. The principle of Load Tap Changing associated with phase-angle switching is used. By controlling the phase-angle and the two taps used, it is possible to control the voltage and the current inside the resistance, and therefore the active power dissipated ($P=U^2/R$) to balance the microgrid.

The waveforms of currents consumed by the CRL can be as figure 3:

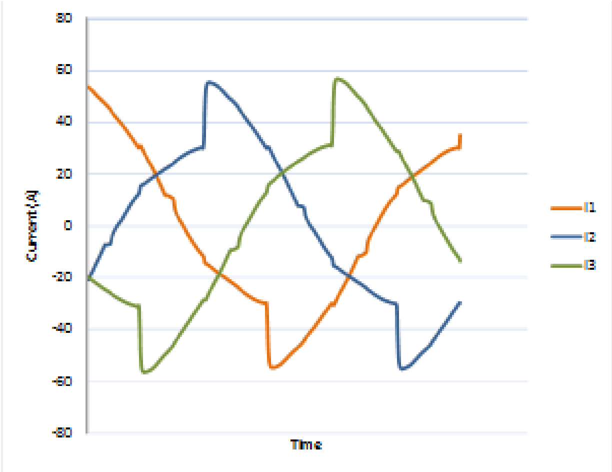

Figure 3 : Waveforms of currents consumed by the CRL

MAINS TECHNICAL CHALLENGES

Our studies underline five main technical challenges for microgrid experiment:

- Dynamic balancing between supply and demand on a very small network without compensation effects;
- Quality criteria of power supplied to consumers (voltage harmonic distortions);
- Protection plan that needs to be adjusted for islanded operation;
- Self-acting of the whole system needing to develop a specific controlling process;
- Strategy of islanding and coupling stages for safety requirements.

Dynamic balancing issue

In such a small islanded network there are few statistic compensations between individual consumptions. Therefore, the microgrid may have to face severe variations of consumption, meaning active and reactive power quick changes.
As the electrical generators used cannot adapt their production to consumption, CRL will be used to instantaneously fill the gap between supply and demand.
Particular attention has been paid to the time response of the CRL devices to prevent dynamic unbalance.

During the lab tests, the regulation rule of the CRL has been implemented with a PID controller. No optimization of the response time has been performed yet**.** Only the feasibility has been verified**.**

The following figures show the voltage and frequency measurements with and without regulation in response to the connection of a resistive load to the load representing the village on the EDF Lab test facility.

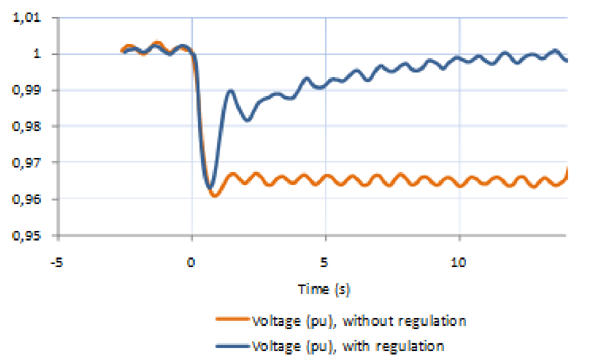

Figure 4: Voltage response to a load variation

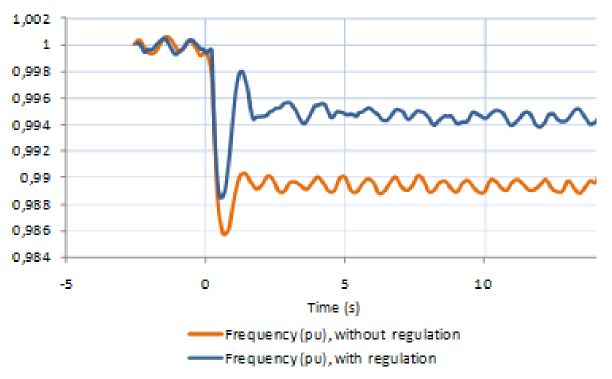

Figure 5: Frequency response to a load variation

The added load is only resistive. As shown above, the voltage value was restored quickly which is necessary to prevent damages on consumers appliances and the frequency is stabilized but significantly below 50 Hz.

These results highlight the smooth running of the solution tested as well as the necessity of a secondary regulation with the CCL to restore frequency, which will be tested in 2015.

Voltage total harmonic distortion

As already mentioned, asynchronous generators are not designed to feed islanded networks. Therefore the voltage waveform created may not be exactly sinusoidal and contains voltage harmonic distortion.
Moreover, as shown figure 3, the CRL consumes harmonics currents that can create voltage harmonic distortions due to the low short-circuit power when the grid is isolated.

During lab tests, it was necessary to evaluate if this could create a blocking problem:

- In islanded operation the voltage harmonic distortion has been measured while the power dissipated in the CRL was varying from 0kW to the entire power produced by the generator.
- The conclusion was that both the voltage harmonic order 1 through 50 and the global distortion rate remain in the accepted standards.

The CRL doesn't increase significantly the harmonics rates even in the islanded mode.

Protection plan

The protection plan is based on the following strategy:

The individual customers will always have the same protecting system. This system is composed of fuses or breakers. In the isolated mode, the generator should have enough short-circuit power to trip those breakers or to melt the fuses. Moreover the voltage transients following the elimination of the fault must not endanger the system stability and cause blackouts.

An overcurrent protection as well as an insulation monitoring relay will be added to protect the LV and MV network.

Short circuit tests were made to validate that the short-circuit power of the asynchronous generator is sufficient to trip the low-voltage branch circuit breaker of the inhabitants, and to check that tripping doesn't cause any black-out.

Issued from lab test of the system, the figure below shows the 3 voltage waveforms as well as the short circuit current waveform during a fault on phase 3.

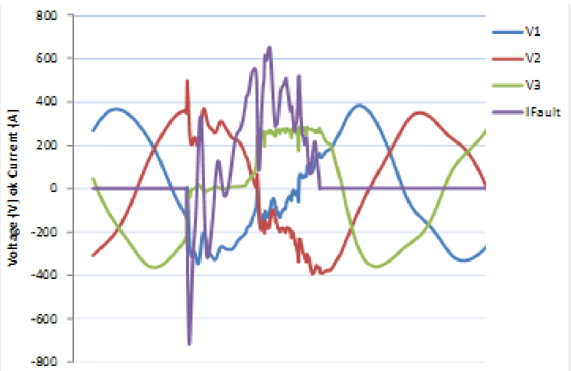

Figure 6: Phases voltage and fault current waveforms

To validate the protection plan the most unfavorable conditions were recreated in the lab:

- An impedance has been added to limit the short circuit current to the smallest expected value on the village,
- A breaker of the largest size is used.

Even under these conditions, the breaker tripped instantaneously.

Then lab tests confirmed that the chosen strategy is efficient in isolated mode both for microgrid infrastructures and consumers.

But it's worth noting that every microgrid system is specific and that such tests will be necessary for every configuration.

Control and supervision system

The local control and supervision system is another issue of microgrid system: it's necessary to define a self-acting process which guarantees both safety and smooth running of the microgrid.

The first point addresses the definition of the communication means and the instrumentation needed as:

- Control inputs: BT voltage and frequency, active power supply by the generators, flows on MV network before islanding,...
- Operation means to keep the efficiency of protection plan and control coupling/uncoupling phases properly.

Next, for each state of the microgrid and each change of state (normal state with microgrid inactive- coupled to MV network, microgrid active - islanded from MV network, microgrid blackout), we define the self-acting procedure step by step to be implemented in a local programmable logic controller.

Those technical challenges require arbitrating between reliability, quickness, and cost of the global solution which have to stand well proportioned in regard of scale of the microgrid.

Islanding and coupling back

Islanding and coupling back the village to MV network could be a critical issue.

In the PAESI microgrid project, as the final purpose is to upgrade continuity of supply instead of complete outage, the chosen approach is as simple as possible:

- Islanding: islanding will be decided on weather alert before any damage on MV network may occur. Actually, after damages, means of communication could also be down making impossible the change to islanding mode.

- Coupling back: the choice is to stop electrical generators and switch off the microgrid before shut down the breaker to reconnect the village network to MV network and then restart local power plant. In this case, a self-acting device could present the advantage to make it "transparent" for consumers and electrical generators but could be expensive in regard of the whole project budget (less than 1 M€).

CONCLUSION

Lab tests have shown that the feasibility of the operation of this microgrid in islanded mode with the chosen mode of regulation and control.

Several technical requirements were met, such as the capacity to regulate dynamically the balance between supply and demand by a resistive load, the efficiency of the protection plan and the compliance with harmonic distortion voltage standards.

Thanks to those first successful lab tests, PAESI microgrid project could go further with 4 main next steps:

- Spring 2015: confirmation of funding.
- Mid-2015 year: second lab tests with CCL device.
- Beginning of 2016: commissioning of the local biomass power plant.
- Mid-2016 year: first life size tests before winter experiments 2016/2017.

All the acquired experience on this project will benefit also to all our researches and projects on both integration of renewable energies and electrification of isolate sites as our innovative system could be a smart complement to all storage technologies currently studied worldwide.

REFERENCES

[1] J. Peças Lopes, C. Moreira, A. Madureira, F. Resende, et al, 2004, "DD1 – Emergency Strategies and Algorithms", *MicroGrids project Deliverable*.

[2] M. Ouali, W. Bahloul, M. Chaabene, M.B.A Kamoun, 2009, "Etude statique d'une génératrice asynchrone autonome alimentant un moteur à induction", *International Renewable Energy Congress*.

[3] J. Barsch, et al, 2012, "Fault Current Contributions from Wind Plants.", A r*eport to the T&D Committee, Electric Machinery Committee and Power System Relaying Committee of the IEEE PES*.

[4] C. Prévé, 1998, *Protection des réseaux électriques*, HERMES, Paris, France.