MICROGRID TEST SITE FOR PROTECTION SYSTEMS

Ignasi Cairó-Molins
IREC – Spain
icairo@irec.cat

Ramon Gumara-Ferret
IREC – Spain
rgumara@irec.cat

Albert Ruiz-Álvarez
IREC - Spain
aruiz@irec.cat

ABSTRACT

In this work, there are some requirements about the introduction of distribution generation in the power grids, and what they will demand in regards to protection systems and devices. From medium voltage to low voltage, there are some challenges in protecting such power grids, and due to such new necessities, it is introduced a test site, that can contribute conducting some test to get more insight into the situation.

Some of the relevant challenges for such protection systems are; the change from radial grid configuration into a mesh network, and the presence of inverter interfaced distribution generation resources. Being able to facilitate the test in such environment is the goal of this work.

INTRODUCTION

The amount of Distributed Generation (DG) connected to Medium Voltage (MV) and Low Voltage (LV) networks is increasing. This is expected to offer an improvement in power quality and reliability, and also power losses reduction in electrical distribution. Such DG systems are changing the way protection systems are being treated. New fault detection and resolution techniques have to be investigated and applied, leading to complexity in operation, control and protection for distribution systems.

Traditional protection systems have been quite straightforward, assuming only current faults in one direction. Distribution networks are prepared to operate radially so that power flows from upper voltage levels to customers along radial feeders. In DG, current may be injected to the distribution network. This presents new challenging situations for protection devices.

Networks need to be protected, so faults are diagnosed and isolated from the system. In traditional distribution systems, the downstream network is disconnected in the event of a fault. On the other hand, in DG, best practice would allow stand-alone operation.

The widespread of DG has been found to be incompatible with conventional distribution protection system approaches, due to load flow changes and miss-coordination of protection devices. Conflicts between DG operation in stand-alone mode and protection purposes raise a problem. When a new DG is added to the network, protection coordination should be checked again.

One solution to handle bidirectional power flow is the use of bidirectional over-current protections. These ones may be used with adaptive coordinated parameter settings. From experience trials, it is shown [1] that suitable parameters depend dramatically on load situation. This means that parameters cannot be calculated automatically but have to be measured and introduced into the algorithms. Another solution is the use of microprocessor-based re-closers and directional elements for feeder relays [2].

DG units are expected to be connected to the network by converters with limited short-circuit current (approximately 2-3 times the rated current [3]).

Many conventional protection relays do not offer communication functionalities. Their operation curves are fixed and the definition of different setting groups is not allowed. With a single setting group it is not possible to guarantee selective trips for all type of faults that may happen.

The Catalonia Institute for Energy Research (IREC), located in Barcelona, Spain, is provided with a 200kVA low voltage microgrid test site. The microgrid is connected to the utility but it is also able to work in standalone mode too. In this paper, it is proposed the capabilities of IREC's laboratory to test protection devices and protection schemes for in both modes of operation: grid-connected mode and the islanded mode.

PROTECTION APPROACHES

Fault characteristics in microgrids in standalone mode, dominated by inverter interfaced DG, are quite different from the ones in traditional power grids with synchronous generators. Although no special protection devices are proposed in this paper, it is worth to mention some of them. In reference [5] it is proposed a post-fault switch for microgrids based on current sequence components. Reference [6] proposes communication-assisted digital relays for protecting microgrids. Reference [7] presents voltage based protection method in a *dq* rotating frame. Reference [8] proposes an strategy for LV microgrids based on programmable microprocessor-based relays and directional elements.

Small DG effect

Small generation units may be connected to the LV or MV voltage grid. However, these grids were designed just for loads, not considering DG.

One problem facing DG in power grid is the impact on grid stability. One single power generator may have small impact on stability. But the sum of many small power units has a big share on the whole produced power. Therefore, also small production units should consider some conditions for the grid.

Protection for MV microgrids

With the penetration of DG in MV, it is more feasible to use MV feeders as microgrids. Such microgrids operate in radial configuration internally, but in parallel with the utility grid. However, during outages they are capable to operate in standalone mode.

Traditional MV networks are protected against short-circuit faults with over-current relays. In standalone mode, due to the drastic change of network parameters and the lack of short-circuit power, these relays may fail to detect fault conditions.

Protection for LV distribution grid

In LV distribution protection is an issue when DG is based on directly connected single-phase generators and converter-connected generation. The contribution of these sources to network fault levels and their effect on over-current protection schemes are considered to be taken into account for future LV distribution networks.

In LV, as in MV, when determining the fault level it has to be considered the contributions of both the feeding of the upstream and the downstream combination of DG, being maximum at the Point of Common Coupling (PCC).

Regarding the cause of the fault, when it is caused by a synchronous generator, it may be as high as 6 times the generator full-load current [9]. When is a contribution of an induction generator that obtains its excitation from the mains, its fault level is lower than the previous one.

When a current fault is caused by a converter-connected unit, either for generaton or storage, it is lower and value. Depending on the converter design, this current fault may be around 2 to 3 times the converter rated current [9].

One can describe two differentiated fault locations to be considered: upstream faults and downstream faults.

Upstream faults

When a fault occurs upstream to the location of the DG, DG may contribute in high level to the fault, and this might force non-directional protection to operate.

Downstream fault

In this case, DG may have a higher contribution to the current fault than the utility does. When this happens the current fault seeing by the breaker, may be lower depending on the DG size. If the fault current contribution from the substation is lower than the tripping level set at the breaker, then a failure to trip may occur.

ANTI-ISLANDING PROTECTION

In networks with DG, new paradigms for faulty detection are found and such faulted parts will need to be disconnected from the healthy network by operation of protection equipment. In that case the area with DG may keep on operation. Disconnection is in most cases not a wanted event for the following reasons:

- When operating in islanding mode, the maintenance of power quality is a difficult task. There may be abnormal voltage or frequency in the network, and the fault level be too low, so that the overcurrent protection may not work properly.
- Reconnection requires a special look into network parameters to avoid damaging equipment and decrease of reliability.
- One can face safety problem to maintenance personnel when deenergized circuits are energized again.

While sustained islanding is a rare event, short-time islanding can be a common phenomenon and very detrimental. Some authors [10] state that only long time islanding, lasting more than five seconds, is regarded as islanding.

MICROGRID DESCRIPTION

The Catalonia Institute for Energy Research (IREC), located in Barcelona, Spain, is provided with a low voltage microgrid test site able to manage up to 200 kVA. This electric installation is mainly divided in two main parts: the header and the microgrid busbars (µG), and both are equipped with the electric and electronic devices detailed below.

Microgrid header: it is the link between the Point of Common Coupling to the utility grid and the microgrid busbars. This strategic emplacement is reserved to equipment able to introduce variations on the power supply characteristics for all the nodes in the microgrid: voltage sags (type A, C and D), variations in the AC voltage and frequency, control of the harmonics, generation of arbitrary voltage signals, and so on. This can be achieved with the following devices:

- Power grid emulator (200kVA)
- Fast disturbance emulator (50kVA)
- Variable inductance

Microgrid busbars (µG)*:* one particular characteristic of IREC's microgrid that is principally composed of emulation devices able to perform the electrical behaviour of wind power systems, PV panels, electric storage systems or any kind of electric load. These devices are the key elements for reproducing the desired electric conditions not only to test hardware but also control strategies and algorithms. The list below contains the different available nodes in the microgrid:

- Electrical emulators (7 x 5kVA)
- Lithium battery (20kWh)
- Supercapacitor storage unit (5.5kWh)
- Electric vehicle slow charging point (2 x 3.7kW)
- Urban wind power generator (2kW) (not currently)
- Photovoltaic generator (5kW) (not currently)

Each emulated node is composed of two identical three-phase voltage sources in back-to-back configuration. These converters can work as active rectifier or active inverter, allowing bidirectional power flow. In the AC side, converters can control active power and reactive power independently, as long as the apparent power does not exceed the maximum (Smax = 5000V A). There are commercial protection and measurement devices and meters in every unit.

Fig. 1 shows the electrical scheme of the IREC's microgrid installation. It is designed for having the maximum flexibility not only in terms of number of installed equipment but also for changing the topology of the microgrid (µG) busbars from star to ring by joining the ends of the ends of the three different µG-Busbars. These busbars allow the installation of any kind of node (consumption, generation, storage, DG, etc.) which or even to be divided by circuit breakers able to isolate smaller sections of the busbar. Furthermore, as it is seen in Fig. 3, the junction point between each one of the nodes and the of the µG-Busbar there is an space reserved for the installation of protection devices for microgrids to be tested in this real electric environment.

A management system controls each unit so that the power supply and the security of the microgrid are guaranteed. Some operations of the management system are time critical, such as a unit emergency disconnection. For this reason, it is preferable to split the management system in a multilevel architecture. This implies decentralizing and reorganizing management tasks and their reallocation in different Intelligent Electronic Devices (IEDs).

IREC's microgrid management system is three-layered, hierarchical and comprises (Fig. 2):

- The Management Control Unit (MCU) level (top layer).
- The iNode level (middle layer).
- The iSocket level (bottom layer).

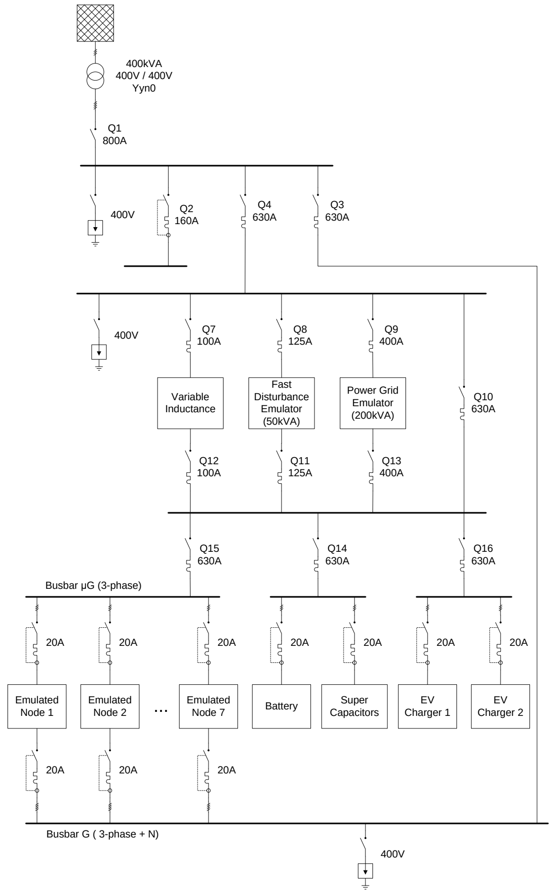

Fig. 1 Unifilar electrical diagram of IREC's microgrid.

The MCU manages the overall microgrid. However, tasks requiring a very fast time response (e.g. electric security and stability) and tasks implying a high information exchange with the units (e.g. execution of active and reactive power control algorithms) are performed by iNode and iSockets.

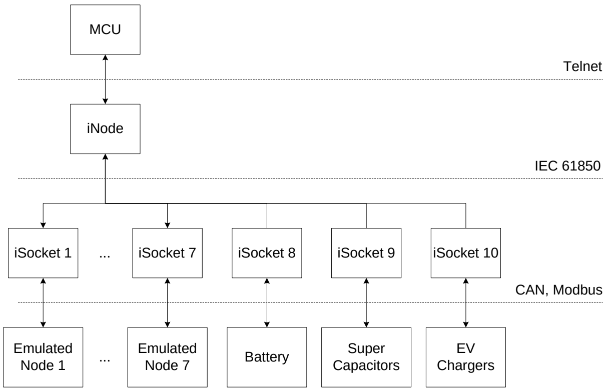

Fig. 2 Microgrid management architecture.

IEC 61850 FOR PROTECTION

IEC 61850 has been elaborated by the ad-hoc group “Substation Control and Protection Interfaces” of IEC Technical Committee 57 “Power systems management and associated information exchange”. The purpose of IEC 61850 is to specify requirements and to provide a framework to achieve interoperability among IEDs.

This standard was first designed for the standardization of communication in Substation Automation Systems (SAS). However, just a few year after the “kick-off” of the IEC 61850 project (in 1995), utility and vendor experts of non-substation related application domains began to realize both the benefits of a single international standard for the electrical energy supply system and the powerful approach and content of IEC 61850. As a result, IEC 61850 has been extended to other domains, such as DER and Hydroelectric Power Plants [2].

IEC 61850 proposes different communication services. For protection automation, for example, the standard proposes Generic Object Oriented Substation Event (GOOSE) messages and Sampled Values (SV) messages. Both services are very fast messages having a 3 ms back-to-back transmission time which is suitable for critical protection devices [11].

CONCLUSIONS

In this paper it has been presented IREC’s laboratory and microgrid as a site to test protections. Protection devices for power grids with high distributed generation must fulfill new challenges. So, it is important to test such devices in situations reproduce the real behavior of such systems. So, in order to test protections, IREC is developing a laboratory with sufficient power and the ability to reproduce faults and disturbances.

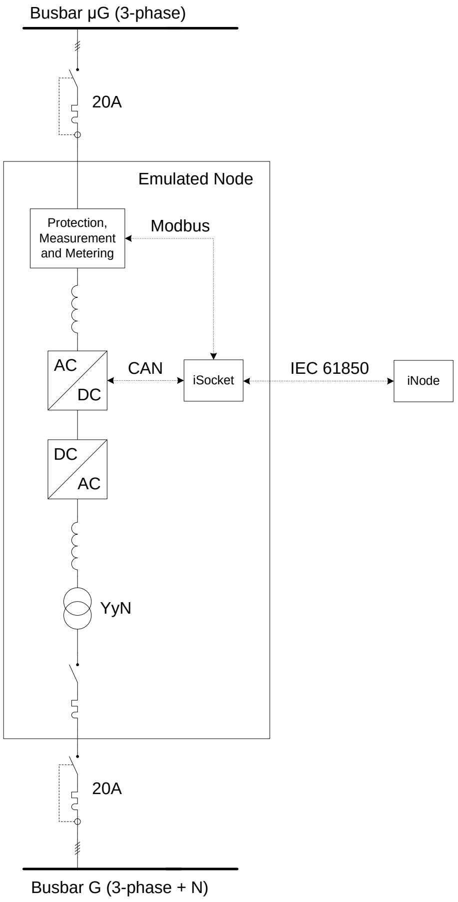

Fig. 3 Example of the functionality of iSocket.

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