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Review

Survey on microgrids: Unplanned islanding and related inverter control techniques

Alvaro Llaria [a,b,*], Octavian Curea [a], Jaime Jiménez [b], Haritza Camblong [a,c]

[a] ESTIA RECHERCHE, Ecole Supérieure des Technologies Industrielles Avancées, Technopôle Izarbel, 64210 Bidart, France
[b] Departamento de Electrónica y Telecomunicaciones, Universidad del País Vasco, Escuela Técnica Superior de Ingeniería, Alameda Urquijo s/n, 48013 Bilbao, Spain
[c] Departamento de Ingeniería de Sistemas y Automática, Universidad del País Vasco, Escuela Universitaria Politécnica, Plaza de Europa 1, 20018 Donostia-San Sebastián, Spain

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ABSTRACT

Nowadays, the importance of electrical generation based on renewable energies is increasing, due to its low emissions of greenhouse gases. At the same time, Distributed Generation and Microgrids (MG) are becoming an important research line because of their peculiar characteristics. MGs are composed of small power sources which can be renewable, placed near customer sites. Moreover, they have the inherent property of islanding: the disconnection of either the MG from the main grid or a portion of a MG from the rest of the MG. There are two kinds of islanding: intentional or planned (for maintenance purposes), and unintentional or unplanned. The latter is mainly due to disturbances and it is used to avoid damages in sources and loads. It is the most critical case because it must be detected as soon as possible to activate all the control systems which allow continuing the energy production and distribution despite the disconnection. In islanding, it is crucial to ensure the power and the electrical signal quality. In grid-connected mode, the inverters use the electrical signal of the main grid as reference. Once in islanding, the main grid reference is lost and new control techniques for the inverters are needed in order to obtain the correct values of voltage magnitude and frequency in the MG.

The main objective of this paper is to make a survey on MGs focussed on two important features: unplanned islanding and control of inverters in that scenario. The idea is to present the basic architectures and regulation techniques of MGs and to study the islanding behaviour, mainly the different detection techniques and the inverters' control once islanded.

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1. Introduction

In the last years, the importance of Distributed Generation (DG) has increased considerably. The interest of DG grows when it is composed of different energy resources forming a Hybrid Energy System (HES), because they can easily support the electrical network in remote sites and rural areas. In this context, Microgrid (MG) concept makes reference to a group of loads and microsources which operate as a controllable system, providing electric power (and optionally heat, which is know as *cogeneration*) to its near area [1]. Nowadays it is proved that a system based on small-scale cogeneration can be more suitable than electrical only DG [2]. Combining cogeneration with absorption or engine-driven chillers allows setting up the concept of *tri-generation* and, in addition, the combination of different energy vectors, such as electricity, heat, cooling, hydrogen, etc., proposes a future energy scenario based on *multi-generation*.

Thus, a new paradigm of electrical network with distributed generation and the need to define its mode of operation appear. The utility considers the MG as a cell controlled by the power system. From the point of view of the customer, the MG can be implemented according to their needs, such as: to increase locally the reliability of the electric supply, to limit the feeder losses, to ensure the voltage quality or to provide uninterruptible power supply, among others. Moreover, from an economical point of view, MG has the advantage of deferring the network investments. It also contributes to adequate the generation because of its ability to control internal loads and generation [3,4].

One interesting property of MG is islanding: the disconnection of either the MG from the main grid or a portion of a MG from the rest of the MG. Islanding can be originated in a planned way or unintentionally and, in both cases, the isolated part can continue providing energy to its connected loads. This feature has clear advantages, but, at the same time, new difficulties which must be resolved.

* Corresponding author. ESTIA RECHERCHE, Ecole Supérieure des Technologies Industrielles Avancées, Technopôle Izarbel, 64210 Bidart, France. Tel.: +33 559 43 84 00; fax: +33 559 43 84 05.
E-mail address: a.llaria@estia.fr (A. Llaria).

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Finally, it is important to point that MGs are placed in the low voltage (LV)/medium voltage (MV) distribution networks. This has important consequences. Traditionally, the hierarchical structure used in electrical networks has carried out the most complex control systems with the greatest automation at high voltage (HV) levels. But now, with plenty of little energy sources connected at the distribution level, there are new challenges, such as system stability, power quality and network operation that must be resolved applying at LV/MV levels the control systems traditionally used at high voltage levels. In other words, distribution networks must pass from a passive role to an active one. This new active distribution network scenario is suitable to implement techniques of Demand Side Management (DSM) [5] in order to improve the efficiency of the MG.

This paper makes a survey on MGs, mainly focused on islanding concerns and inverter control techniques with the MG isolated. In Section 2, a description of the basic architecture of a MG, with the two different approaches, the European and the American one, is made as a start point of the study. Afterwards, Section 3 presents the basic applicable regulation techniques employed in MGs. Related with islanding, Section 4 explains different algorithms used to detect unplanned islanding. Once in islanding, one of the most important issues to be resolved is the control of MG's inverters. Therefore, in Section 5, a state of the art of different inverter control algorithms is made. Section 6 concludes this paper.

2. Basic architecture of a microgrid

The electrical micro-sources which exist in MGs are usually low power, under 100 kW, with interfaces based on power electronics in order to provide adequate control and flexibility. The typical sources used in MG are micro-turbines, photovoltaic (PV) panels, fuel cells and wind turbines. They have low greenhouse emissions, low power and high reliability. In addition, these sources can be placed easily near the customer's home. The basic architecture of a MG consists of a radial connexion of several feeders with their associated loads and micro-sources, as it was described by the first time in [1].

According with [6] an example with four feeders, A, B, C and D, is shown in Fig. 1. The voltage in a feeder is about 480 V, but it can be lower. Each feeder has a *circuit breaker* and a *power flow controller* commanded by the *energy manager*. If there is a disturbance into the MG, the *circuit breaker* is used to disconnect the correspondent feeder to avoid the propagation of the perturbation through the MG. In islanding, if there are variations in the connected loads, local micro-sources will either increase or reduce their production to keep constant the energy balance, as far as possible. That is not the case in grid-connected operation, because in this situation, the main grid compensates the increases or decreases of the load. The MG is connected to the distribution system by a *point of common coupling* (PCC). There is also a separation device known as *static switch*, which has the capability to island all the MG when faults or events described in the standard IEEE 1547 [7] occurs, or for maintenance purposes. If a feeder has sensitive loads (those that need uninterruptible power supply) connected, it will have local generators in order to avoid interruptions of electrical supply. To achieve an uninterruptible generation, those sources cannot be, for example, wind turbines or PV panels, because of the intermittence of the wind and the solar energy. Technically, there are batteries with enough energy saving capacity to act as a backup system when there is not enough wind or sunshine, but they are very expensive. One solution to avoid generation interruptions is the utilization of uninterruptible sources such as diesel generators, which are widely employed and known, or fuel cells, for example. From the basic architecture of MG described before, other approaches have been developed in Europe and USA in the frame of different projects. These new proposals are described in next Sections.

2.1. Architecture of MGs using microgrid central controller

The architecture of MGs that employs a *microgrid central controller* (MGCC) was firstly developed in the EU Microgrids Project [8] and proposes a hierarchical structure to guarantee a robust operation. An example of this architecture is shown in Fig. 2.

In these MGs, the most important element is the MGCC (the first hierarchical level), which is installed on the side of the medium voltage/low voltage (MV/LV) substation connected to low voltage line (LV). Its function is to carry out a high level management of the MG operation by means of technical and economical functions. In a second hierarchical level are *micro-source controllers* (MC) that control, obviously, the micro-sources and the energy storage systems. Finally, each load or set of loads is controlled by a *load controller* (LC). To perform the interchange of information between

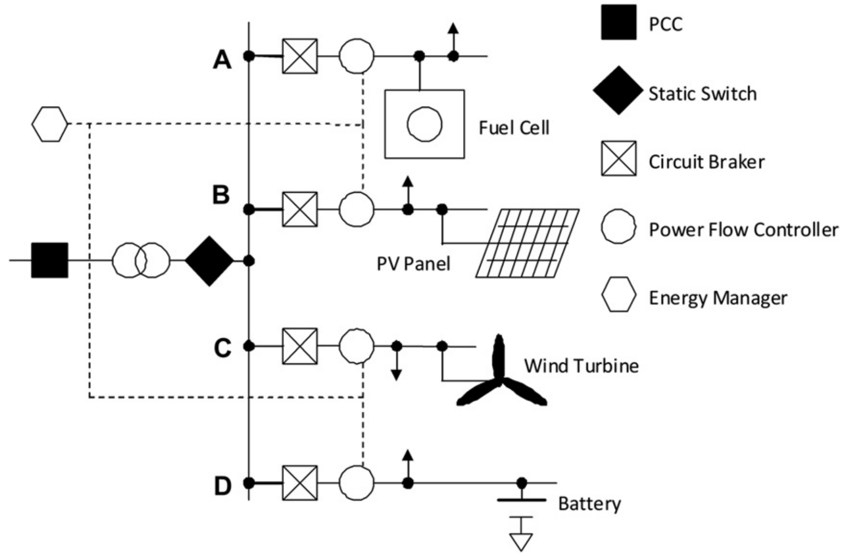

Fig. 1. Basic architecture of a MG.

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