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Microgrids Operation Based on Master-Slave Cooperative Control

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***Abstract*—Low-voltage microgrids can be seen as the basic tiles of the smart grid patchwork, owing to their capability to efficiently manage the distributed energy resources in aggregate form. They can support the grid in terms of demand response, power quality, ride through capability, and, at the same time, they can ensure electrical continuity to the loads, even in case of grid failure. This paper describes a simple and effective approach to manage microgrids by synergistic control of the power electronic interfaces acting therein, i.e., the Utility Interface (UI), installed at the point of common coupling with the utility, and the Energy Gateways (EGs), interfacing the distributed energy resources with the distribution grid. The proposed master-slave control uses the UI as control master for the EGs. In grid-connected operation, the UI performs as a grid-supporting unit and dispatches active and reactive power references to the EGs so as to improve energy efficiency and power quality; in islanded operation, the UI performs as a grid-forming voltage source and ensures the power balance by exploiting every power source and energy storage unit available in the microgrid. The paper discusses the theoretical background, architecture, and algorithms of the proposed master-slave control and demonstrates the resulting microgrid performance by means of simulation and experimental results.**

***Index Terms*— Energy gateway, Master-slave control, Microgrid, Utility Interface, Power sharing.**

I. INTRODUCTION

LOW VOLTAGE microgrids will play a major role in future smart grid [1]. The presence of distributed micro-generation and energy storage owned by end users (prosumers) creates a new paradigm for electrical grids and a potentially huge new market for technology manufacturers, service providers, energy traders, distributors, and regulatory boards. Several challenges must be tackled; these challenges are in the area of technology, organization, standards, rules, and economy [2-4].

According to the new paradigm, the distribution grid can be seen as a patchwork where microgrids play as basic tiles, supporting the utility in terms of demand response, power quality, network dynamics management, and other ancillary services, also ensuring electrical continuity to the loads even in case of grid failure.

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A major goal of microgrids is to integrate and manage effectively every kind of distributed energy resource (DER), either micro-generation (MG) or energy storage (ES) [5]. In fact, the increasing pervasiveness of renewable energy sources (mainly photovoltaic) can generate misbehavior of the distribution grid due to over-production along daytime [6], and also affects some economic assets of the electrical market [7]. The capability to control and plan the energy in- and out-flow of microgrids, seen as aggregate entities, will play a major role in ensuring stability, efficiency and cost-effectiveness of future smart grids [8-10]. For this aim, the distributed units must be driven cooperatively, and the control architecture must be flexible and scalable to integrate every type and number of DERs and dynamically adapt to load power demand and energy supply [11-15].

This paper proposes a microgrid control architecture which allows full exploitation of distributed energy resources, optimization of steady-state performance, both on-grid and off-grid, and effective management of transients. Seen from the utility terminals, the microgrid behaves as an aggregate prosumer with extended power capacity and wide control functions. Moreover, multiple microgrids can plug to the same electrical distribution system without affecting voltage or frequency stability. These features open new technical and economical scenarios, where communities of prosumers, aggregated in microgrids or pools of microgrids, may gain an increasing role in the electrical market by taking advantage of their cumulative energy resources and control capabilities.

II. MICROGRID STRUCTURE

The considered structure of low-voltage microgrid is shown in Fig. 1, with K nodes connecting end-users.

At the point of common coupling with the utility (PCC, *node 0*), the microgrid is equipped with a Utility Interface (UI) with energy storage (UI-ES). The UI is driven as a voltage source and interacts, via bidirectional communication links (e.g., on power lines or wireless), with the other nodes of the microgrid.

N grid nodes are *active*, i.e., link-up power sources and/or energy storage devices interfaced to the grid by Energy Gateways (EGs). EGs are driven as current sources [16] and have bidirectional communication with the UI.

The remaining M nodes are *passive*, i.e., link-up loads only, and are equipped with Smart Meters (SM), which perform local measurements and handle one-way communication to