Cooperative Control in a Hybrid DC/AC Microgrid based on Hybrid DC/AC Virtual Generators

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***Abstract*—This paper deals with the dynamic control of the DC bus voltage and the AC voltage magnitude and frequency in a hybrid DC/AC Microgrid (MG). In order to allow a high penetration of renewable energies, provide an increased system reliability during islanding and reduce the dependency on the mains, Energy Storage Systems (ESSs) are included in both the DC and AC grids. The MG is composed by a multiport solid-state-based transformation center, with connexion to the mains and a central battery energy storage system (BESS), and a flexible number of AC Nanogrids (NGs) coupled to a Low Voltage DC bus (LVDC) through DC/AC 3-phase Power Electronic Converters (PECs) operated as grid forming, hereinafter referred as Nanogrid Head Converters (NGHCs). The MG control presents two main characteristics: 1) A DC bus regulation scheme is proposed based on DC virtual generators and P/V DC droop that allows to adapt the participation in the power sharing for DC bus regulation and provides with an automatic transition between *grid connected* and *islanding* modes; 2) In order to provide a cooperative operation between the different AC NGs, allowing the automatic power sharing between them through the DC bus, a DC/AC virtual generator control scheme, based on the theory of Virtual Synchronous Machines (VSM), is proposed for its implementation in the NGHCs, thus coupling the control of the LVDC and the NGs. The theoretical discussion is supported with simulations.**

***Index Terms*—DC/AC Hybrid Microgrid, MG control, Virtual Inertia, Virtual Synchronous Generator**

I. Introduction

The increasing concern about environmental issues, the problematic of renewable energies integration, and the rising popularity of concepts such as local generation and self-consumption have led to an increasing interest on alternatives to the conventional utility grid as Microgrids (MGs), Nanogrids (NGs) and Smart grids. Despite its advantages, the weakness and stability problems associated to a MG, due to its low inertia and the presence of renewable energy systems (RES), have demanded a significant research interest since its apparition. Studies for different types of contingencies have been carried out, pursuing the power quality improvement [1], [2]. Furthermore, with the apparition of hybrid DC/AC MGs, where the Power Electronic Converters (PECs) may share power not only in the AC grid but also in the DC lines, new MG issues appears as the stability, voltage regulation and quality maintenance in both DC and AC grids [3]–[5].

Several methodologies and control topologies for distribution network (DN) and MGs have been presented in the literature to ensure the voltage control and power flow, as the central controller, the master-slave, the Q/V and P/f droops, the virtual impedance, and hybrid approaches [6]–[9]. In addition, during the recent years a relatively novel approach for MGs distributed control is becoming popular, consisting on the emulation of Synchronous Generators through PECs leading to the well-known terms of Virtual Synchronous Generators (VSG), Virtual Synchronous Machines (VSM), Synchronverters and Virtual Inertia (VI). The integration of VSGs in the MGs allows to imitate the behavior of conventional grids dominated by Synchronous Generators (SG), providing the MG with an additional inertia, softening the frequency and magnitude rate of change during active power transients. Moreover, VSGs avoid the use of frequency or phase detectors for synchronization and allows the integration of conventional SGs in the MGs together with DGs, RESs, ESS and loads interfaced by PECs. Additionally, the stability and dynamic active power balance in the grid can be improved by adding a VI using ESSs, increasing the grid inertia and damping, adding flexibility to the system [10]–[14]. Besides, the VSG scheme can also be combined with Q/V and P/f droops in order to

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