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PH.D. THESIS ABSTRACT

SMART-GRID Integration of Renewable Energy Sources

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Abstract

Energy market liberalization processes and incentive programs by various National governments are driving an increasing diffusion of a wide variety of Distributed Generation (DG) power plants, causing huge changes and challenges in Electrical Power Systems (EPS). In fact, while in the past the power generation was mainly concentrated in a small number of large power plants directly connected to the high voltage Transmission Networks (TNs), DG units can be connected directly to Distribution Networks (DNs), causing both DNs planning and management issues. Thus, innovative planning and management approaches of these new active networks are necessary to ensure the best integration of Distributed Energy Resources (DERs) within EPSs as well as TNs and DNs optimal use.

The thesis work addresses these aspects by investigating DERs integration issues and their impact on voltage profiles within DNs. The work proposes a technique for DERs decentralized control at the Point of Common Coupling (PCC) with the DN, designed to contain voltage variations within regulatory limits and to maximize active power delivery to the grid.

The current global, European and Italian energy scenarios, as well as the long-term trend of the primary energy sources mix for electricity production are presented at the beginning of the work in order to understand the overall reference domain. Then, the issues concerning the introduction of DERs in EPSs, traditionally designed as passive networks essentially characterized by unidirectional power flow, are pointed out. Thus, the opportunities offered by the Smart Grid concept to solve these issues are discussed.

The thesis proposes a unified approach to the management of DG units connected to the DNs by means of electronic converters. A series of case studies concerning traditional voltage regulation performed through the on-load tap changer of the HV/MV (High Voltage/Medium Voltage) transformer is firstly proposed to point out the effects of DGs integration. These simulations are run on a south-Italy weak DN with and without renewable based DERs integration.

The choice of this type of network is due to the fact that it well represents the typical structure of sub-urban and extra-urban DNs that are housing the most part of the aforementioned renewable DERs. Furthermore, the reduced value of the reactance vs. resistance ratio that generally characterizes these DNs tends to increase the issues concerning voltage profiles rising.

The thesis work proposes an algorithm for decentralized voltage profiles control at the DERs PCC in the case of DERs equipped with electronic interfaces. Furthermore it points out an optimization procedure aimed at minimizing the reactive power exchanged between the DERs and the DN and the losses within the network.

The developed methodology presents modularity, flexibility and scalability characteristics. Due to these peculiarities and the satisfactory results obtained considering DNs not extensively equipped with communication and information technology solutions, the proposed methodology results particularly versatile for future Smart Grids development scenarios.

A series of simulations related to the previously analyzed case studies shows the impact of the proposed solution on both the voltage profiles and the energy fed into the grid, highlighting its efficiency, simplicity, and promptness. An extensive results analysis concludes the work.