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Optimal Energy Storage System Control in a Smart Grid including Renewable Generation Units

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Abstract. The paper deals with energy storage systems applications in Smart Grids. Several services can be performed thanks to the energy storage systems use, with objectives aimed at meeting needs internal or external to the Smart Grid. Optimal nonlinear constrained problems can be formulated and properly solved in order to perform the services in the best economical and technical way. In this paper, optimal control strategies are proposed in order to allow the Smart Grid to minimize internal losses and to sell energy and ancillary services during high power prices periods. The procedure involves the formulation of optimal power flow problems; proper objective functions and constraints are imposed to satisfying the services that have to be carried out. A numerical application on a 30-bus low voltage Smart Grid shows the effectiveness of the proposed procedure.

Key words

Smart Grid, Energy Storage Systems, Renewable Energies, Control strategies, Optimization techniques.

1. Introduction

Smart Grid means complex power networks that use bi-directional communications among Distributed Energy Resources (DERs), customers and a Central Control System (CCS), in order to optimize the power supply while guarantying the overall system efficiency. Use of a Smart Grid usually refers to power quality improvements, optimal exploitation of renewable energy resources, network self-repairing when failures happen, opportunity for the customers to manage their electricity usage for minimizing their expenses and so on [1-3].

On the other hand, liberalization of the power market and widespread use of DERs, in particular Dispersed Generation (DG) and Energy Storage Systems (ESSs), could enable Smart Grids to have a significant influence on electricity market prices and ancillary services [4]. As focused in [4], the charge/discharge of various ESSs can be controlled in order to guarantying proper applications. Further, in modern power distribution systems, where a significant amount of the total electricity demand is met by renewable generation, ESSs can mitigate the uncertainties of energy sources (such as solar and wind) and can store the energy during high renewable production and/or low price periods, and deliver when either necessary or convenient. Based on the ESSs technologies, in [4] the applications of ESSs are classified in instantaneous, short-, mid- and long-term. Instantaneous and short-term applications are involved in real time regulations, for example aiming at ancillary services provision or integration of electric drive vehicles batteries in the networks [5, 6].

In the most general case, ESSs in a Smart Grid including renewable energies can operate with several objectives, aimed at meeting needs internal (for example, the minimization of losses) or external to the Smart Grid (for example, sell of energy during high power prices periods and storage of energy during the other periods). These objectives can be obtained thanks to a proper control of ESSs.

The problem of ESSs control in distribution systems with DG have been already treated in the relevant literature, (e.g. [7-10]). In [7], an ESS control algorithm, aimed at reducing the power exchange between the grid and the interconnected network, is proposed. In [8] a single-objective optimization problem is proposed for providing a ESS control strategy aimed at obtaining peak load shaving. Based on dynamic programming, the algorithm maximizes the benefit obtained by the peak shaving application. In [9] a methodology for operation of ESSs in distribution networks with wind generation is proposed. Through the formulation of a single-objective optimization problem, the algorithm aims at scheduling the ESSs daily active power provision, while minimizing the grid power losses. In [10] a methodology for emulating the distribution network behavior in presence of ESSs and DG is proposed. The algorithm is based on a single-objective optimization problem aimed at maximizing the profit provided by the power exchanged between ESSs and the grid.

The methodologies proposed in [7-10], such as other proposals, are based on the control of ESSs active power and their stored energy status but do not consider their potential to provide reactive power (thanks to the presence of interfacing static converters) for power losses reduction and voltage regulation. Moreover, they deal with either internal service (e.g. power losses or peak shaving) or external service (e.g. reducing the power