Optimized Control of Multi-Terminal DC Grids Using Particle Swarm Optimization

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Abstract

The electric networks of the future will make an extensive use of DC grids. Therefore, the control of Multi-terminal DC (MTDC) grids is a key issue, which is gathering the attention of the industry and the research community. In this regard, this paper proposes a grid control strategy for voltage-source converter (VSC)-based MTDC networks, based on the use of the particle swarm optimization (PSO) technique. In the proposed approach, the controllers of the power converters belonging to the MTDC grid are acting based on the concept of vector control, in which the AC currents and voltages are transformed into a rotating direct-quadrature (dq) reference frame for controlling of the active and reactive powers as well as the DC and AC voltages. Since the VSCs are nonlinear plants in nature, the classical approaches for tuning of the control system, which are usually based on the approximate linear model of the plants, do not lead to optimal results. As an alternative, in this paper an efficient PSO algorithm is used for tuning optimally the parameters of the controllers in the MTDC grid. In addition, the voltage droop control scheme is utilized to ensure the active power balance within the MTDC grid. The simulation results, obtained through a detailed model of a four-terminal DC grid, demonstrate the efficiency of the proposed approach. Finally a comparison with PI controllers which have been conventionally tuned also confirmed the favorable performance of the proposed PSO-tuned controllers.

Introduction

Recently, Multi-terminal DC (MTDC) grids have been receiving a special attention from the electric power systems researchers and also from the industry professionals in this field. Therefore, the modeling, simulation and control of the MTDC grids are among the main research topics, pursued during the recent years [1-3].

The appropriateness of the MTDC grids for the integration of offshore wind farms into the AC mainland, have been the main focus of various studies [4-6]. The MTDC grids eliminate the large capacitive currents, associated with long-distance AC transmission, and hence are suitable for wind farm integration into the mainland AC grids [7]. Furthermore, the MTDC transmission system can facilitate the development of the so-called "European Supergrid" [8].The researches performed in the field of renewable energies have launched other initiatives associated with the exploitation of other resources, such as Desertec and Medgrid, linked mainly to the exploitation, transmission and integration of photovoltaic (PV) generation systems [9].

The MTDC grids are usually characterized by the interconnection of several high voltage DC (HVDC) stations through high voltage DC links [4]. Among the available HVDC technologies, i.e. the line-commutated converter (LCC)-HVDC and the voltage-source converter (VSC)-HVDC, the latter exhibits more favorable features such as full controllability of the DC network and ease of connecting multiple converters to the same DC grid. Thus, the VSC-HVDC technology is considered as the prime candidate and the most promising idea for constructing the VSC-MTDC grids [10].

In terms of network topology, the MTDC grids may be connected in series or parallel. The parallel connections are further divided into radial and meshed networks, where the meshed configuration will be the most common topology [11].

The control of VSC-MTDC grids includes regulation of active and reactive power, control of DC voltage and regulation of AC voltage at the point of common coupling (PCC), resulting thus in a multi input – multi output (MIMO) control system. The most commonly used control strategy for the VSC-HVDC stations is based on the vector control [10-12]. This control technique, formed by inner and outer loop controllers, desirably allows the fully decoupled control of the AC and DC quantities through transformation of AC quantities into the direct-quadrature (*dq*) rotating reference frame [13].

In these applications the proportional-integral (PI) controllers are widely used due to their simple structure and robust performance over a wide range of operating conditions [14], to drive the controlled variable (e.g. active power and amplitude of the AC voltage at the PCC) towards their target values.

However, to achieve a good control performance based on the use of vector control, which is adopted in this paper for the control of a VSC stations, the corresponding PI controller's parameters should be optimally tuned and adjusted. The optimal tuning of the controllers will improve both transient and steady-state control performances. However, in case of the nonlinear systems and plants (e.g. voltage-source converters), it is quite difficult to tune properly the gains of the PI controllers [14, 15]. In such circumstances, classical methods proposed for the tuning of the PI controllers face difficulties to determine an optimal or near optimal PI parameters [16].

In order to improve the performance of PI controllers various computational intelligence (CI) approaches have been employed

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