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Coordinated Converter Control Strategy in Hybrid AC/DC Power Systems for System Frequency Support

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Abstract

This paper proposes a coordinated converter control strategy for multi-terminal dc (MTDC) grids in hybrid AC/DC power systems. Previous works have shown the possibility of providing frequency containment reserve (FCR) from offshore wind farms to ac grids through MTDC grids using frequency and dc voltage droop control. However, due to the characteristics of dc voltage droop control, the frequency support would come both from offshore wind farms and all other ac grids connected to the MTDC. This paper proposes a coordinated MTDC converter control strategy that maximizes the share of the FCR contribution from an offshore wind farm and reduces the contribution of other ac grids. A hybrid AC/DC power system consisting of offshore wind farm and two asynchronous grids connected through an MTDC grid is used as a test system. Using the test system, different scenarios are analyzed to demonstrate the performance of the proposed coordinated control strategy.

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1. Introduction

Previous works have shown the possibility of providing frequency containment reserves (FCR) from offshore wind farms through HVDC links and multi-terminal HVDC (MTDC) grids support [1-3]. This is achieved by adding a frequency droop to the active power control of the converter connected to the ac grid that is receiving the FCR support. For HVDC connected offshore wind farm, as the wind farm would be connected to only one onshore grid, the frequency support comes solely from the wind farm. However, in MTDC connected offshore wind farm, due to the nature dc voltage droop control, the power needed for the frequency support comes not only from the wind farm but also from other ac grids connected to the MTDC grid. Hence, the frequency of the other synchronous zones is affected by frequency reserve sharing.

In this paper, a coordinated MTDC converter control strategy is proposed that maximizes the frequency support contribution of the offshore wind farm while reducing frequency disturbances (caused by FCR sharing) in other ac grids connected to the MTDC. A hybrid AC/DC power system consisting of offshore wind farm and two asynchronous ac grids connected through an MTDC grid is used as a test system. Different scenarios are analyzed using the test system to demonstrate the performance of the proposed coordinated control strategy.

2. Onshore grid frequency support from offshore wind farms

The offshore converter determines wind farm's collection grid frequency and voltage when dc transmission is used to connect offshore wind farms to onshore ac grid. In normal operation, the wind turbines are controlled in such a way that they are operating at optimal speed; extracting maximum possible power from the available wind. However, when wind turbines are involved in onshore frequency and/or inertia support, auxiliary controllers are introduced to the wind turbine converter controllers so that the turbines change their power output depending on change in onshore grid frequency. Since the dc transmission decouples onshore and offshore wind farm grid, the offshore wind turbines do not sense the change in onshore frequency immediately. Rather, auxiliary terminal converter controllers and/or communication system are used to convey the frequency deviation signal across the dc system.

The different methods proposed in the literature to signal onshore frequency change to offshore wind turbines can broadly be categorized into three. The first method requires additional controllers on both onshore and offshore terminal converters, and uses change in dc voltage as a signaling medium [4-6]. The second method requires additional controller only on the offshore terminal converter, and uses communication system to transmit onshore frequency change signal to the offshore terminal converter [7]. The third method proposes use of communication system to send onshore frequency measurement directly to offshore wind turbines [6, 8]. This paper proposes a coordinated control of converters in MTDC systems for improved system frequency support from offshore wind farms. For this reason, the brief review of the first two types of system frequency change signaling methods are presented in the following section.

2.1. HVDC connected offshore wind farms

Primary frequency support to onshore grids from HVDC connected offshore wind farms are discussed in [4-7]. The onshore side HVDC converter controls dc link voltage, while the offshore side converter determines frequency and ac voltage for the offshore wind farm collection grid. If the offshore wind farm is to participate in frequency regulation of the onshore grid, then auxiliary controllers are added to both the onshore and offshore HVDC converters. If a frequency deviation occurs in the main grid, then the onshore side converter changes dc link voltage. The offshore side HVDC converter will then change offshore grid frequency according to the change in dc link voltage. The auxiliary controllers introduced to the onshore and offshore side HVDC converters are shown in Fig. 1. f_{grid}, V_{dc} and f_{owf} represent onshore (main) ac grid frequency, dc link voltage and offshore wind farm collection grid frequency, respectively. ρ_f and ρ_{DC} represent frequency droop and dc voltage droop constants, respectively. The superscript * indicates a reference signal.