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A Review of Small-Signal Stability Analysis of Integrated VSC-Based DC/AC Power Systems

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Introduction

Voltage source converters (VSCs) are the most important dynamic components in a DC/AC power system based on VSCs. The VSCs connect the renewable power generation, VSC-based HVDC lines, and multi-terminal DC (MTDC) network to the AC power system. This paper summarises the most recent major research advances and conclusions regarding the small-signal stability of the VSC-based DC/AC power system. The study on the small-signal stability of a grid-connected single VSC system, an integrated VSC-HVDC/AC power system, and the MTDC/AC power system is covered in the review [1].

Voltage source converter (VSC) based HVDC lines and multi-terminal DC (MTDC) networks are of many technical advantages over the conventional LCC HVDC lines. They are the favourable solution to the large-scale transmission of renewable power generation, such as the offshore wind power. Furthermore, VSCs are critical components for the grid connection of renewable energy generation. As a result, the small-signal stability of an AC power system integrated with VSCs has piqued the interest of many power system researchers and engineers. The potential instability risk posed by the integration of VSCs, the VSC-based HVDC line, or the MTDC network has been investigated from various perspectives in recent years [2].

There have been two major concerns about the smallsignal stability of a VSC-based DC/AC power system. The first is the VSC-based system's small-signal stability, such as a single grid-connected VSC system or an MTDC network. The second issue is the small-signal stability of an integrated VSC-based DC/AC power system, such as an AC power system integrated with renewable energy generation, a VSC-HVDC/AC power system, or an MTDC/AC power system. The main issue is how the VSCs' grid connection affects the small-signal stability of the integrated VSC-based DC/AC power system [3].

The paper summarises the research progress and main findings regarding the small-signal stability of three types of integrated VSC-based DC/AC power systems. The grid-connected single VSC system, the AC power system integrated with the VSC-based HVDC line, and the AC power system integrated with the MTDC network are the three options. The study on the small-signal stability of the grid-connected single VSC system is reviewed in the following section. The simplest VSC-based DC/AC power system is the single VSC system.

The research focuses on the small-signal stability of the VSC system without taking into account the impact of its dynamic interactions with the external power system. The converter control and the phase locked loop have the greatest impact on the small-signal stability of a single VSC system (PLL). The paper explains why the small-signal stability of the VSC system is determined by the dynamic interactions between the converter control and the PLL. The explanation is broad and applies to more complex AC power systems that are integrated with the VSC-HVDC line and the MTDC network.

Description

Long-distance transmission of large-scale wind power was discovered to be unstable. When the SCR was reduced below a certain value, the dominant poles of the PMSG system moved into the right half of the complex plane, according to modal analysis. The computation of participation factors revealed that unstable dominant poles were associated with the grid side converter's AC voltage control outer loop (GSC). Similar conclusions were drawn from the cases studied in. However, the PLL was identified as the primary source of system instability in [4].

The investigation focused on determining the source of the instability and confirmed that the PLL was the main dynamic component causing the VSC system's instability when the grid connection was weak. The impact of transmission impedance and load impedance on the low-frequency dynamics of the PLL was thoroughly investigated in using the PLL's quasi-steady state model. According to the findings, when the transmission impedance is high, the VSC system may experience growing oscillations. The results of root loci computation in [13] clearly showed that when the SCR was small, increasing the PI gains of the PLL caused the VSC system to become unstable. In, the small-signal stability of a grid-connected PMSG was investigated. The analysis revealed that the dynamic interactions between the PLL, DC, and AC voltage control outer loops were detrimental to the PMSG system's stability because they were similar to the function of positive feedback [5].

Conclusion

Early research based on the state-space model of the VSC system using modal analysis revealed that the dynamics of the PLL affected the VSC system's small-signal stability. When the SCR was reduced, the maximum power transmission capability decreased. Lennart Harnefors investigated the small-signal stability of the VSC system from the standpoint of control system parameter conditions. The passivity theory was used to conduct the investigation, which was based on the input impedance matrix model of the VSC system. The results of the investigation revealed that increasing the PI gains of the VSC's current control inner loops may cause system instability.

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Conflict of Interest

There are no conflicts of interest by author.

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