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Transient Stability of Grid Forming Inverter Using Virtual Synchronous Generator Algorithm
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ABSTRACT

As converter-interfaced renewable generation continues to replace conventional synchronous machines, modern power systems experience substantial changes in dynamic behavior due to the reduction of physical inertia. In this context, grid-forming inverters have attracted considerable attention because they can establish system voltage and frequency autonomously. One of the most relevant control approaches in this category is the Virtual Synchronous Generator algorithm, which emulates synchronous-machine dynamics through virtual inertia, virtual damping, and power-based synchronization. Nevertheless, the transient behavior of grid-forming inverters remains a critical issue, particularly under large disturbances such as bolted fault and sudden active-power reference variations. Therefore, this study aims to investigate the transient response and synchronization stability margin of a grid-forming inverter controlled by a Virtual Synchronous Generator algorithm. The proposed methodology utilizes the Equal-Area Criterion (EAC) to analytically evaluate the transient stability boundaries and establish critical operational limits. Furthermore, an averaged dynamic model in the dq reference frame is developed to analyze the internal relationships among power angle, frequency, and output-voltage dynamics. The theoretical EAC predictions are subsequently compared and validated against detailed time-domain simulations under severe disturbance scenarios. This study is expected to provide a stronger theoretical basis for controller tuning and stability boundary assessment, thereby contributing to improved transient stability of Virtual-Synchronous-Generator-based grid-forming inverters in inverter-dominated power systems.

Keywords: Grid-Forming Inverter, Virtual Synchronous Generator, Transient Stability, Virtual Inertia, Equal-Area Criterion.