Abstract

The interconnection standards have made it mandatory for the utility-scale inverter-based resources (IBRs) to comply with the low-voltage ride-through (LVRT) requirement. Additionally, the IBRs have been instructed to provide dynamic reactive power support and enable active power curtailment provision during low-voltage and over-frequency events, respectively. However, the instability issues associated with the IBRs integrated power grids arising due to unintentional islanding and grid-induced voltage sag events are mostly overlooked. To address these issues, the work in this thesis presents a comprehensive assessment of the stability issues associated with IBRs integrated power grids. First, the conflicting interaction between the P(f) and Q(V) regulations of IBRs leading to oscillatory instability in power islands has been investigated analytically using the small-signal stability analysis technique. This is a significant contribution to the prior art where the analysis has only been carried out with the help of non-detection zones of IBRs. Following this, the small-signal stability analysis of a full-order model of IBR interconnected to weak grids has been performed under varying set-points of real and reactive power as well as under reduced grid voltage. A supplementary stabilizing controller has been designed for the IBRs to enhance their small-signal stability margin under weak grids and reduced grid voltage scenario. Next, the large-signal/transient stability of grid-tied inverters has been assessed extensively. An equivalent-circuit model of a three-phase grid-tied inverter has been developed and leveraged to assess the large-signal stability considering its full-order averaged dynamics. Following this, reduced-order models have been developed and innovative approaches have been applied for assessing the large-signal stability of multiple grid-following (GFL) inverters having the same and different points of synchronization. Finally, the conflicting requirement between the stringent LVRT standards and transient stability boundary of GFL and grid-forming (GFM) inverters has also been investigated by leveraging Lyapunovs direct method. The work in this thesis may provide some reference for the revision of interconnection standards/grid codes in the future where the small-signal, as well as large-signal stability issues will be taken into account.

The major highlights of the work are summarized as follows:

(1) The cause for sustained oscillations arising in active distribution networks following unintentional islanding has been investigated using eigenvalue analysis and non-detection zones.

(2) Small-signal stability analysis of weak grid-tied IBRs has been performed and auxiliary stabilizing controller has been designed for enhancing the stability margin.

(3) Large-signal stability assessment of IBRs integrated power grids has been performed leveraging Lyapunov's direct method.

Key Words: Inverter-based Resources, Lyapunov's Method, Small-signal Stability, Transient Synchronization Stability, Weak Grids.