Robust and Decentralized Power Sharing Control of Plug-and-Play Converters for DERs Integration

Abstract

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Grid-tied inverters (GTIs) play an important role in integrating different types of distributed energy resources (DERs) into the distribution networks or micro-grids for controlling the current injection, while simultaneously improving the power quality. However, since the distribution networks or micro-grid for DERs integration are typically electrically weak and traditionally suffer from poor voltage quality at the end buses or unstable point of common coupling (PCC) voltage when the micro-grid operated in an islanded mode, any non-ideal grid conditions (e.g., harmonics, magnitude/ frequency/ phase variation) caused by external disturbances may adversely affect the grid injected current quality and the stability of inverter control. Moreover, depending on the grid configuration, the grid impedance, which is mainly determined by low power transformers and long distributed lines, varies over a wide range, especially in the weak grids. It should be noted that when the micro-grid for the GTI integration changes the operation mode (i.e. from grid-connected mode to islanded mode), the PCC voltage is maintained via other grid-forming units, while the grid impedance will be affected significantly. It is a considerable challenge for GTIs to continue their stable operation and to supply high-quality sinusoidal current from DERs with smoother transient response under such conditions.

The filtered tracking error (FTE)-based method, which comes from some filtered error notions standard in non-linear control theory, has superior dynamic response, high trajectory tracking performance and being easily compatible with the robust control methods. Therefore, a robust control strategy is proposed to control the GTIs connected to a non-ideal grid (with grid impedance variation, harmonic pollution and magnitude/frequency/phase fluctuation) through an LCL filter, to deliver the pure sinusoidal and three-phase balanced current to the grid.

In parallel inverters situations, a robust decentralized Lyapunov-based control strategy is proposed to ensure close voltage regulation and accurate power sharing of each paralleled inverter under different line impedances and system conditions. The designed controller can obtain fast dynamic response and tracking convergence, and thus provide better voltage regulation ability. Meanwhile, the load current can be precisely shared automatically in presence of the unbalanced filter parameters and unknown line impedances, which offers the plug-and-play capability for DGs and ensures efficient and reliable operation of the micro-grid. It is a truly decentralized approach since each module only requires the local measurements and no inter-communication among inverters is needed. Furthermore, the controller is easier to implement, in the sense that it does not need to be retuned even if the system configuration is changed, e.g., additional parallel inverters are added. Extensive simulation and experimental validation are carried out using the same state variables and control laws implemented in synchronously rotating frame.