

Preface

Renewable energy-based distributed power generation systems (RE-DPGS) represent promising solutions to mitigate energy crisis and environmental pollution. The *LCL*-type grid-connected inverter, being a conversion interface between the renewable energy power generation units and the power grid, has been widely used to convert dc power to high-quality ac power and feed it into the grid, and it plays an important role in maintaining safe, stable, and high-quality operation of RE-DPGS.

This book aims to present the control techniques for the *LCL*-type grid-connected inverter to improve the system stability, control performance, and suppression of grid current harmonics. The detailed theoretical analysis with design examples and experimental validations are included.

This book contains twelve chapters.

Chapter 1 gives a brief review of the key techniques for the *LCL*-type grid-connected inverter, including the design and magnetic integration of the *LCL* filter, design of the controller parameters, the control delay effects in digital control and the methods of reducing the control delays, suppression of the grid current distortion caused by the grid voltage harmonics, and the grid impedance effects on the system stability and the methods to improve the system stability.

Chapter 2 introduces the modulation strategies for the single-phase and three-phase inverters, and presents the design methods of *LCL* filters for both single-phase and three-phase inverters.

Chapter 3 presents magnetic integration methods for *LCL* filters, aiming to reduce volume and weight.

In Chap. 4, the resonance hazard of *LCL* filters is analyzed, and six basic passive-damping solutions are discussed in terms of their effects on the characteristics of *LCL* filters. It is pointed out that adding a resistor in parallel with the filter capacitor can effectively damp the resonance peak and does not affect the frequency response of the *LCL* filter, but it results in high power loss. The

active-damping solutions, equivalent to a virtual resistor in parallel with the filter capacitor, are derived, and the capacitor-current-feedback active-damping is found superior for its simple implementation and effectiveness.

Chapter 5 presents a step-by-step parameter design method for the *LCL*-type grid-connected inverter with capacitor-current-feedback active-damping, including the capacitor current feedback coefficient and current regulator parameters.

In Chaps. 6 and 7, methods based on full feedforward of the grid voltage are proposed for single-phase and three-phase grid-connected inverters with capacitor-current-feedback active-damping. The feedforward function consists of a proportional, a derivative, and a second-derivative component. The proposed full feedforward scheme does not only reduce the steady-state error of the grid current effectively, but also suppresses the grid current distortion arising from the harmonics in the grid voltage.

In Chap. 8, the mechanism of the control delay in digital control systems is discussed, and the influence of the digital control delay on the system stability and control performance are analyzed in detail. Then, the range of the *LCL* filter resonance frequency that would lead to instability is identified and hence should be avoided. Then, the system stability evaluation method is presented by checking the phase margin and the gain margin at one-sixth of sampling frequency ($f_s/6$) and the resonance frequency of the *LCL* filter.

In Chap. 9, a real-time sampling method is presented to reduce the computational delay, and it is not restricted by the modulation scheme and can be applied to the single-phase and three-phase grid-connected inverters. Furthermore, a real-time computational method with dual sampling modes is given to completely eliminate the computation delay, and it is suitable for the single-phase grid-connected inverter since it is based on the unipolar SPWM. With the two computation delay reduction methods, the steady-state and dynamic performances of the *LCL*-type grid-connected inverter can be improved, and high robustness against the grid-impedance variation is obtained.

In Chaps. 10 and 11, the virtual series-parallel impedance shaping method and weighted-feedforward scheme of grid voltages are proposed, respectively. The purpose is to improve the harmonic rejection capability and the stability robustness of the *LCL*-type grid-connected inverter when connected into a weak grid.

In Chap. 12, the complex-vector-filter method (CVFM) is adopted to derive various prefilters in the synchronous reference frame phase-locked loops (SRF-PLLs), and some insights into the relationships among different prefilters are drawn. A brief comparison is presented to highlight the features of each prefilter. Moreover, a generalized second-order complex-vector filter (GSO-CVF) with faster dynamic response and a third-order complex-vector filter (TO-CVF) with higher harmonic attenuation are proposed with the help of the CVFM, which are useful to improve the dynamic performance and the harmonic attenuation ability of the PLL for the grid-connected inverter.

This book is essential and valuable reference for the graduate students and academics majoring in power electronics and renewable energy generation system and the engineers being engaged in developing grid-connected inverters for photovoltaic system and wind turbine generation system. Senior undergraduate students majoring in electrical engineering and automation engineering would also find this book useful.

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