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DISTURBANCE-OBSERVER BASED CONTROL FOR PWM RECTIFIERS WITHOUT DC VOLTAGE OSCILLATIONS UNDER UNBALANCED GRID CONDITIONS

by

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Abstract

A three-phase controlled rectifier is a power electronic converter that employs the grid voltages as an input to produce a constant dc voltage at its output through the use of a capacitor, known as dc-link capacitor. However, the switching devices of power converters can create harmonics in the grid current, which mandates the need for filters to ensure high-quality grid current. This explains why the power converter is normally connected to the grid through the use of passive filters such as *L* filter or *LCL* filter. The *L* filter is normally preferred over *LCL* filter to reduce harmonic distortions in grid currents as it can offer better stability margin and it requires less-complex controllers. When operating under unbalanced grid voltages, the rectifier can face challenges in maintaining ripple-free dc-link voltage due the instantaneous power ripples. Indeed, unbalance in grid voltages can cause the instantaneous power delivered by the host grid to include double fundamental frequency oscillations. These oscillations can be viewed as a periodic exchange of the energy delivered by the host grid with the energy stored in the inductor's filter and/or the dc-link capacitor. Therefore, if a part of this periodic exchange of energy takes place between the host grid and the dc-link capacitor, then, the dc-link voltage will eventually include an ac signal that oscillates with twice the grid frequency. Driven by this observation, ripple-free dc-link voltage requires the entire periodic energy to be exchanged only between the host grid and the inductor's filter; there should be no periodic exchange of the energy delivered by the grid with the energy stored in the dc-link capacitor. When it does so, only the dc component of the grid-side power is delivered to the dc-link capacitor, which can guarantee ripple-free dc-link voltage. This can be achieved by setting the grid currents to follow appropriate sinusoidal and unbalanced current references. These current references can be used to compute the active and reactive power commands to be delivered by the grid with a view to achieve the task of ripple-free dc-link voltage under unbalanced grid voltages. It turns out that the active and reactive powers to be delivered by the host grid should include double fundamental frequency oscillations around a dc component to eliminate the dc voltage ripples. Thus, under unbalanced grid voltages, advanced control techniques are required to allow the currents and the active and reactive powers to accurately and robustly track their sinusoidal references. This thesis presents the design and experimental validation of a robust control strategy for both the current control scheme and the power control scheme. The proposed controller is based on combining a state-feedback controller with a disturbance observer. The feedback controller is used to stabilize the closed-loop system, while the disturbance observer is employed to compensate for the effect of model uncertainties considering the oscillatory behavior of disturbances under unbalanced grid voltages. Various simulation and experimental tests were conducted to validate the performances of the proposed control technique. The obtained results show that both power control scheme and current control scheme are able to achieve accurate tracking of sinusoidal references under both balanced and unbalanced grid conditions. The accurate tracking of the power/current references under the composite controller was effective in eliminating steady-state error and dc voltage ripples under both balanced and unbalanced grid voltages.

Keywords: PWM rectifier, ac-dc conversion, disturbance observer, feedback linearization, sinusoidal disturbance rejection, unbalanced grid voltages.