DEPARTMENT OF ENERGY TECHNOLOGY
AALBORG UNIVERSITY

PhD Public Defence

Title: Stability and Control of Dc-Link Dynamics in Three-Phase Grid-Connected Converters

Location: Pontoppidanstræde 101, room 1.001

Time: Wednesday 11 December 2019

PhD defendant: Dapeng Lu

Supervisor: Professor Frede Blåbjerg

Moderator: Associate Professor Tomislav Dragicevic

Opponents: Associate Professor Daniel Ioan Stroe, Dept. of Energy Technology, Aalborg University (Chairman)
Professor Xiaoming Yuan, Huazhong University of Science and Technology, China
Principal Scientist Mats Larsson, ABB Corporate Research, Switzerland

All are welcome. The defence will be in English.

DEPARTMENT OF ENERGY TECHNOLOGY
AALBORG UNIVERSITY

Abstract:

Grid-connected converters are widely used in the power system as essential interfaces between renewable energy sources and the power grid, which are bringing new challenges to the power system by imposing multiple-timescale dynamic characteristics. Stability issues are majorly concerned, which may be caused by the control of the grid-connected converter. Generally, the control can be divided into the dc-link control, the grid synchronization control, and the current control loops, where the stability of the current control has been well analyzed with different types of filters and the dynamic impact of the grid synchronization control is also documented recently. Although the dc-link control has been well implemented in utilizations, the stability impact of dc-link dynamics are still infancy.

Several control-oriented models of dc-link dynamics have been proposed to regulate the dc-link voltage and current in grid-connected voltage-source converters (VSCs) and current-source converters (CSCs), which are the two main topologies of grid-connected converters. However, with the limitation of separating the timescales, i.e., a low control bandwidth of dc-link and a high control bandwidth of current control must be satisfied, these models can only reflect the dc-link dynamics in a limited low frequency range, which fails to predict the stability of the dc-link control. Moreover, active damping methods have been reported for enhancing the stability of dc-link current control in grid-connected CSCs. However, the impacts of dc-link current dynamics are overlooked, and the necessity of using the active damping is still not fully identified either. Additionally, several VSC-based active dampers have been proposed to address the stability issues of power-electronics-based power systems. In contrast, the CSC-based active damper is seldom found, even though the CSC has a better current-tracking dynamic performance.

This thesis has developed the stability analysis and controller design tools for regulating the dc-link dynamics in both grid-connected VSCs and CSCs to cope with the aforementioned issues. Characterizing dynamic interactions between the dc-link and ac-side is the first contribution, which enables to model the dc-link dynamics for stability analysis. Moreover, it shows the dc-link dynamic impact in VSCs and CSCs are different. Then, in VSCs, an impedance model is developed to analyze the dc-link voltage control under weak grid conditions, where the impedance-based analysis identifies the resulted resonances and reveals a frequency-coupling effect. In CSCs, regions of active damping for the single-loop dc-link current control are obtained and three active damping methods are proposed, which advances in circuit perspectives and high flexibility. Finally, a CSC-based active damper is proposed to address the instability of VSC systems, which benefits of a high compensation performance and a simplicity of controller implementation.