PhD Public Defence

Title: Harmonic Mitigation and Resonance Damping Based on Impedance Model using Series LC Filtered VSI

Location: Pontoppidanstræde 105, room 4.127

Time: Friday 1 September 2017 at 13.00

PhD defendant: Haofeng Bai

Supervisor: Professor Frede Blaabjerg

Moderator: Associate Professor Dezso Sera

Opponents: Professor Birgitte Bak-Jensen, Dept. of Energy Technology, Aalborg University (Chairman)
Professor Patrick Wheeler, University of Nottingham, UK
Professor Vladimir Katic, University of Novi Sad, Faculty of Technical Sciences, Novi Sad

All are welcome. The defence will be in English.

After the defence there will be an informal reception in Pontoppidanstræde 111 (coffee room).
Abstract:

The usage of grid-connected Voltage Source Inverters (VSI) enables the Power Electronics (PE) based power system and brings new harmonic issues such as the switching harmonic attenuation for high power VSIs and harmonic instability, where high order harmonic resonance arises from the interactions between the VSIs and the grid impedance. Damping of the resonances becomes important with more VSIs connected to the grid. The series LC filtered VSI, whose operating principle is to mimic the behavior of a damping resistor, has been used to dampen the harmonic resonance and stabilize the PE based power system with reduced power rating and dc-link voltage.

Meanwhile, impedance modelling is an effective method to analyze the harmonic interaction within a PE based power system. The Norton equivalent model of a grid-connected VSI consists of a current source, which is determined by the current reference and the closed-loop gain, and the output admittance, which is the transfer function from the disturbance to the output. However, in existing studies, the output admittance is often neglected, which leads to some limitations for real applications. In this work, the output impedance of the series LC filtered VSI is investigated for three objectives: 1) harmonic stabilization of PE based power system, 2) switching harmonic attenuation of the high power VSI with low switching frequency and 3) resistance emulation at low order harmonics.

In order to stabilize the PE based power system, impedance based stability analysis is first carried out, which indicates that the negative real part of the output admittance of the VSIs are the origin of the instability. Instead of mimicking the behavior of a resistor, the operating principle of the active damper is changed to enhance the passivity of the system. A simple control scheme based on the proportional current controller and low-pass filter is proposed for the active damper. Since the resonant current controller is not needed, the online detection of the resonance becomes unnecessary.

An active Trap Filter (ATF) is proposed based on the physical representation of the current controller of the series LC filtered VSI. Virtual capacitance can introduced by the integral current controller. Based on that, an output impedance shaping method that introduces series LC resonance is proposed. The ATF can bypass the switching harmonics of the high power VSI, which are at kilo Hertz level. Compared with the traditional high frequency APF, the current reference of the ATF is set to zero and the design of the current controller becomes much easier. Also, the output current of the high power VSI maintains sinusoidal even in the presence of a distorted grid voltage.

In order to dampen the low order harmonic resonance, an AC voltage sensorless Resistive-Active Power Filter (R-APF) is proposed. Instead of tracking a special current reference obtained from the harmonic voltage information, the output impedance of the series LC filtered VSI is used to emulate the damping resistance. Thus, the harmonic voltage does not need to be measured. Also, a fundamental voltage estimation method is proposed, which allows the DC-link voltage control. As a result, the AC voltage sensor can be removed in the R-APF. The system cost of the R-APF can be reduced and the isolation between the control circuit and the power stage can be improved.

With this work, it can be stated that the impedance model of the series LC filtered VSI offers more possibility to mitigate the harmonics in a PE based power system.