Modeling and Observer Design of a Nonlinear LCL Filter for Three-Phase Grid-Connected Voltage Source Converter

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Introduction

Power quality is an important issue in electrical systems. It is characterized by terms such as harmonics distortions, reactive power, flicker and unbalances. An ADF (Active Dynamic Filter) is a solution to these problems. [1] It includes many parts that must work perfectly together in order for the power quality goals to be achieved. One of these parts is the line filter. The main tasks for the line filter (LCL filter) are to attenuate the switch harmonics from the voltage source converter (VSC) with a reduced overall size and weight and generate the reactive power that is needed for the compensation process. Then, the signals from the line filter will go to the computer controller and be used for current control.

Purpose

The major goals of this master thesis are:

1. To give insight into the mathematics of the line filter dynamics [3].
2. To study how the inductance depends on the amount of current through it and to design the nonlinear inductors in the Matlab/Simulink environment.
3. To estimate the voltage across the capacitors and grid current for the line filter by designing the Kalman filter (KF).
4. To replace the inductors by the designed nonlinear inductors and then design the Scheduled Kalman filter (SKF) for the nonlinear system

All the above goals are achieved in this thesis and moreover the effect of the sampling frequency is studies and discussed.

Fig. 1 simplified circuit scheme of the LCL filter connected to the VSC and the grid

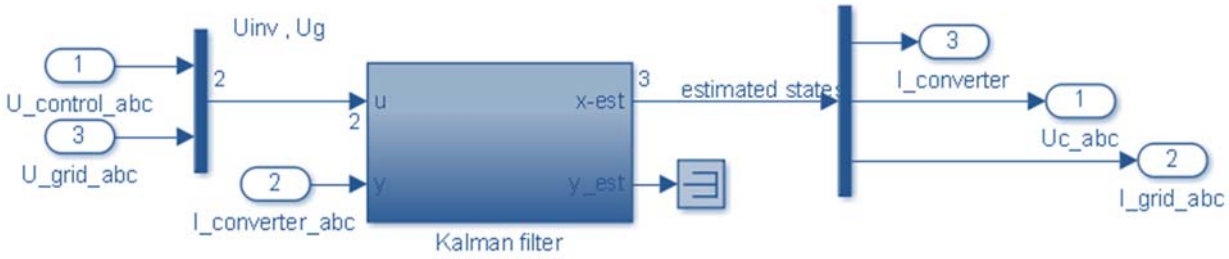

Fig. 2 the Kalman filter designed in Matlab/Simulink with all inputs and outputs signals

Result

The project results show that the reduction of the inductance value, leading to the nonlinearity of the system, is a very important term that should be taken into consideration when modeling the line filter. The bandwidth of the system is affected directly by this kind of nonlinearity. Thus, the attenuation of the current ripple will decrease drastically.

The results for the KF and SKF for different sampling frequencies show that higher sampling frequency will lead to better reconstruction of the signals at the cost of observer speed. In other words, estimating a continuous-time system by using sampled observers requires more care concerning how to choose sampling method. A SKF is applied on the nonlinear system and the result shows that the method is good enough if the ambition is not to reconstruct and follow the harmonics and the ripples on the signals. The ripple amplitude and frequency are too high and the Nyquist theorem says that the reconstruction of the ripple needs a sampling frequency that is at least twice as fast as the ripple frequency [2].

References

[1] Comsys homepage, www.comsys.se

[2] T. Saryan, *Modeling and Observer Design of a Nonlinear LCL Filter for Three-Phase Grid-Connected Voltage Source Converter*, Master thesis, Lund University, Department of Automatic Control, Sweden, March 2014

[3] M. Lindgren, *Modeling and Control of Voltage Source Converters Connected to the Grid*, Technical report for the degree of Doctor of Philosophy No.351, Chalmers University, Department of Electric Power Engineering, Sweden, November 1998