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EVALUATION OF THE PERFORMANCE OF THE DC-LINK VOLTAGE CONTROLLER OF A GRID-CONNECTED AC/DC-DC/AC EMULATOR OF SEVERE GRID DISTURBANCES

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Abstract. This paper focuses on the most important aspects that ensure stable operation of a grid-connected power converter, which is used to emulate severe grid conditions, such as harmonic distortion, voltage interruption, phase shift et cetera. The power converter consists of two three-level IGBT voltage-source converters; the grid-side and the load-side converter. Stable operation of the load-side converter, which acts as test generator, is ensured by its own controller and by the constant dc-link voltage level, which in turn is controlled by the grid-side converter. Modeling and simulation of the unique smart grid testing facility – Flex Power Grid Lab at DNV GL - Energy (formerly DNV KEMA Energy & Sustainability) in Arnhem, the Netherlands – in MATLAB/Simulink environment and experimental measurements will verify the validity of the described methodology.

Keywords: control, dc-link, power converter, stability, validation

INTRODUCTION

The Flex Power Grid Lab (FPGLab) in Arnhem provides an ideal testing and research environment for advanced power electronic components. Both industries and academic institutes can make use of this facility to study how locally generated energy, such as wind turbines, solar cells, CHP plants, can be safely integrated into the public grid. The lab facility is equipped with a four-quadrant (4Q), medium voltage (MV) power electronic converter and it is capable of supplying up to 24 kV AC at continuous power rate of 1MVA. It is also capable of generating both static and dynamic voltage phenomena and creating testing conditions, such as harmonic distortion, voltage dips and interruptions, frequency and voltage fluctuation. As a result, sophisticated smart grid components can be tested under the influence of realistic “bad grid” conditions and de-risked before their actual connection to the grid.

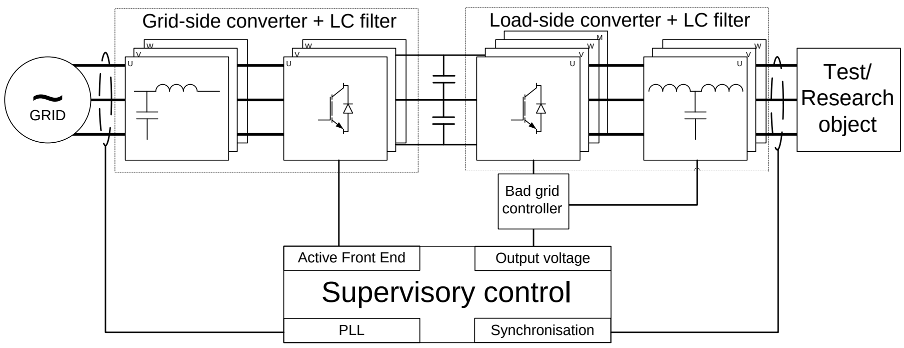


Figure 1 Overview of the FPGLab grid-connected power converter **[1]**

It is of high importance for the safety of the FPGLab itself, as well as for the object-under-test to ensure stable operation of the power converter. In order to achieve this, the grid-side converter should maintain the dc-link voltage at a constant level, regardless of the commanded output of the load-side converter and the load changes. An Active Front End (AFE) comprises the grid-side converter, which uses the vector control scheme. Similarly to the FPGLab, in [2], a three-phase voltage-source converter (VSC) is controlled in the dq reference frame, in order to keep the dc-link voltage constant. This control method is further analyzed in [3], [4] and [5], where it is becoming clear that PI current-regulated VSCs can eliminate the steady-state error and maintain the dc-link voltage to the required level only in the rotational dq reference frame. Moreover, state-feedback controller stabilizes the system of the load-side converter, which is controlled by the use of resonators in the stationary abc reference frame [6].

This paper deals with the modeling of the controllers, and gives emphasis on the performance of the dc-link voltage controller at the time instants of significant events at the output of the converter. The effectiveness of the controllers will be verified by both simulation and experimental measurement results.

METHODOLOGY

The FPGLab controller design of the grid-side PWM converter is based on the vector control method. This method requires modeling of three phase systems by using axis transformations. In PWM converters for ac applications, vector control systems can be utilized to obtain independent control of the active and reactive power. Vectors of ac currents and voltages occur as constant vectors in steady state and hence static errors in the control system can be avoided by using PI controllers.

The idea is based on the power balance along the path from the ac to the dc side. The controller consists of two regulators: the inner current regulator and the outer dc voltage controller. The inner controller is the active current or active power controller. For steady-state operation, active power exchange P_{ac} will be equal to the power exchange at the dc side, P_{dc}. Neglecting the filter and semiconductor losses:

(1) $$P_{ac} = P_{dc}$$

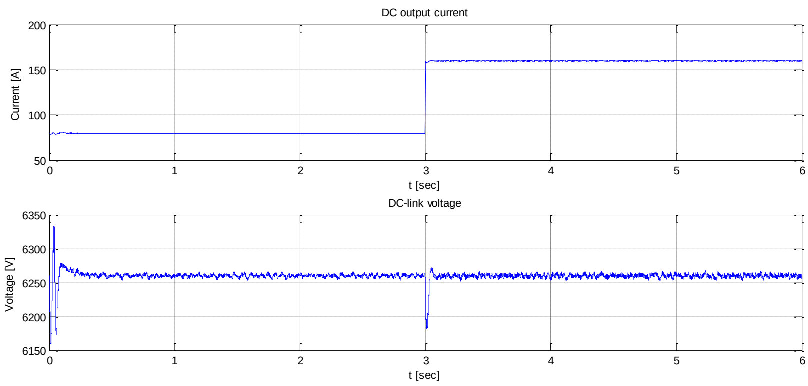
(2) $$3/_2\, v_d i_d = V_{dc} I_{dc}$$

(3) $$I_{dc} = \frac{3 v_d i_d}{2 V_{dc}}$$

The converter, as seen from the dc network side, will be a constant current source of magnitude I_{dc}. Moreover, a phase locked loop (PLL) ensures that the d-component of the voltage coincides with the voltage vector, so that v_d=1pu. As a result, from equation (3) it can be deduced that regulating the ac active power (at the grid side) and hence the i_d, it is possible to keep the dc voltage at a constant level.

SIMULATION AND EXPERIMENTAL RESULTS

For the scope of this paper, it is important to show significant event, such as the case of having half (500kVA) and eventually full load (1MVA) conditions at the output of the converter. The dc-link voltage has to remain constant, so as the operation of the load-side converter remains safe and the system is stable. The following figure depicts the simulation result of the dc-link voltage and current.



In the full paper, different case studies of extreme output changes will be simulated and compared with the corresponding real measurements carried out in the FPGLab.

CONCLUSIONS

The FPGLab is dedicated to generating severe grid conditions, which can possibly increase the required control effort to maintain the dc-link voltage at the commanded level. It is vital to evaluate the performance of the dc-link voltage controller, in order to ensure the safe operation of the facility and guarantee the safety of the object-under-test.

REFERENCES

[1] E. de Jong, E. de Meulemeester and P. Heskes, "Design and realisation of a unique MV converter implemented in a new power electronic equipment test laboratory for emerging MV applications," in *IEEE PES General Meeting*, 2008.

[2] V. Blasko and V. Kaura, "A Novel Control to Actively Damp Resonance in Input LC Filter of a Three Phase Voltage Source Converter," *IEEE Transactions on Indusrty Applications,* vol. 33, no. 2, pp. 542-550, 1997.

[3] C. Wessels, J. Dannehl and F. W. Fuchs, "Active damping of LCL-filter resonance based on virtual resistor for PWM rectifiers — stability analysis with different filter parameters," in *Power Electronics Specialists Conference*, Rhodes, 2008.

[4] L. Serpa, "Current Control Strategies for Multilevel Grid Connected Inverters," ETH Zurich, PhD Dissertation, 2007.

[5] E. Twining and D. Holmes, "Grid current regulation of a three-phase voltage source inverter with an LCL input filter," *IEEE Transactions on Power Electronics,* vol. 18, no. 3, pp. 888-895, 2003.

[6] S. A. Richter, J. von Bloh, C. P. Dick, D. Hirschmann and R. W. De Doncker, "Control of a medium-voltage test generator," in *Power Electronics Specialists Conference*, Rhodes, 2008.