Voltage Stability Assessment in Semi-Autonomous DC-Grids with Multiple Power Modules

K. Rykov, J.L. Duarte, U. Boeke, M. Wendt, R. Weiss

TU/e
Den Dolech 2
5612 AZ
Eindhoven, The Netherlands
k.rykov@tue.nl

Introduction

Low-voltage DC-grids with up to 1500 V DC are conceived as an enabling technology to integrate (sustainable) electricity sources, energy storage devices and a variety of loads in an efficient way. The system design and integration require a variability of operating conditions and, therefore, system stability issues may arise from dynamical interactions among multiple components, which are normally designed to meet their own stability requirements. As the result, after the system integration, interactions among modules can lead to instabilities in the DC-grid.

Content

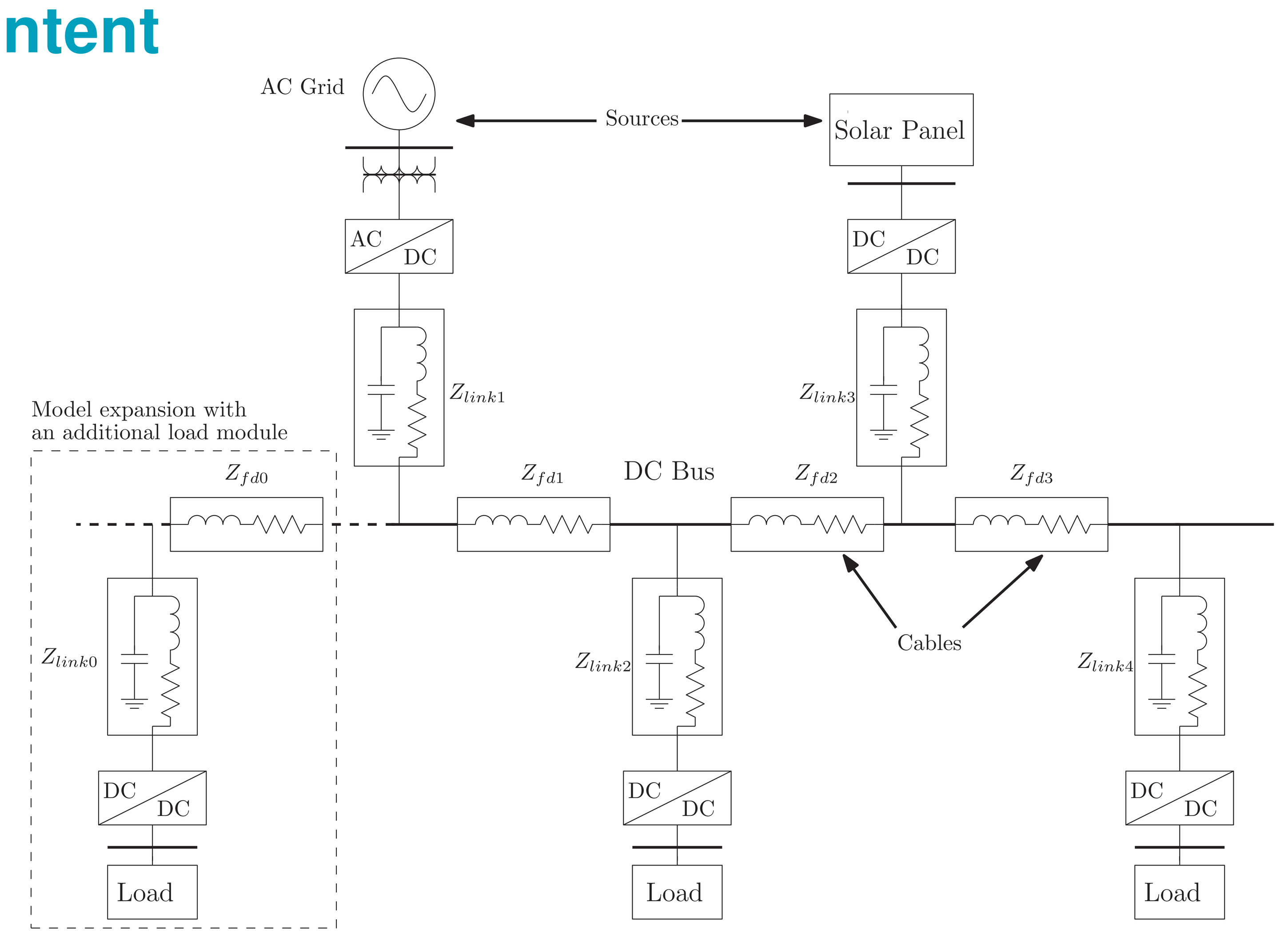

Figure 1: Semi-autonomous DC-grid with heterogeneous source and load modules.

A model of a small-scale DC-grid containing two loads and two sources represented as Norton equivalents was built (Fig. 1). Impedance information of each module combined into an impedance matrix provides the possibility to analyse the system behaviour at each network point utilizing the Nyquist stability criterion, frequency response and output characteristics.

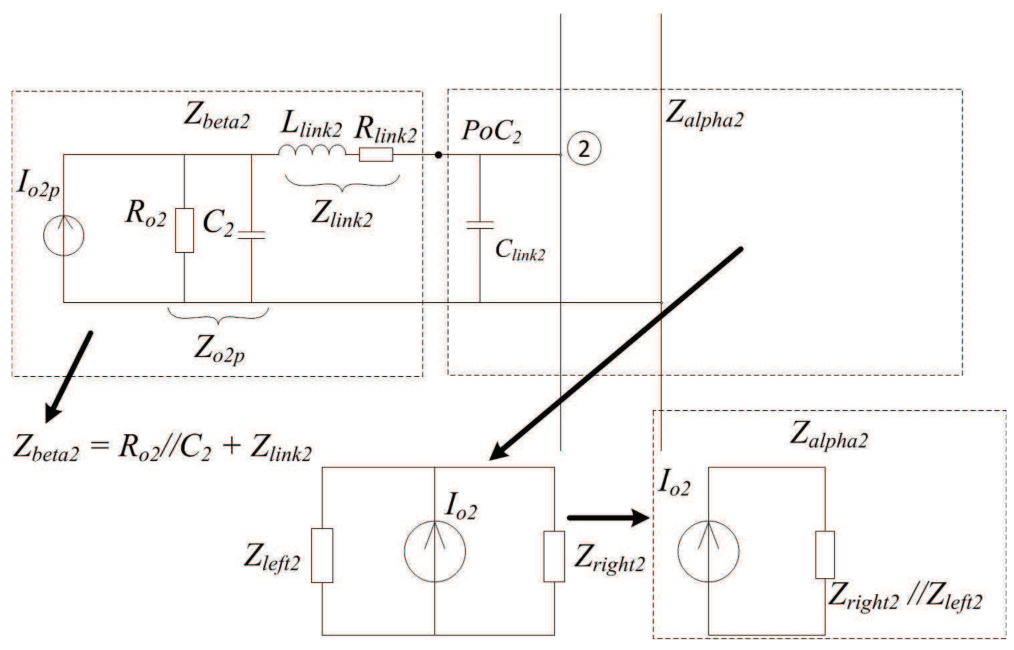

Figure 2: System decomposition for Nyquist analysis.

The Nyquist Stability criterion proved to be an effective tool for the system stability verification. In order to apply the criterion, system should be decomposed properly (Fig. 2). Corresponding voltage waveforms and Nyquist plots are depicted in Fig. 3.

Results

One of the important tasks was to develop a technique for transfer function analysis based on measurements of real signals. The experimental set-up (Fig. 4 (b)) was built to exploit the method of practical impedance identification injecting small signal excitation AC voltages and carrying out voltage measurements on the both sides of excitation (Fig. 4 (a)).

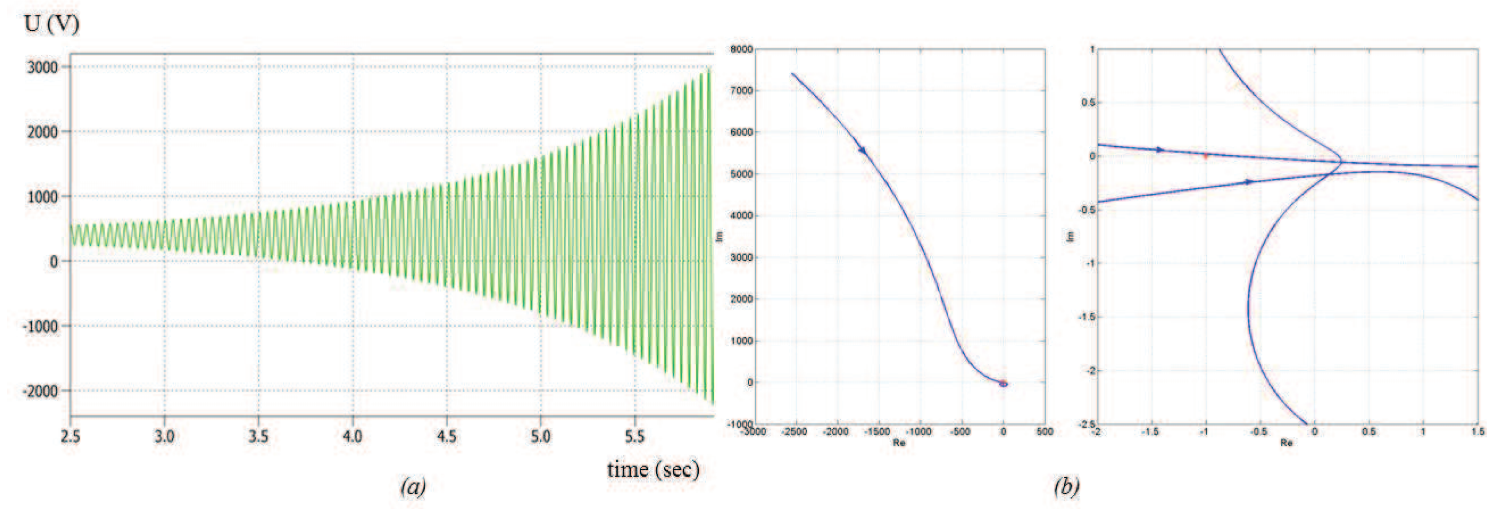

Figure 3: (a) Simulated load step response of the unstable system(b) Corresponding Nyquist plots with different axis scaling.

The applied approach helps to obtain Bode plots of the converter modules (Fig. 5 (b)), which subsequently were used for analysis. The next steps will be made in the direction of software generalization and conducting measurements in real commercial test-beds.

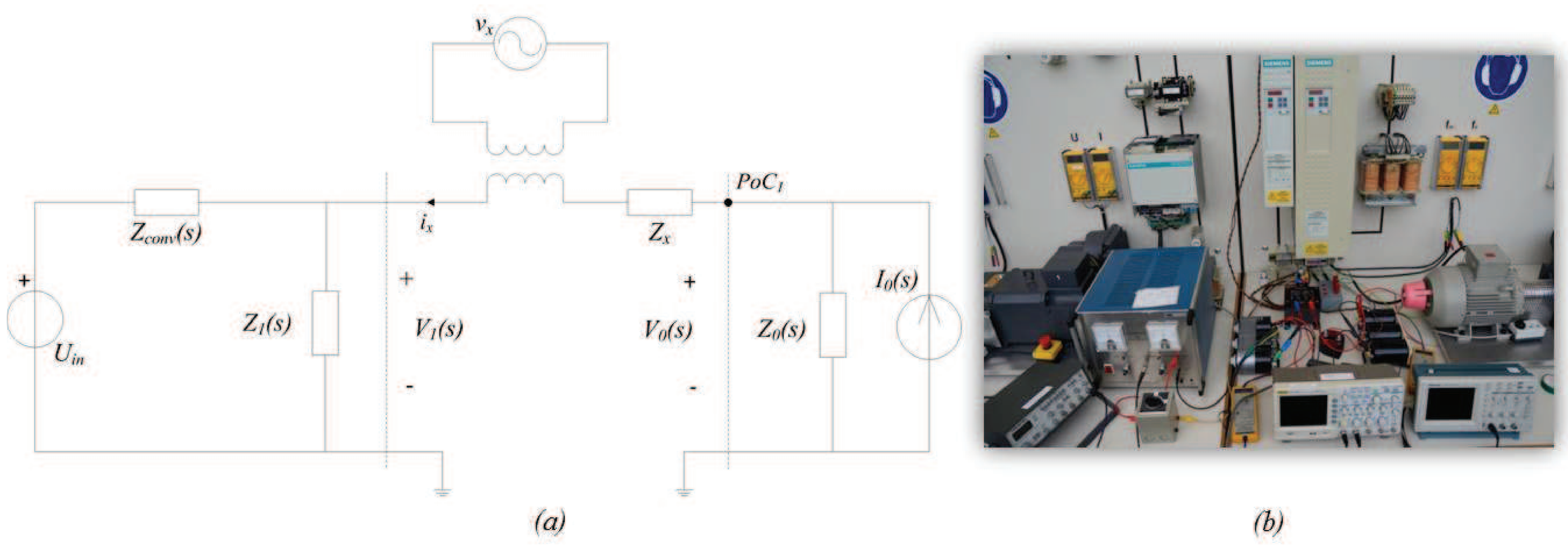

Figure 4: (a) Impedance identification method applied to a single converter module; (b) Experimental set-up.

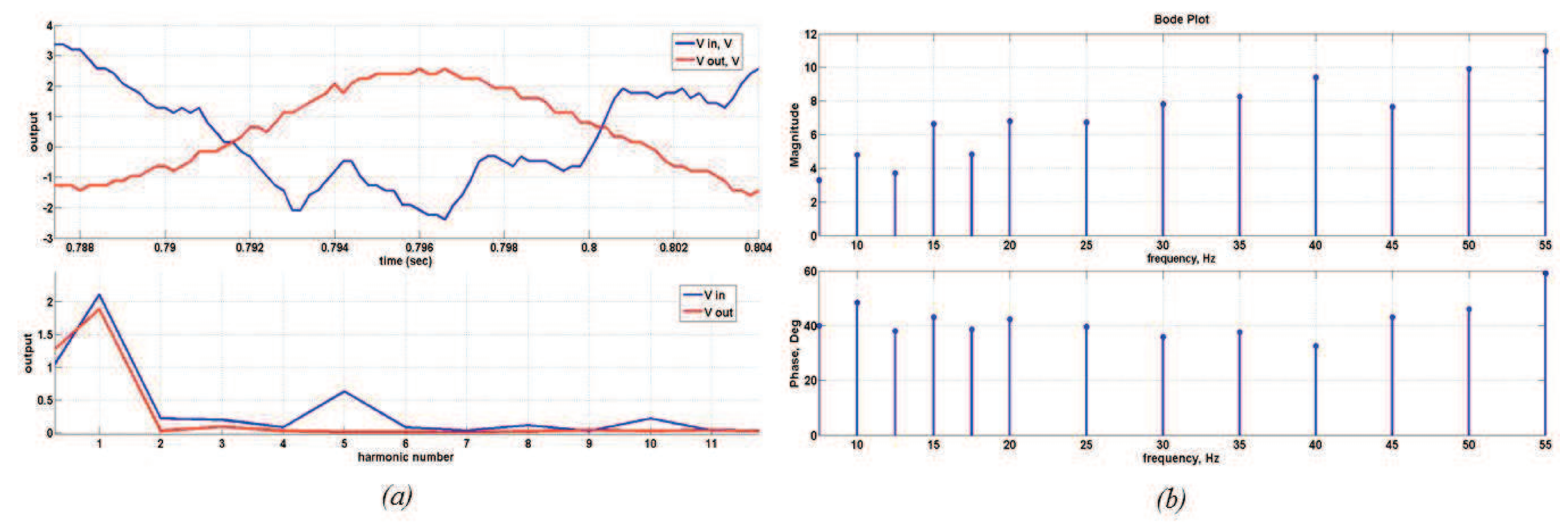

Figure 5: (a) Measured voltage waveforms on the both sides of excitation together with FFT plot; (b) Obtained Bode plot of the system.

Conclusions

A method is proposed to analyse voltage stability issues in small-scale DC-grids, which accommodate heterogeneous sources and loads. Simulation results confirm that it is possible to forecast the origin of unstable voltage oscillations on the basis of equivalent converter impedances. The presented analysis approach allows choosing converter control parameters or output capacitances which yield stable grid operation. Detailed numerical simulation results verify the proposed ideas.