RWTH AACHEN UNIVERSITY

E.ON Energy Research Center
ACS | Institute for Automation of Complex Power Systems

Master-Thesis / Diplomarbeit:

Stability Analysis of Control Structure for Multi-Terminal DC Systems

Context:

The development of DC distribution networks facilitates the desired high integration of renewable energy sources (RES) and energy storage systems (ESS) in the power grids, due to the DC nature of these power units. In this context, the research project Flexible Electrical Networks (FEN) focuses on the development, implementation and analysis of control structures for multi-terminal DC (MTDC) systems. In the framework of the FEN project, system-level control for MTDC grids, as well as converter-level control for DC/DC converters, have been developed.

The system-level control is realised through an optimal power flow (OPF) algorithm, to determine the nominal voltage set-points by considering the power flow in the MTDC network, while coordinating the distributed energy resources (DER) in the system. The enhanced OPF algorithm is developed in a distributed form, to be able to run fast, to realise a real-time system-level control. The distributed OPF algorithm is independent from the network topology and the converter-level control (voltage control or constant power control). In fact, the converter-level control does not need to include power control loop (power sharing), since the power flow in the system is regulated from the OPF algorithm (system-level control). In this way, the converter-level control can have less control loops and become thus faster.

The converter-level control applied in DC/DC converters is based on the concept of Active Disturbance Rejection Control (ADRC). This method offers a converter controller independent from the network model and the converter model. External and internal model uncertainties are represented as a virtual disturbance, which is estimated and cancelled by the ADRC. In this way, the ADRC controller achieves fast and tight DC voltage regulation. The stability of the MTDC system with multiple ADRC-controlled converters has been analysed, to validate the ability of the ADRC controller to mitigate the interactions between converters and stabilise the system. Limitations regarding the size of the MTDC system have also been determined. Specifically, the applied ADRC model challenges the stability of MTDC systems with short lines. Therefore, it is not directly applicable to MTDC microgrids.

In this thesis, the relation of the two control levels is going to be investigated and the stability of the entire control structure is to be analysed.

Your tasks:

The student should analyse in depth the interactions between ADRC-controlled converters and the ability of the ADRC controller to damp system oscillations. Modal analysis methodologies should be applied to analyse the stability of the system in a general approach, independently from the network size and topology. In addition, the student should investigate the impact of the simultaneous change of converters set-points on the system operation and stability. Moreover, the student should apply methodologies of stability analysis of systems with delays. In this way, he/she should demonstrate theoretically the extent of the disturbances that the ADRC-controlled converters can mitigate within the achieved time cycle of the developed system-level control. In addition, the stability of the MTDC system should be analysed in the case that the connection of the two control levels fails. The conclusions of the aforementioned analyses should lead to the development of solutions for the enhancement of the system stability. In particular, the OPF algorithm can consider the current system status and provide solution with restricted voltage changes. On the other hand, the ADRC control model can be modified to include event-activated power sharing control loop (droop control), to be able to mitigate disturbances in the system independently from the OPF algorithm. Furthermore, the additional droop controller adds virtual impedance in the converter model, making thus the ADRC controller applicable in systems with shorter lines (DC microgrids). The student should investigate also the stability of the MTDC microgrids with the modified ADRC converter controller. The work will be performed in Matlab/Simulink for the modification of the control models and the stability analysis.

Your profile:

- Good knowledge of power systems, power converters and their control
- Matlab/Simulink is a prerequisite skill

The collaboration with the supervisor will be done in English and the thesis should be written in English.

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