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DC-link Control for Airborne Wind Energy Systems During Pumping Mode

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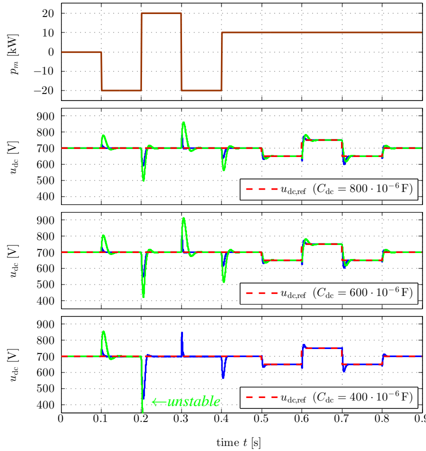
Airborne wind energy (AWE) systems with electrical machine on the ground are a promising alternative to classical wind turbines. Such systems are operated in pumping mode with the reel-out phase generating electrical power and the reel-in phase dissipating power [1]. We discuss DC-link voltage control of the grid-side voltage source inverter (VSI) which controls active power flow from the machine to the grid. For pumping mode AWE systems, DC-link voltage control is a non-trivial task due to the bidirectional power flow: the underlying DC-link dynamics are nonlinear and non-minimum phase [2,3] during the reel-in phase. Control objective is to design a robust controller which achieves set-point tracking of the DC-link voltage for given set-point(s) under unknown loads.
We compare the classical PI controller design with constant gains with a PI controller design where the gains are adjusted online to the actual operating point and, hence, become state-dependent. Starting with the analysis of the linearised system dynamics, we derive stability bounds on the constant gains of the classical PI controller and illustrate the non-minimum phase behaviour during the reel-in phase. In a second step, we design the "adaptive" PI controller where explicit expressions for the controller gains are derived based on pole placement and the physical boundaries of the system.
Based on realistic models of VSI, pulse width modulation, and filter [2,3], we illustrate the control performance of the classical PI controller and the "adaptive" PI controller under load changes (see interval [0.0–0.5 s]) and set-point changes (see interval [0.5–0.9 s]) for decreasing values of the DC-link capacitance. The "adaptive" PI controller (blue line) shows a better tracking and disturbance rejection capability than the classical PI controller (green line). For a small DC-link capacitance, the classical PI controller even becomes unstable. The "adaptive" PI controller remains stable and, so, allows to use smaller (cheaper) DC-link capacitors.



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