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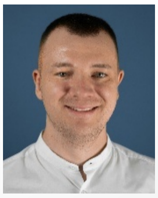

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Start: immediately possible **Duration:** 6 Months

☐ experimental ☐ application-oriented ☒ theory-oriented

Interessen:

☒ Passivity and Stability ☒ Lyapunov-Theory
☐ Identifikation ☐ Regler-/Beobachterentwurf

Master's Thesis

Passivity Properties of Switched Loads in DC Microgrids

Motivation

The increasing deployment of DC microgrids - in hospitals and data centers, in industrial facilities, and in off-grid island networks, etc. - places growing demands on the stability of these systems. At the same time, the ongoing integration of renewable energy sources (RES) replaces centralised generation with a large number of distributed generation units (DGUs). The RESs volatile and intermittent nature raises the bar for system-level stabilisation, since every connection, disconnection, or fluctuation in power injection can significantly perturb the network dynamics.

Passivity-based control (PBC) has become a standard tool for decentralized stability guarantees in such networks. Existing PBC frameworks for DC microgrids, however, are built on averaged source- and load-side models that idealize the switching behaviour of power-electronic devices. For loads implemented as controlled switching converters, this idealization introduces an unquantified discrepancy between the passivity properties certified by the averaged model and those actually exhibited by the exact switched system. The discrepancy between the averaged certificate and the actually achieved certificate under switching has not been addressed in the literature and constitutes the central open problem of this thesis.

Task Description

The goal of this thesis is to characterize the passivity properties of controlled switched converter loads exhibiting constant-power properties in DC microgrids, with particular attention to the difference between averaged-model passivity certificates and the exact switched behaviour.

Following an introduction to passivity theory, switched dynamic systems, and dissipativity under switching, a structured literature identifies the shortcomings of the existing load passivity certificates and defines applicable dynamic load models. An early foundational result, to be formally proven in the thesis, is that a pure impedance load is trivially passive. This finding motivates the shift to the non-trivial cases: an impedance load under arbitrary switching and an impedance load under controlled switching exhibiting constant power draw, for which no such trivial certificate exists, for the latter, its passivity-breaking property is proven in the literature.

The core theoretical contribution is the derivation of the bus-port admittance of the controlled converter load, first from the averaged small-signal model and then from the exact non-averaged switched model. For both models, the passivity index is analytically derived as a function of the bus parameters yielding conditions on the validity of the averaged passivity certificate.

The theoretical findings are validated in simulation (Matlab/Simulink), demonstrating scenarios, where the certificates are equal, and when the averaged certificate under- or overestimates the passivity index under switching.

If you are interested or have further questions, feel free to reach out — I look forward to your application.