Hardware-in-the-loop test of distributed model predictive control scheme for interconnected microgrids

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Due to the steady growth of renewable energy sources (RES), the operation control of interconnected microgrids (MGs) is becoming an increasing challenge. As usual in electrical power systems, operation control is understood as the adaptation of the units' power setpoints on a time-scale of minutes. One approach for the operation of interconnected MGs is model predictive control (MPC). Here, setpoints for all units are derived by taking their states of charge, the forecasts of load and available renewable infeed as well as power and energy bounds into account.

Within the ASN Group, a hierarchical distributed MPC strategy for interconnected microgrids has been previously implemented.[1] The proposed approach is scalable with respect to the number of MGs and preserves their independent structure by employing local controllers communicating through a central entity. Using a iterative scheme that includes alternating calculations at the local controllers and the central entity, power setpoints for the units are derived. In the proposed approach, each local controller is in charge of one MG, i.e., it decides, for example, how much power each unit in the MG provides or consumes. The central entity is in charge of the power lines and ensures that the constraints on the transmission capacities are met.

So far, the control scheme has only been tested in simulations. In the far future, the developed algorithm shall be use to control a real-world MG. In this context, hardware-in-the-loop (HiL) tests provide a good intermediate step between simulations on a computer and real-world tests. In such HiL tests, the MPC algorithm would be running on real control hardware, whereas the plant to be controlled would be emulated in software that runs on a different computer. This allows to explicitly test important properties, such as, the time required to solve the MPC problem, and identify challenges associated with the real-world use of the controller.

Goals

Within the thesis, an HiL test system for distributed MG operation control schemes shall be developed. The major goal of the project is to test the existing distributed MPC scheme. However, it should be designed such that potential future controllers can be tested with the HiL test system as well. Therefore, it is important that it is designed such that the same control algorithms, i.e., the same code base, can be used in software simulations and in the HiL tests. In summary, the following subtasks can be formulated:

- Literature research
  - Distributed optimization in the context of MGs
  - HiL test systems
- Implementation in software
  - MPC scheme with MG controllers and central entity
  - Plant simulation model
- Implementation of MPC scheme on hardware
  - MG controllers
  - Central entity
- Implementation of HiL test system on hardware
  - Plant simulation model
  - Communication with controllers
- HiL test to assess applicability of the MPC scheme and identify differences to numerical simulation

References

[1] C. A. Hans, P. Braun, J. Raisch, L. Grüne, and C. Reincke-Collon. Hierarchical distributed model predictive control of interconnected microgrids. *IEEE Transactions on Sustainable Energy*, 10(1):407–416, 2019.