Testing Automated Operation and Control Algorithms for Distribution Grids Using a Co-simulation Environment

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Abstract

This publication presents a co-simulation framework that enables the coupling of various simulation components of energy systems that are not only modeled at three geographically distributed Fraunhofer Institutes, but are also vastly different in terms of their functionality, control algorithms, time resolution, speeds and used tools. This framework facilitates their joint usage despite these differences especially with regard to their time resolutions (real-time combined with non-real-time systems) and is applied in the DistributedGridLab of the Fraunhofer Cluster of Excellence Integrated Energy Systems (CINES) [1]. The DistributedGridLab thus allows users - e.g. grid operators, manufacturers and research institutes - to test their solutions before field deployment with special consideration of their interaction with other solutions at different remote testing facilities, and without the need to use the same software and hardware setups. A demonstrator of the DistributedGridLab is introduced where an electric energy system is modeled, which contains a medium voltage grid with three connected low voltage grids. The different control approaches interact to stabilize the entire system without a centrally controlled simulation of the systems.

Motivation

Due to the growing number of new prosumers in the electric energy system, automated solutions for the efficient operation and control of distribution grids are emerging. However, prior to implementation into the real operation system a simulation-based development and testing of the functionalities is vital to ensure the correct behavior. In order to test an integrated energy system containing different components, appropriate software solutions are necessary that also allow for power and control hardware in the loop testing. Suitable testing facilities are often available at research institutes and laboratories at different locations with various scopes. In this publication, a framework that enables their joint usage is presented.

Structure

This publication introduces the DistributedGridLab of the Fraunhofer Cluster of Excellence Integrated Energy Systems (CINES), which allows for the interconnection of testing and simulation facilities at different locations. This Fraunhofer Cluster corresponds to a "virtual institute" spread over multiple locations. In a showcase example, the Advanced System Technology Branch of the Fraunhofer Institute of Optronics, System Technologies and Image Exploitation (IOSB-AST), the Fraunhofer Institute for Solar Energy Systems (ISE) and the Fraunhofer Institute for Energy Economics and Energy System Technology (IEE) work together to test a control use case within the DistributedGridLab, which combines their different research facilities. The goal is to build a simulation setup, which uses different operation and control approaches for distribution grids contributed by these institutes. This setup uses their combined strengths in a joint simulation environment, which is technically enabled by the co-simulation framework OpSim developed by Fraunhofer IEE and the Department of Energy Management and Power System Operation at the University of Kassel (e^2n) [2] [3]. After the introduction of the DistributedGridLab, a demonstrator that is developed to show the feasibility and possible applications of this simulation environment is presented. It allows for the coupling of several components containing grid models and control modules and can be used to extensively test the components in a simulated energy system by analyzing their behavior and interaction with other components. Moreover, thanks to OpSim, it is possible to couple components with different time resolutions, software, functionality and even hardware components. For this particular demonstrator different time resolutions, simulation speeds (real-time and non-real-time) and approaches have to be coupled in a co-simulation. Therefore, a novel coordination and data exchange method has to be developed that specifically enables the joint use of static power flow calculations and real-time simulations. This approach will be illustrated in this publication. Subsequently, details of the demonstrator setup are introduced. In this demonstrator, a medium voltage (MV) grid and three connected low voltage (LV) grids are coupled using OpSim. The MV grid is based on the CIGRÉ MV distribution grid introduced in [4]. Each institute is responsible for modeling one of the LV grids with the corresponding control algorithms at their respective location. Figure 1 illustrates the schematic setup of the system and the interconnection between the components. The information exchange at the interfaces of the modeled grid components is realized using OpSim.

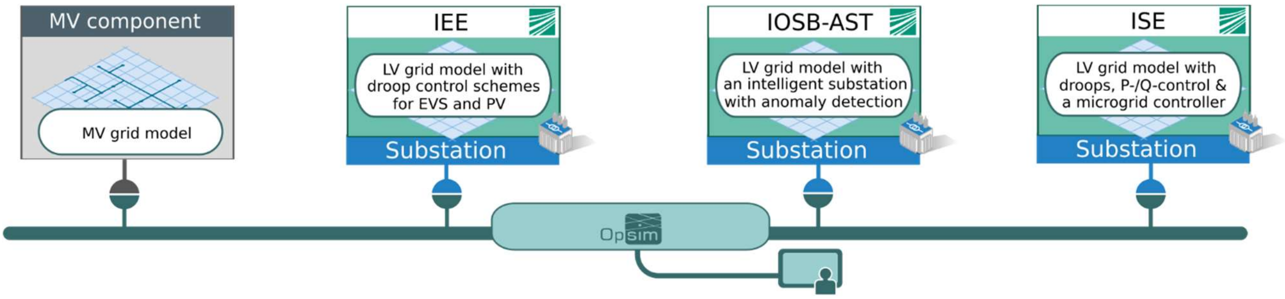

Figure 1:Schematic representation of the demonstrator setup

The Fraunhofer IEE LV component contains an LV grid where individual droop control schemes are applied to electric vehicles and solar panels. It is modeled using pandapower, which is an open source tool for power system modeling, analysis and optimization developed by the Fraunhofer IEE and the e^2n [5]. This component is not a real-time one and power flow calculations can be performed at any time interval. The Fraunhofer ISE LV grid is a dynamic model and uses a microgrid controller, P(U)-droops for electric vehicles and P- and Q-control for solar panels and storages. The LV grid is modelled with Typhoon HIL, which enables perfect integration into the DistributedGridLab power hardware-in-the-loop facilities [6]. The IOSB-AST component simulates the dynamic behavior of the grid in a transient time domain. Beside electric vehicles and renewable energy resources, the model implements an intelligent substation, which analyses the grid situation continuously and detects anomaly situations [7] [8] [9]. The hardware-in-the-loop setup also contains the possibility of the integration of real hardware components into the grid simulation.

Results

This publication highlights the capabilities of the DistributedGridLab, which enables the joint usage of geographically distributed components thanks to the co-simulation environment OpSim. It can therefore serve as an approach to test vastly different control algorithms for distribution grids, which is essential for a realistic representation of an integrated energy system. A joint simulation might imply that all components need to be shared with all parties involved and that they must be available at every location, however OpSim facilitates their interaction even without knowledge of each other. This also allows for completely separate development processes of the components. The coordination procedure that is necessary to combine the aforementioned different simulation approaches in a multi-location co-simulation platform is illustrated with a simulation example. In this example a voltage drop in the MV grid, caused by a drop of feed-in energy of a wind farm, is mitigated thanks to the individual control algorithms in the LV grids and their contribution to the stabilization of the system. This example emphasizes the novelty of this co-simulation, where the different simulation approaches and control algorithms work together to stabilize the system without a centrally controlled simulation of the systems.

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