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Smart Grid Laboratory as Testing Environment for innovative Technologies and Key Component for Knowledge Transfer

Abstract
Building upon the initial concept and implementation of the Smart Grid Laboratory at the University of Wuppertal, this paper presents recent advancements that significantly broaden its scope for research, development, and education in the field of smart grids. The laboratory has been enhanced with remotely controllable circuit breakers, allowing dynamic reconfiguration of the grid topology. A grid-forming inverter pair enables microgrid operation of the laboratory, facilitating the study of grid reconstruction strategies. Furthermore, the integrated frequency converters are used to simulate various energy storage technologies, supporting the evaluation of their impact on grid stability and flexibility. The laboratory was used as a field test environment for a platform for conducting peer-to-peer electricity market simulations, providing valuable insights into future decentralized trading models and promoting energy efficiency at the local level. In addition to research activities, the laboratory now plays a central role in a university course focused on smart grids, offering students practical insight in the proper use of modern smart grid equipment and real-world grid automation systems. These developments position the laboratory as a key enabler for both innovation and education in the transition towards intelligent, decentralized energy systems.
Motivation
Germany's 2025 coalition agreement places strong emphasis on accelerating the energy transition through digitalization, decentralized markets, and innovation-friendly regulation. However, real-world implementation of smart grid concepts still faces hesitation due to infrastructure risks and limited testing environments. This gap between political ambition and technical readiness underscores the need for safe, practice-oriented validation spaces. The Smart Distribution Grid Laboratory contributes to bridging this gap by aligning research and education with national energy policy goals. It enables the development of future-proof solutions and supports the training of skilled professionals—both essential to realizing a secure, intelligent, and citizen-oriented energy system.

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