Testing in Microgrids

Subjects: Automation & Control Systems | Energy & Fuels | Engineering, Electrical & Electronic

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This entry covers testing in Microgrids. The most common strategies are described and some papers are critizied. Testing in Microgrids can be done in a variety of ways, among others digital simulation, co-simulation, Real-Time simulation (RTS) Hardware-In-the-Loop (HIL), Controller-Hardware-In-the-Loop (CHIL), Power-Hardware-In-the-Loop (PHIL) and emulators. To choose the desired strategy, the trade-off has to be made between the cost, test fidelity and test coverage. The entry is based on section in "Testing Smart Grid Scenarios with Small Volume Testbed and Flexible Power Inverter" by Milosz Krysik et al.

Microgrid testing | smart grid | microgrid emulator | power hardware in the loop (PHIL) | control hardware in the loop (CHIL) | hardware in the loop (HIL) | simulation | Real-Time simulation (RTS)

1. Introduction

Testing Microgrids (MGs) can be done in a variety of ways, among others digital simulation, co-simulation, Real-Time simulation (RTS), Hardware-In-the-Loop (HIL), Controller-Hardware-In-the-Loop (CHIL), Power-Hardware-In-the-Loop (PHIL) and emulators. Several reviews and analyses have been made that compare these testing strategies and present a diversity of paths to create simulation within each category of test approaches[1][2]. To choose the desired strategy, the trade-off has to be made between the cost, test fidelity and test coverage[2]. The entry is based on section in manuscript[3] written by Milosz Krysik et al.

2. Testing in Microgrids

2.1 Digital Simulation

The digital simulation consists of solving mathematical models with the use of high-level language code and platforms. It is mostly used for the initial state of the system development. The benefits are flexibility, rapidity, versatility and no risk of damaging the equipment[4]. Cost varies depending on license period, but can reach several thousand EUR by year, in the case of choosing, the most popular solution, e.g., Matlab. Worth mentioning is that there are free simulation tools available, like Julia or GNU Octave. There is also a possibility that diverse power system modules can be simulated in different simulation tools; therefore, all simulations need to be merged in a co-simulation environment, for instance, mosaik.

2.2 Real-Time System Simulation

A real-time system is performed on parallel processors. All parts of the system, for example, the control, protection and measurements, are modeled on the simulation platform[5]. The key issue of RTS is to ensure appropriate timescale, including idle time of processors[1].

2.3 Hardware in the Loop Simulation

When some parts of the system exist physically and the software part of the simulation is connected with the hardware, then the HIL approach is implemented. It is well known that HIL requires more time to build and investment costs are usually higher than in the previously mentioned approaches. A noticeable benefit is the behavior being closer to the real behavior of the given module. There are certain issues that ones designing the HIL system need to take into account, such as stability criteria and also time delay formed in simulation, which might be reflected in harmonics of output signal[4]. The CHIL systems add hardware to RT simulator, for instance, a power converter controller and signals are exchanged between them with the use of Analog-to-Digital or Digital-to-Analog converters[4]. That approach is widely used, and it gives scientists a valuable, small volume object to test basic algorithms like voltage control or power-sharing in MGs[6] or testing data exchange methods[7].

2.4 Power Hardware in the Loop Simulation

PHIL has a similar architecture to CHIL, but requires an additional power amplifier stage. This allows the use of devices that are involved in exchanging power such as solar inverters or generators. The appropriate selection of power amplifier requires a priori determination of bandwidth, expected accuracy and stability of the desired power amplifier[8]. Voltage and current amplitudes flowing through the PHIL system might be closer to the real values flowing in the power system, thus PHIL simulation has the ability to test more risky, complex and demanding scenarios. Examples of possible test cases are fault condition detection, protection validity or power exchange between units. A common approach to performing the test is to first simulate the system only in software and then compare the results in the PHIL environment. The authors of[9] present PHIL with the use of a commercial micro-inverter and put it through a series of stability tests. A complex test class was presented in[10], among others, abnormal voltage and frequency conditions, voltage regulation or unintentional islanding were investigated. Another paper[11] presents a simulation of a PV inverter, for voltage regulation in distribution networks, with the use of a variable voltage source. The system features and protection, together with reactive power behavior in case of fluctuating power capability of the PV array, were well tested. There are numerous PHIL simulators with the use of inverters. However, most of them use the commercial inverters that are dealing with dangerous voltages and are hard to configure.

2.5 Microgrid Emulator

The idea of the MG emulator is to imitate, as much as possible, the real behavior of the MG. Performing test scenarios on an emulator, instead of the real power system, has several advantages. For instance, there is no possibility of damaging the real equipment, it has the possibility of concentration of long tests in a shorter period by changing the timescale, it consumes less space, costs less and is more flexible[12]. One of the examples of such an emulator is presented in[13]. The authors present the Generator Emulator Controls that was designed to reproduce favorable grid-forming characteristic of a synchronous generator. The paper presents tests of plug-n-play ability in MG with 15-inverters. The testbed used a commercial inverter in the closed case, and it is slightly limiting the flexibility, although the authors sized the appropriate filter. In[14], the authors introduced an emulator with a voltage source inverter. The size of the test system is relatively small and due to the modular concept of the system, it is flexible to made changes in topology, but no test was performed to present that feature. In the paper, the authors test parallel operation as well as response to load step changes, but only for two values of the load and without measuring the frequency deviations at Point of Common Coupling.

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