MIST Case Study

Microgrid Controller Testing using HIL and Digital Twins

The Challenge

Utilities have traditionally maintained a strong focus on thoroughly testing protection and control schemes to guarantee reliable and robust network operation. However, the introduction of modern digital control systems has significantly changed the landscape.

These systems now benefit from enhanced processing power, seamless communications, and the incorporation of advanced machine-learning algorithms. While these innovations deliver a wide array of functional capabilities, they simultaneously introduce new complexities regarding the testing and validation of both protection and control performance, as well as cybersecurity considerations.

Many manufacturers now supply black box controllers that are designed to perform intelligent functions. The black box nature of these controllers, however, presents a major challenge: it becomes increasingly difficult to validate performance using traditional testing techniques. This limitation is particularly significant as utilities seek to ensure the reliability of critical systems.

Field testing of such advanced systems is often both expensive and carries inherent risks. As a result, digital twins and hardware-in-the-loop (HIL) testing have emerged as crucial tools for validating the operation of black box controls in a controlled, risk-free environment.

Our Approach

In the MIST Facility, a black-box testing methodology was created to rigorously evaluate microgrid controller performance. This process utilises our Real-Time Digital Simulator (RTDS) with HIL test techniques, enabling comprehensive verification of the controller's functionality within realistic operating scenarios.

The focus of this validation is the microgrid control scheme, where the controller is responsible for managing diverse energy resources to achieve a range of economic and technical objectives. While commercially available microgrid controllers offer various features and capabilities, utilities face significant challenges validating these control schemes, particularly when there are conflicting priorities and objectives that must be balanced.

The MIST approach streamlines the testing process by simulating an entire year of microgrid operation within a condensed timeframe. Despite this accelerated schedule, all relevant system dynamics are maintained, ensuring that the integrity of the device under test is not compromised. This method offers utilities an efficient and effective way to assess controller performance under a variety of operational conditions.

During testing, the RTDS is used to create a digital twin of the microgrid, which comprises a grid-forming battery, diesel generator, solar resources, and controllable loads. This digital twin enables precise replication of real-world conditions, allowing for thorough examination of the controller's responses and decision-making capabilities. The relationship between the microgrid digital twin and the physical microgrid controller is shown in Figure 1.

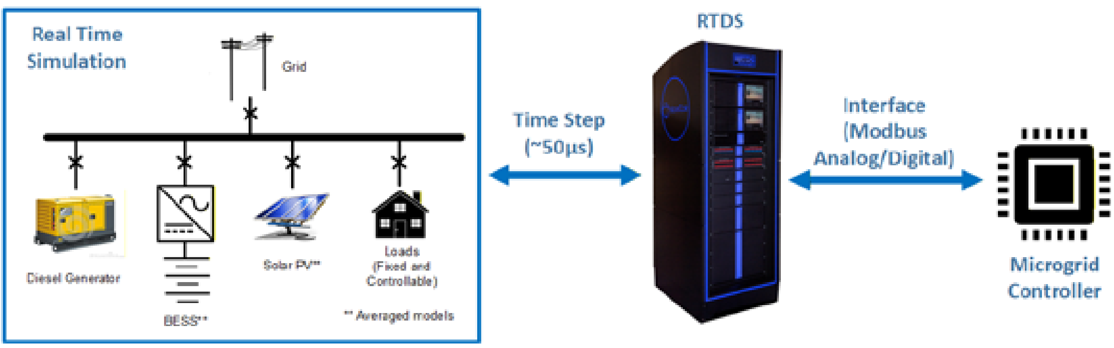

Figure 1: Overview of the connection between the microgrid controller and RTDS.

Test Results and Analysis

Within the MIST environment, the closed-loop response of the black-box controller was thoroughly validated under a variety of network conditions. The testing process confirmed that the controller maintained accurate performance and effectively coordinated the microgrid assets when it was subjected to different operational scenarios and disturbances.

An accelerated time simulation technique was used to assess the microgrid controller's ability to control the microgrid for extended time periods under a range of scenarios. This meant the load profile of the microgrid, which was given at 5-minute intervals, was able to be compressed down to 5-seconds. The other simulated microgrid assets were also accelerated in a similar fashion (e.g. energy stored in the battery) to ensure the accurate interaction between the microgrid digital twin (simulated environment) and the controller (physical environment) was maintained.

By leveraging the accelerated simulation timeframe, it was possible to demonstrate the effectiveness of the controller without any compromise in accuracy. This approach provided clear evidence of the controller's ability to deliver reliable performance while efficiently managing the complexities of real-world microgrid operations. This also allowed any bugs or deficiencies in the microgrid controller's design to be identified and rapidly rectified prior to the controller being deployed to site.

Different control philosophies, for example minimising generator use or maximising profits, could also be trialled to provide the microgrid operator confidence in the microgrid's performance. An example of the microgrid controller coordinating the microgrid assets over a one-month time period is provided in Figure 2. This allowed accelerated controller performance testing without loss of fidelity.

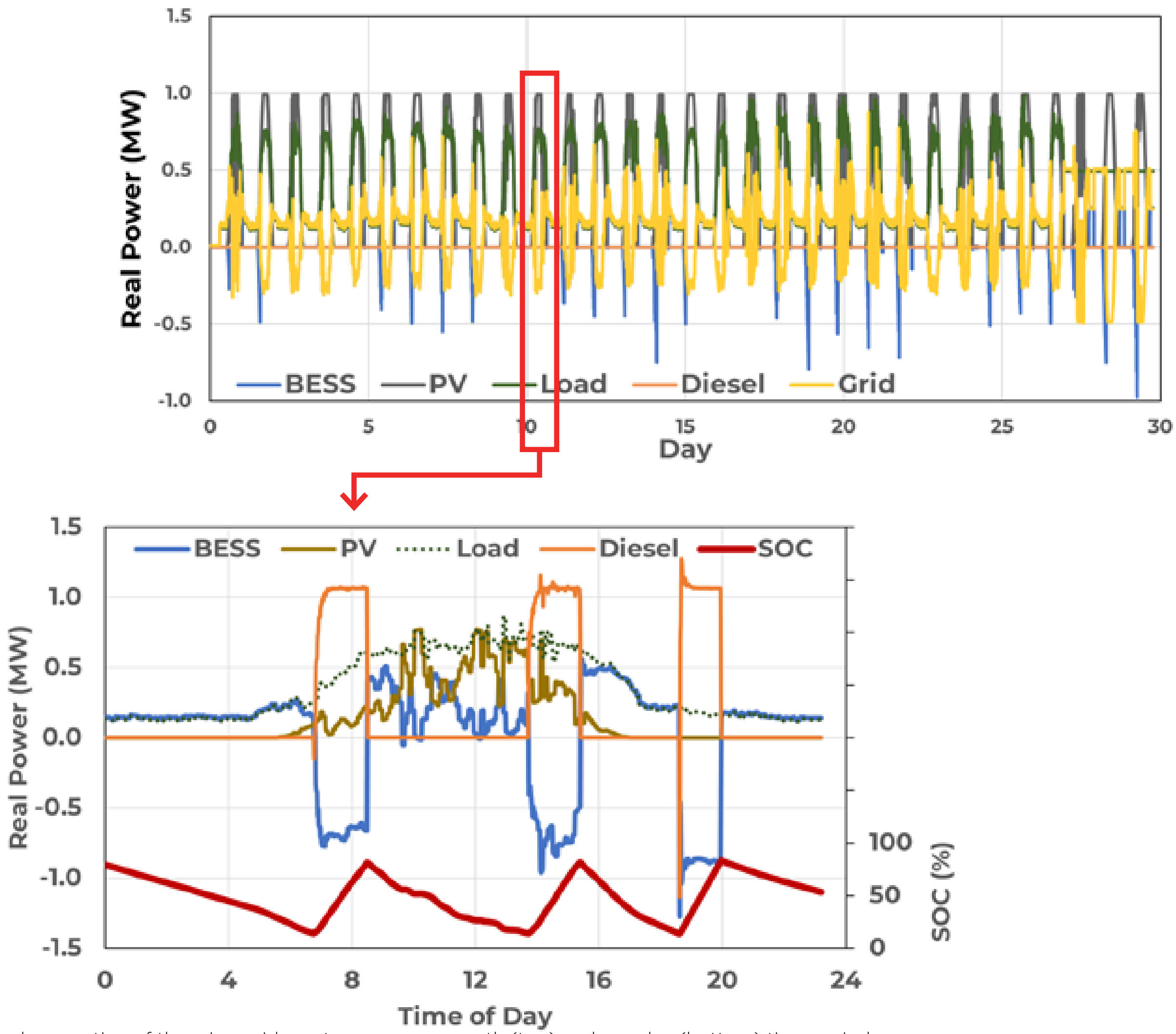

Figure 2: Example operation of the microgrid assets over a one month (top) and one day (bottom) time period.