

## Inverter Simulation Based on OPAL-RT Platform

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### 1. Research Background and Objectives

As renewable energy increases, the inverter-based resources (IBRs) become dominant in the power grid. These IBRs are controlled by methods of grid-following Inverters (GFLIs) and grid-forming Inverters (GFMI). Power Hardware-in-the-loop (PHIL) simulation allows the physical GFMI and GFLI to be connected to the power grid, which is in the host computer, enabling the verification of IBR dynamic characteristics on the grid. This study uses the OPAL-RT real-time simulation platform with HYPERSIM simulation software to conduct these tests. The grid in simulation includes a conventional synchronous machine, a virtual synchronous generator (VSG), a grid-following inverter, the utility grid, and loads. This grid configuration is used to investigate the characteristics of the conventional synchronous machine, the virtual synchronous generator, and the grid-following inverter.

### 2. Research Content

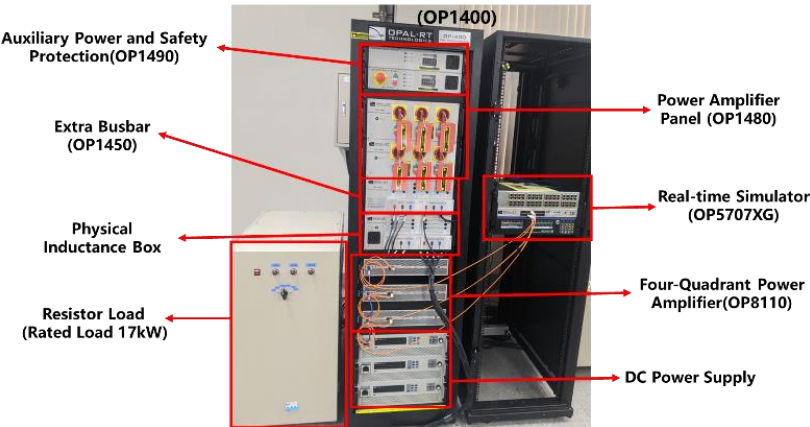
As renewable energy penetration in power transmission and distribution systems continues to rise, the proportion of inverters in the power grid is increasing annually. Solar power generation accounts for the largest share of this growth. Most solar inverters are GFLIs<sup>[1]</sup>. These inverters rely on the external grid's voltage and frequency to operate, injecting power to the grid and behaving like an AC current source. GFLIs are the most widely used inverter type for renewable energy systems like solar and wind power. In a stable and strong grid environment, GFLIs can reliably track the grid's phase and perform grid-connected operations effectively.

As the proportion of IBRs continues to increase, particularly with large-scale adoption of GFLIs, the overall system inertia and short circuit ratio (SCR) will decrease significantly. This leads to a decline in the power system's stability and its ability to recover from disturbances.

This challenge has spurred international efforts to develop GFMI technology actively<sup>[2]</sup> to enhance system stability and active control capabilities. Therefore, with the rapid expansion of renewable energy and the rising integration of IBRs, the application of GFMI technology is becoming increasingly vital. It plays a crucial role in future smart grids, microgrids, and large-scale power grids.

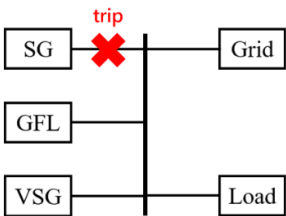
Based on those mentioned above, this study constructed a simplified microgrid model to better understand the characteristics of inverters in the power grid. The model includes a conventional synchronous machine, a VSG, a GFLI, the utility grid, and loads. The research used the OPAL-RT real-time simulation platform with HYPERSIM simulation software for the PHIL experiments. The simplified grid model incorporates a synchronous generator (SG), a GFLI, and a GFMI. The control method used for the GFMI in this study is virtual synchronous generator control. This setup was used to verify the stability and feasibility of the SG, the GFLI, and the VSG within the simplified model. Figure 1 shows the OPAL-RT testing platform. Fig. 2 illustrates the microgrid architecture used in this study for the simulation of the SG trip experiment. Fig. 3 shows the scenario where the SG, GFLI, and VSG are operating in parallel to supply a 4 MW load, with the SG tripping at

the first second. From Fig. 3, the VSG reacts quickly to thereby maintaining a stable system power supply. compensate for the power generation lost from the SG trip,



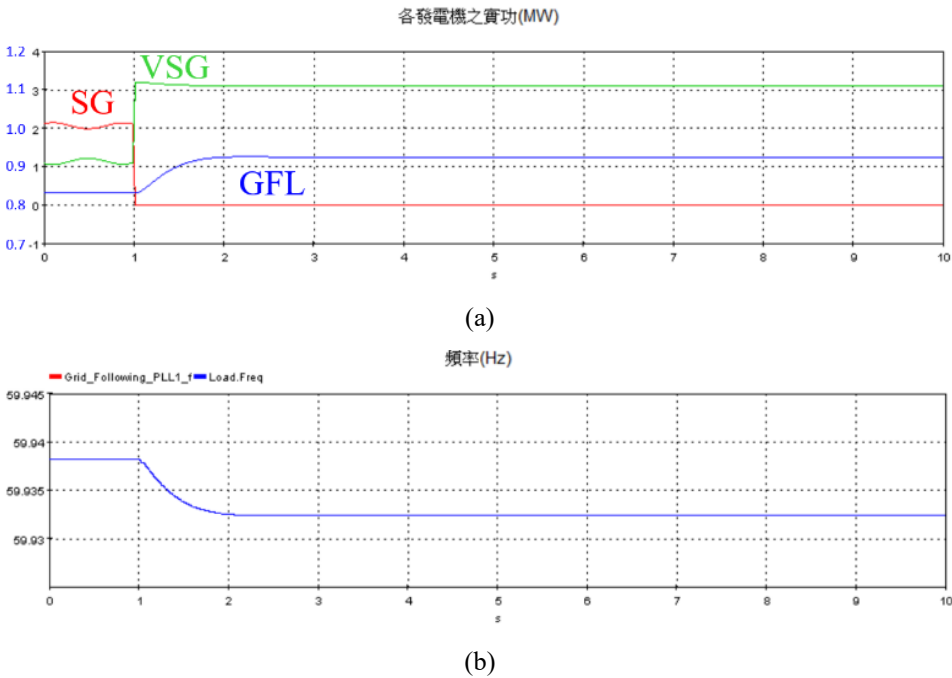
Source: Drawn by authors

Figure 1. OPAL-RT testing platform



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Figure 2. Microgrid architecture used in this study



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Figure 3. SG trip simulation with SG, GFLI, and VSG operating in parallel

(a) active power output of each generation unit; (b) system frequency

include physical devices in the hardware loop. This would allow for the study of the stability and feasibility of grid-connected PV inverters and energy storage projects within a specific regional grid, as shown in Fig. 4(a). Additionally, this platform can be connected to a physical GFMI. Based on international GFMI standards (such as the UK's GC0137 and the test methods recommended by ERCOT and NERC), a comprehensive testing procedure for GFMI can be established, as shown in Fig. 4(b).



Figure 4. Inverter power hardware-in-the-loop test based on OPAL-RT

#### 4. Reference

- [1] Q. Peng, Q. Jiang, Y. Yang, T. Liu, H. Wang, and F. Blaabjerg, "On the stability of power electronics-dominated systems: challenges and potential solutions," *IEEE Transactions on Industry Applications*, 2019.
- [2] J. Rocabert, A. Luna, F. Blaabjerg, and P. Rodriguez, "Control of power converters in AC microgrids," *IEEE Transactions Power Electronics*, vol. 27, no. 11, pp. 4734–4749, Nov. 2012.