KGS as power amplifier for PHIL test

With the increase of distributed energy resources (DERs), including renewable energy sources such as wind and solar energy, energy storage systems, and electric vehicles (EVs), the power grid is undergoing a transformational shift that is both challenging and demanding for the continuous advancement of "smart grids." Advanced communication, control, and monitoring in smart grids enable the grid to better cope with changes in the power system, providing more reliable and resilient electricity, including fewer interruptions, faster recovery, and increased deployment of DERs.

Since most DERs connect to the grid using power electronic inverters, comprehensive testing is required to ensure the performance and stability of these inverters and their control systems. A powerful testing method widely used in testing applications is Hardware-in-the-Loop (HIL), which allows external devices to connect with real-time simulations running on a Digital Real-Time Simulator (RTS) to enhance the realism of the results and achieve safe and reliable device and controller design.

Hardware-in-the-Loop includes.Controller Hardware-in-the-Loop (CHIL) and Power Hardware-in-the-Loop (PHIL).

In PHIL testing, a power amplifier is connected between the RTS and the Device Under Test (DUT), as shown in Figure 1. The power amplifier amplifies the low-voltage signals from the RTS, converting them into actual voltage and current so that the power device under test can connect at its rated power.

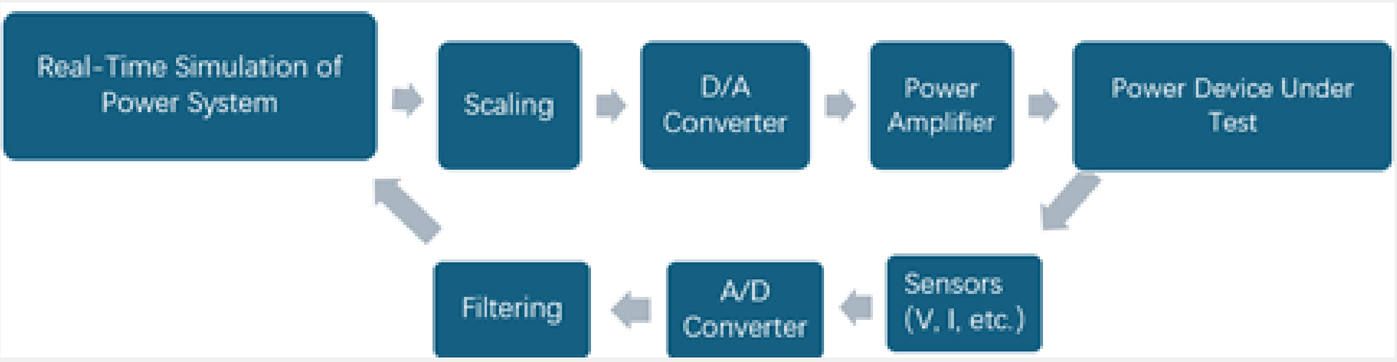

Figure 1 PHIL Configuration

KGS as power amplifier for PHIL test

For the selection of power amplifiers, the main requirements include rated power, single or three-phase output, AC or DC output, four-quadrant operation, output impedance, dynamic characteristics, harmonic distortion, and so on. One important specification is the transient response speed of the power amplifier, which is how fast the amplifier responds when a set point is sent to the amplifier.

BriPower KGS series, a switching mode power supply, which uses SiC as the power device, has excellent electrical performance and meets the above requirements for power amplifiers in PHIL testing, providing a high-performance, low-cost option for PHIL testing. The KGS series operates in four quadrants, with a frequency output range from DC to 5kHz, a small signal bandwidth of 10kHz, rapid dynamic characteristics, and provides an analog control interface, which amplifies real signal (not RMS value),with an output response time of less than 20μs.

To illustrate the characteristics of KGS as a power amplifier in PHIL testing, the following tests were conducted. The test connection is shown in Figure 2.

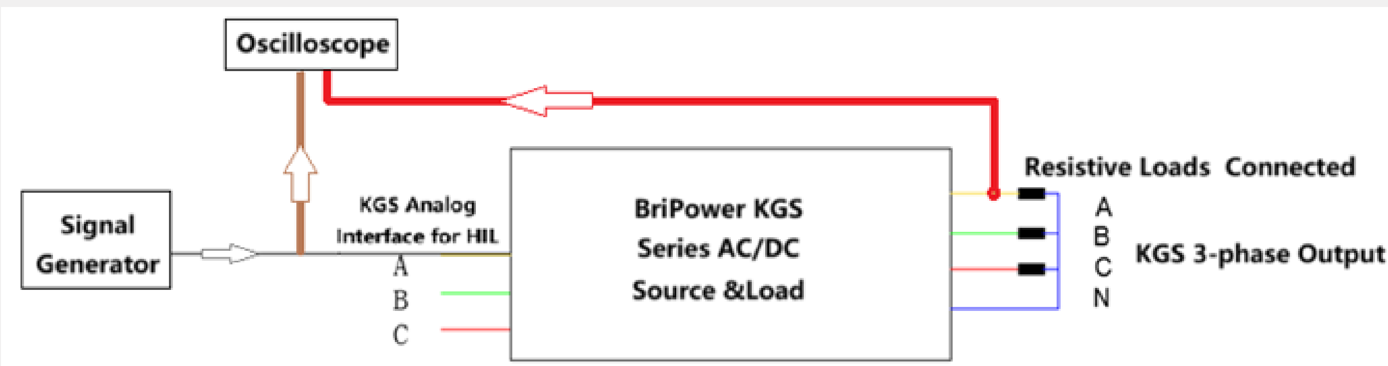

Figure 2 Test Connection

KGS as power amplifier for PHIL test

A Rigol DG821 signal generator is used to output a small signal to the KGS's analog input interface to control the output of phase A, while a Tektronix MSO44 was used to measure the output of the signal generator and the output of phase A. The signal generator output was set to a triangular wave at a frequency of 1kHz; the KGS was set to analog control, CV output. The test waveform is shown in Figure 3. The test results show that the output delay of KGS is less than 20µs.

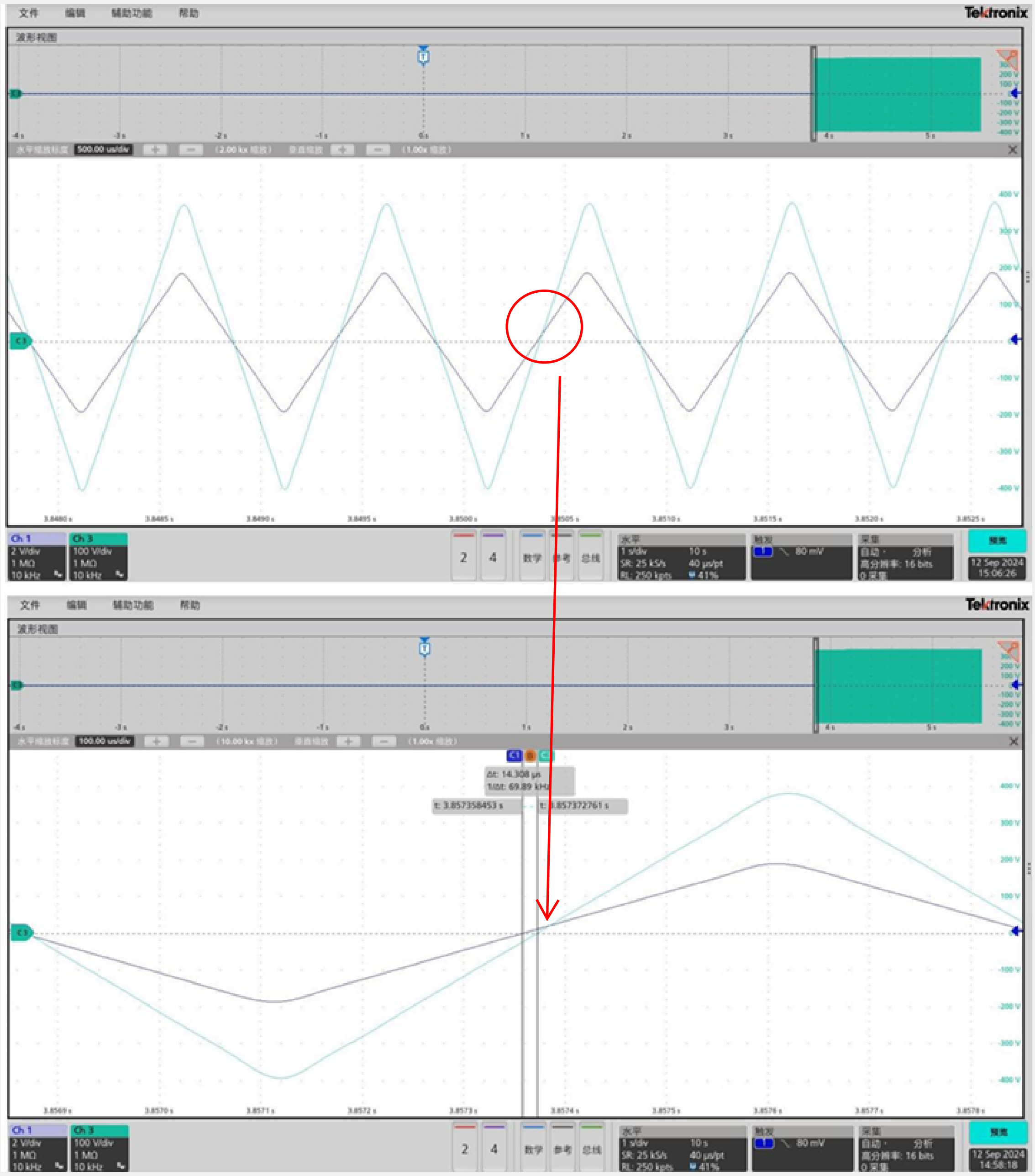

Figure 3 KGS in CV mode, Output Response Time <20µs

KGS as power amplifier for PHIL test

Currently, PHIL testing is mainly of the voltage type, where the power amplifier is used as a voltage source during the test process. This is primarily because most of the DUTs are current sources, such as inverters using grid-following strategies.

If the PHIL test is of the current type, for example, if the DUT is a grid-forming inverter, the power amplifier will act as a current source at this time, the RTS sends the current set value to the amplifier and measures the voltage response of the DUT.

The KGS series also supports a constant current mode. The following test, using the same connection as in Figure 2, sets the signal generator to output a sine wave at a frequency of 1kHz, controlled through the KGS's analog interface for phase A output, with the KGS set to constant current output. The oscilloscope was used to synchronously measure the output waveform of the signal generator and the output waveform of phase A of the KGS power supply. The test waveform is shown in Figure 4, and the test results show that the output response time of KGS is also less than 20μs.

KGS provides three BNC connectors for analog controlling the three-phase output of the power supply, as shown in Figure 5.

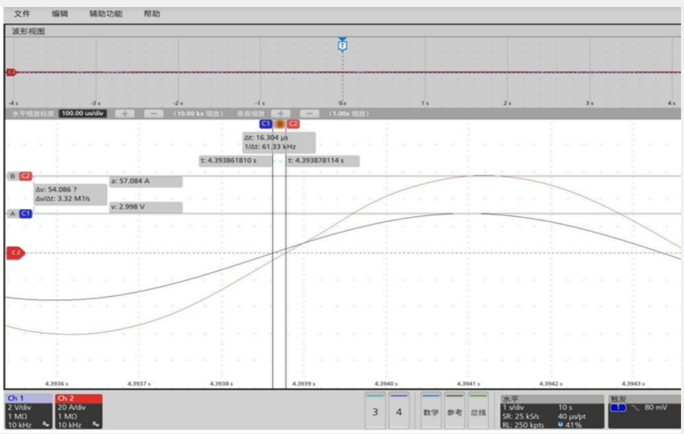

Figure 4 KGS in CC Mode Response Time <20μs

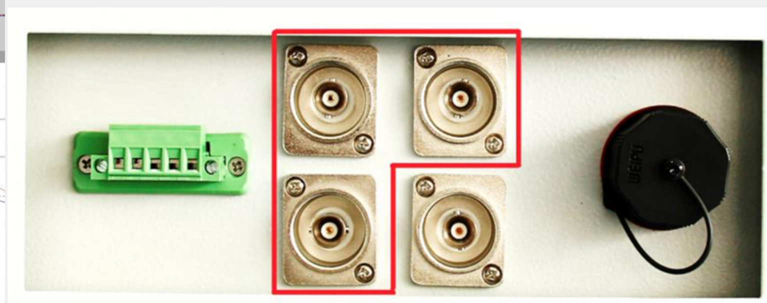

Figure 5 KGS Analog Control Interface for HIL

The KGS series also provides analog measurement interfaces, also using three BNC conectors, which can be used for closed-loop testing in PHIL. In open-loop PHIL testing, there is no feedback from the DUT to affect the simulation of the power system. In closed-loop testing, the feedback from the DUT affects the simulation of the power system, which in turn affects the performance of the DUT system.