Abstract
This paper presents a systematic approach to characterize the stability of a power-hardware-in-the-loop (PHIL) platform, an important step in PHIL tests. Many existing works focus the stability assessments on the PHIL interface algorithm; however, this work considers all software and hardware subsystems that form the closed loop of the PHIL experiment and develops a complete closed-loop stability assessment. This assessment is developed in the context of a common framework that can be readily applied to other PHIL platforms. This paper presents methods for characterizing key PHIL subsystems toward obtaining transfer functions to be used for analysis. The systematic stability assessment approach is demonstrated for a case study involving PHIL testing of a solar inverter and validated using experimental data.

PHIL Platform Configuration
- Equivalent circuit of the simulated electrical power system (Thevenin circuit)
- PHIL system software interface (signal conditioning, interface algorithms, and system controllers)
- PHIL system hardware interface (analog/digital converters, power amplifier, transformer, and sensors)
- Hardware under test (HUT)

Characterizing the PHIL Platform
- Virtual system equivalent grid impedance \( Z_s \): applying the frequency scan approach in the selected experimental data.
- Power amplifier \( G_{GS} \) and \( Z_{GS} \):

\[ G_{GS}(s) = \frac{V_{GS}}{V_{GS}} = \frac{1}{s + 0.02} \]

\[ Z_{GS}(s) = 7.4 + 0.12 \]

- HUT inverter \( Y_{HUT} \): modeled as a Norton equivalent comprising a controlled-current source with a parallel-connected admittance.

\[ Y_{HUT} = Y_{l} + Y_{s} \]

- Interfacing components: \( G_{Reg}, G_{Comp}, H_{reg}, \) and \( H_{s} \) are designed by the user; \( K_{u}, K_{v}, K_{DAC}, G_{TX}, \) \( H_{TX}, H_{TX}, K_{DAC}, K_{u}, K_{v}, D_{TX}, D_{TX}, K_{u}, \) and \( K_{v} \) can be derived from element specifications/data sheet.

System Stability Evaluation
- Open-loop transfer function

\[ G_{OL}(s) = \frac{V_{OL}}{V_{IN}} = \frac{1}{(s + 0.02)(s + 0.12)} \]

Conclusion
This paper presents the stability evaluation of a PHIL platform prior to normal lab test and study. First, a diagram of the PHIL platform including all the associated elements is presented to give a high-level view of the system. Then, characterization is performed to get the mathematical representation of each element with special focus on four elements: amplifier gain and output impedance of the power amplifier, equivalent voltage source impedance, and equivalent HUT admittance. Next, the stability is evaluated analytically by checking the open-loop transfer function by the Nyquist criteria and poles of the closed-loop system. Finally, experimental tests are performed to demonstrate the stability of the PHIL system. This work provides a highly efficient tool to predict the stability of a PHIL simulation with accurate models of the components in the loop.