Real-time Inertia Estimation Tool Implementation Based on Probing Signals

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INTRODUCTION & BACKGROUND

What is power system inertia?

- A critical parameter in power systems that determines the system's ability to withstand disturbances and maintain stable operation.
- Provided by the rotating masses of synchronous generators and motor loads in tradition power grids.

Why do we need accurate inertia estimation?

- Increasing deployment of inverter-based resources (IBRs) → Reduced system inertia
- Variable nature of renewable generation → Amplified inertia fluctuations
- Knowing accurate inertia → Secure grid operations and provide insights on artificial inertia contribution from the IBRs

Why choose probing-based method for real-time inertia estimation?

- System inertia can be estimated in real-time and at grid operators' desire time by controlled probing injections.

PROBING-BASED INERTIA ESTIMATION METHOD & PHIL TEST RESULTS

The basic idea of probing-based inertia estimation is to utilize controllable inverters in the field to **inject active power pulses** into the grid and estimate system inertia using **frequency measurements**.

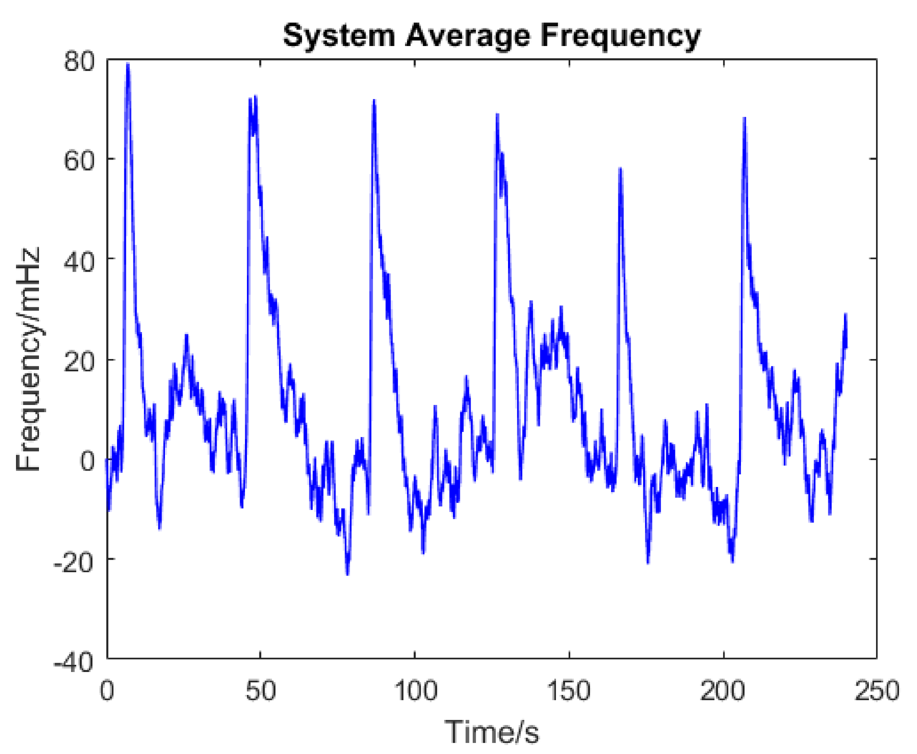

Figure 1. Frequency deviation during probing test

Two sets of estimation algorithms that based on system identification are developed:

1. Inertia only estimation: To estimate system inertia from SGs and provide insights on assessing the artificial inertia contribution from the IBRs.
2. Inertia + droop estimation: To estimate both the SGs' inertia contribution and the droop control of the IBRs.

	Case 1A	Case 1B	Case 1C	Case 1D	Case 2A	Case 2B	Case 2C	Case 3	Case 4
Inertia Ground Truth	**102.046**	**97.5**	**86.347**	**90.847**	**102.046**	**102.046**	**102.046**	**187.233**	**187.233**
Estimated Inertia without Noises	99.228	102.020	81.866	91.876	106.754	97.099	94.849	184.764	163.845
Estimated Inertia with Noises	105.28	99.30	90.07	88.97	92.511	94.273	105.372	191.184	211.319
Droop Ground Truth	**/**	**/**	**/**	**/**	**8.486**	**6.422**	**4.009**	**8.775**	**16.553**
Estimated Droop without Noises	/	/	/	/	8.400	6.773	3.653	9.099	16.466
Estimated Droop with Noises	/	/	/	/	8.208	6.095	3.848	9.046	16.886

Table 1. Inertia and inertia + droop estimation results on test cases with various online SGs & GFL IBRs & GFM IBRs

PHIL TEST SYSTEM SETUP

PHIL test system with identical hardware and control as the actual Kauai Island power grid is being set up at the NREL Flatirons campus.

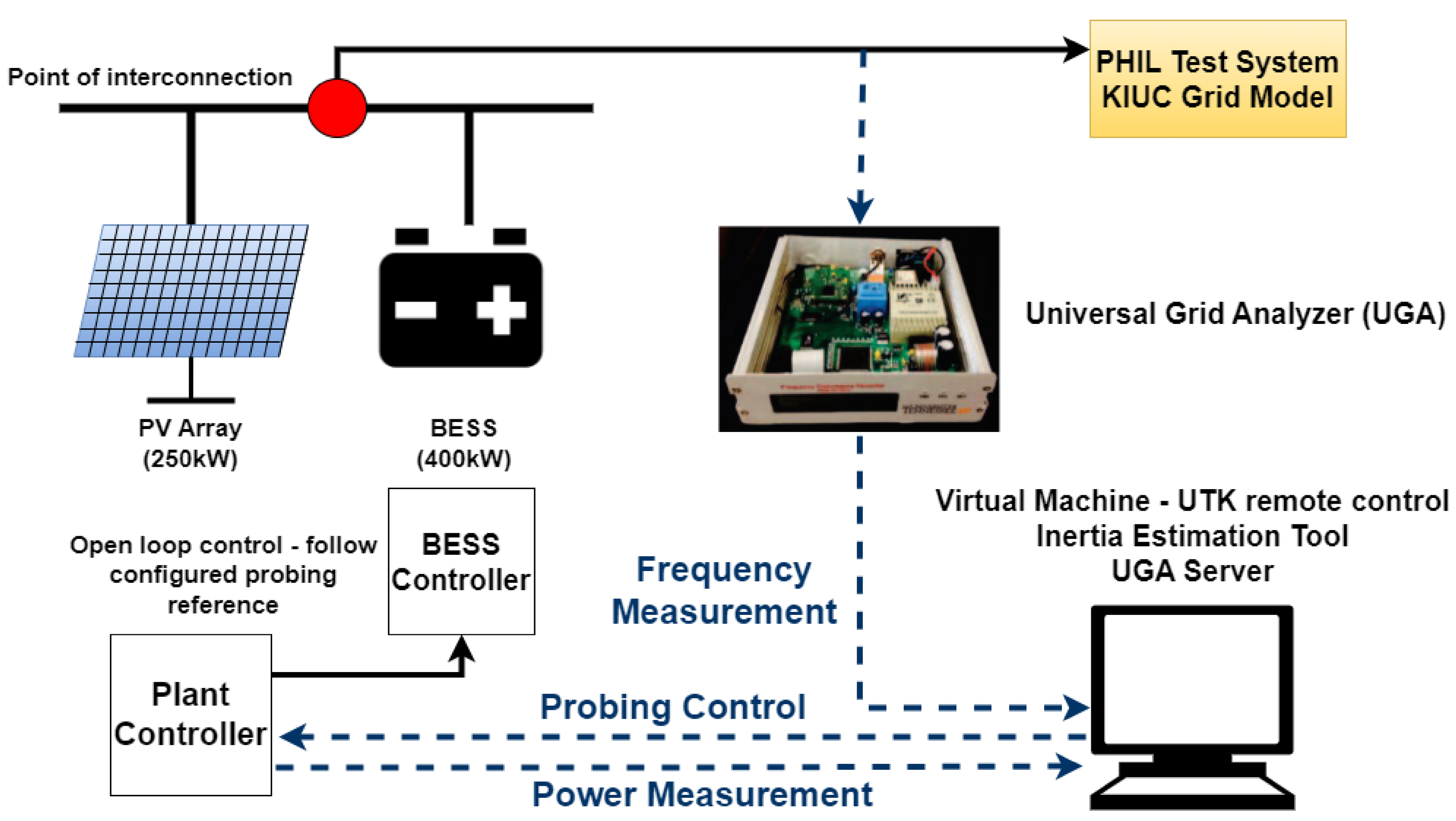

Figure 2. PHIL test system

CONCLUSIONS & FUTURE WORKS

- Four test scenarios with various combinations of online SGs and IBRs have been designed to validate the algorithms' accuracy and study the artificial inertia contributions from the IBRs.
- For the test scenario with only SGs online, the inertia estimation algorithm can achieve an average estimation error of < 4% with or without noise impact.
- For the test scenarios with various IBRs online, the inertia + droop estimation can achieve < 8% average error for inertia and <4% average error for droop with or without noise impact. The inertia only algorithm can provide valuable insights in quantifying artificial inertia contribution.
- The future work will focus on actual KIUC field deployment.