Black-Box Impedance Identification and Stability Analysis of Grid-Connected Inverter

EPICS Workshop, CSIRO Energy Center, Newcastle

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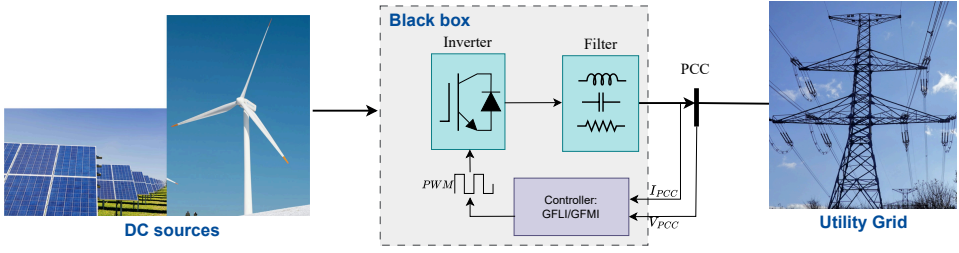
Grid-Connected Inverter-based Resources



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1 - What challenges do we meet?

2 - How to obtain dynamic behaviour of an IBR from a black box?

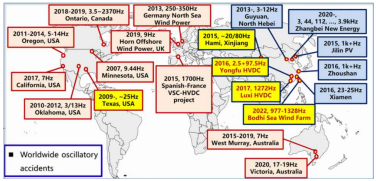
3 - Results and Validation

4 - Future Work

Grid-Connected Inverter-Based Resources – Challenges

Causes of Oscillations

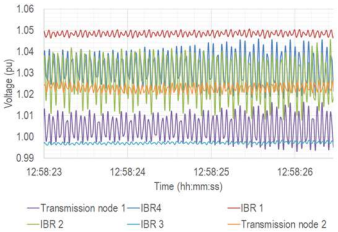
- Coupling among internal control loops
- Inverter-grid interaction
- Grid operating conditions



Source: Adapted from X. Xie, IEEE-PELS TC Webinar, 2024

Impacts of Oscillations

- Voltage and power oscillations
- Degraded power quality
- Potential equipment stress or damage



Source: AEMO, West Murray Zone 17 Hz Oscillation, 2020

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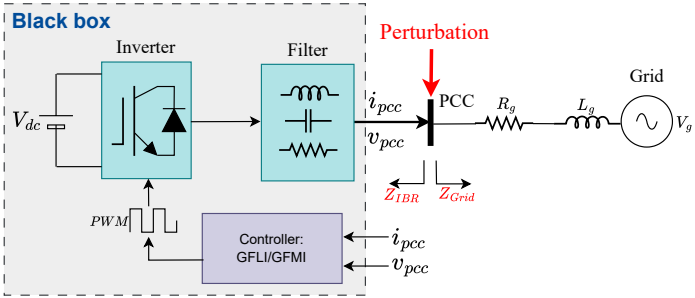

- **White-box** models (CCM, DAE) require full internal inverter information.
- **Black-box** impedance models use only terminal measurements.

CCM: Component Connection Method; DAE: Differential–Algebraic Equations; PCC: Point of common coupling.

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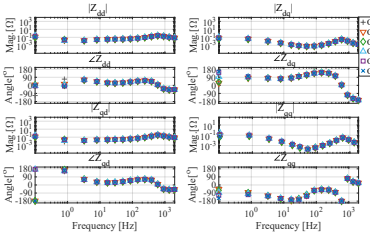
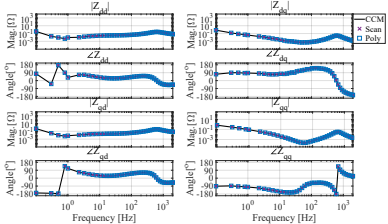
VSG-based Grid-Forming Inverter (GFMI)



Step 1: MOPs impedance identification from frequency scan (v/i at PCC)

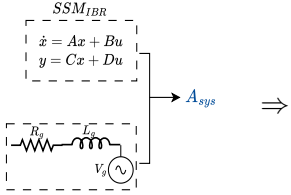
$$Z_{IBR}(s) = \frac{\sum b_{k,n}(s) V_d^p I_d^q I_q^r}{\sum a_{k,n}(s) V_d^p I_d^q I_q^r}$$

Step 2: Polynomial representation



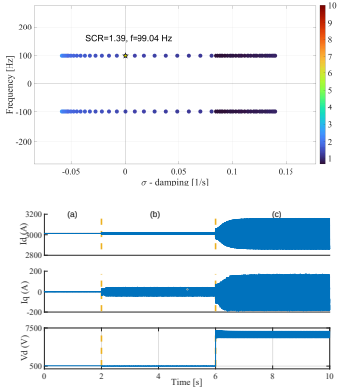
Step 3: Impedance identification via polynomial model at unseen operating point

VSG-GFMI: Virtual Synchronous Generator–based Grid-Forming Inverter. MOPs: Multiple operating points.



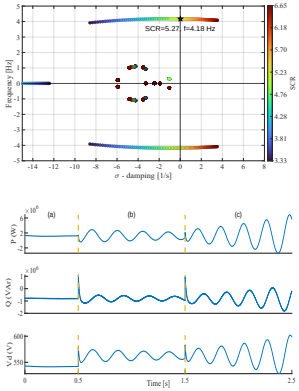
$\Rightarrow$

CC-GFLI



Eigenvalue & time-domain validation [SCR = (a) 10, (b) 1.5, (c) 1]

VSG-GFMI



Eigenvalue & time-domain validation [SCR = (a) 3, (b) 5.2, (c) 6]

SCR: Short Circuit Ratio.

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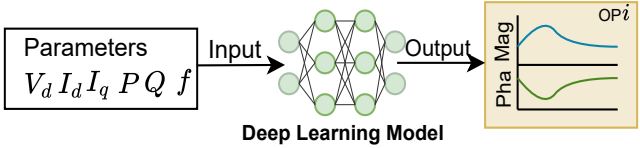
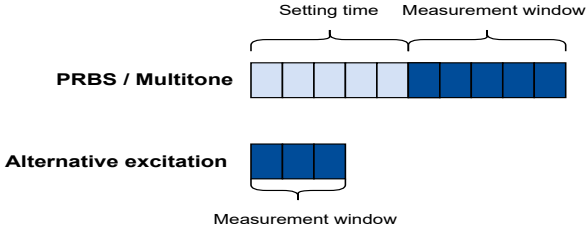

Parameters
V_d I_d I_q P Q f
Input
Output
OPi
Pha Mag
Deep Learning Model


Setting time
Measurement window
PRBS / Multitone
Alternative excitation
Measurement window

Thank you.