Impedance Measurements of Motor Drives and Supplies in NASA NEAT Facility

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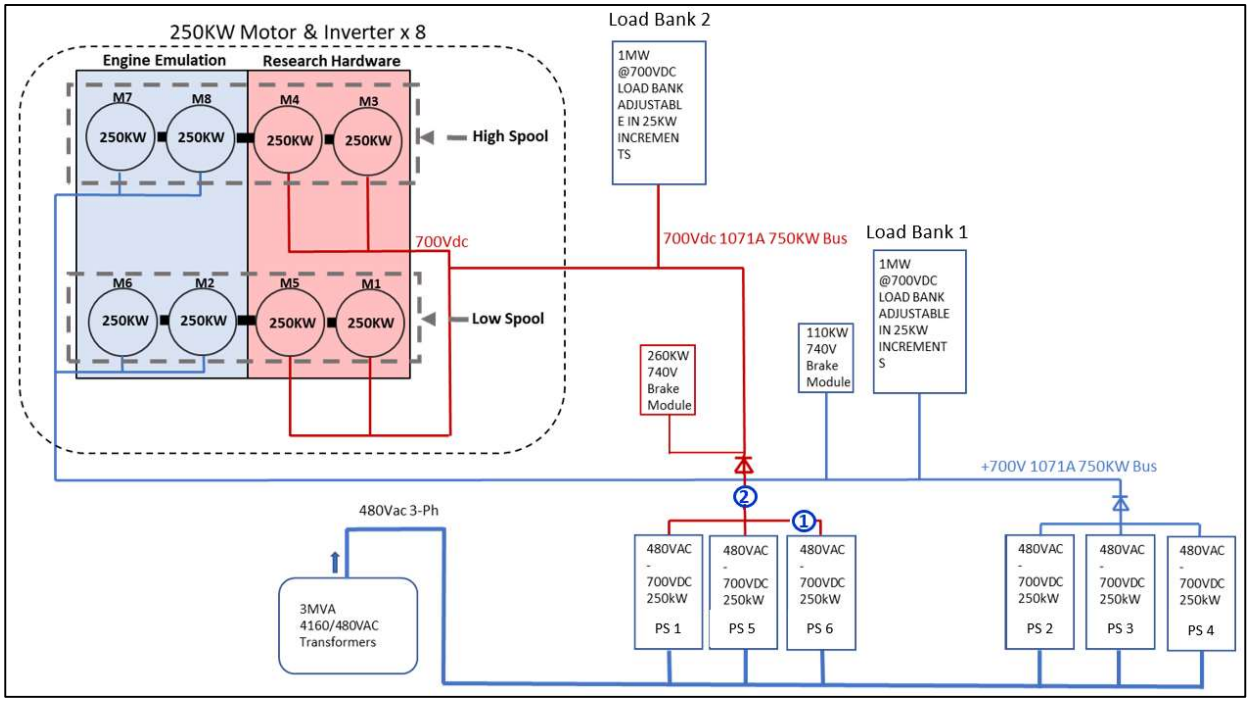
Presentation Overview

1. NEAT facility overview
2. Impedance measurement details and restrictions
3. Source and load testing configurations
4. Measured impedance data
5. Load impedance model
6. Stability analysis

NEAT Facility Overview

- 8 250 kW PMSM, 2 common shafts
- Motor drive with a built-in controller
- DC bus 700 V (standard operation)
- 2x3 250 kW unidirectional PS
- Reconfigurable load banks (1 MW)
- Safety brake modules
- Measurement points



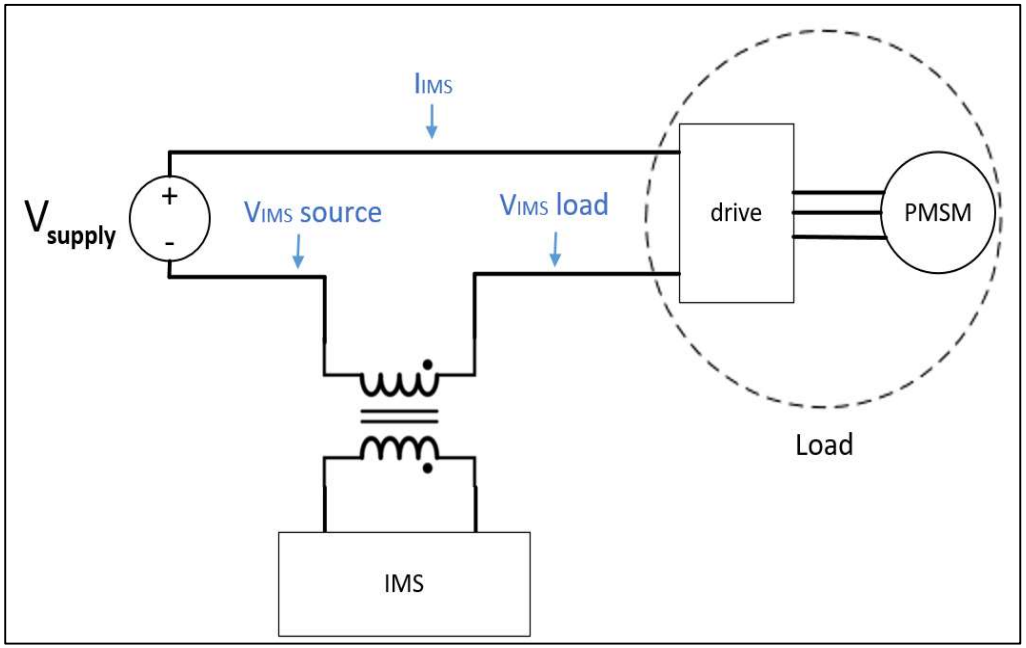
Impedance Measurement Details

Components

- DC Supply: source
- Load: drive and PMSM
- IMS

Impedance Measurement System (IMS)

- Low level sinusoidal signal
- Power amplifier
- Transformer to inject the signals
- Voltage and current measurements
- Load and source impedances calculated



Impedance Measurement Restrictions

IMS Limits

- 300 volts during measurements
- Range: 100 Hz and 50 kHz
- Future work: higher power and wider frequency

Signal Selection

- Equipment safety
- Measurement quality
- Z not known in advance! (resonance depth or location)
- Conservative experimental approach to guide selection

Testing Configurations

1-supply and 3-supply tests (18 tests)

- Resistive load only
- Motor only
- Generator only
- Each at 3 power levels

Additional 3-supply (1 test)

- 1 machine motor and 1 machine generator on same bus

Load bank settings:

Step	Power (kW)	Resistance (Ω)
1	25	19.6
2	25	19.6
3	50	9.8
4	100	4.9
5	100	4.9
6	100	4.9

Step	Power (kW)	Resistance (Ω)
7	100	4.9
8	100	4.9
9	100	4.9
10	100	4.9
11	100	4.9
12	100	4.9

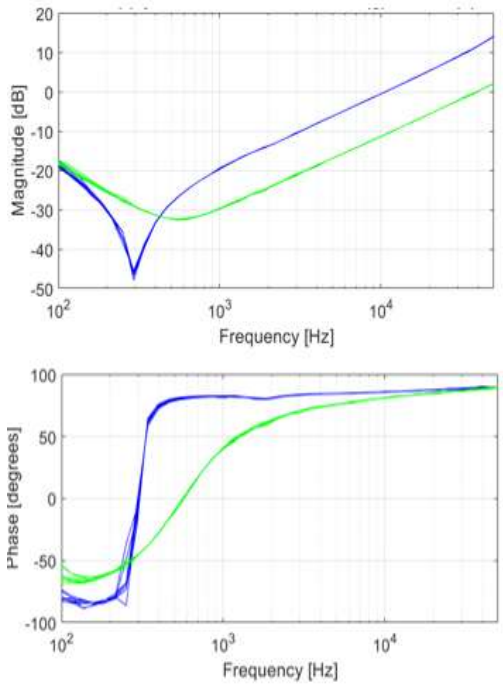
Measured Impedance Data

Single-source vs. three-source

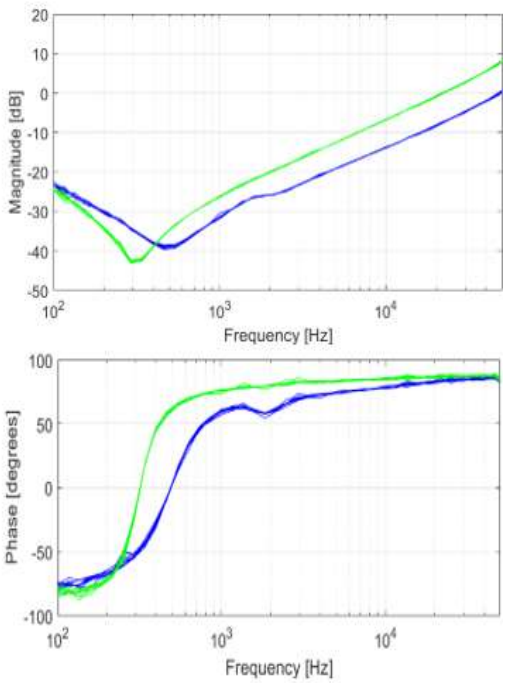
Measurements similar within configuration
- lower frequencies, capacitive
- higher frequencies, inductive

Variations (1 and 3 supply)
- Resonance points sharpness & location
- Differences expected

Observations
- Lower f & Higher P expectations
- *Structure consistent with predicted*
- *Relevant stability info for this system possibly captured*
- *First NEAT Z data*



Measured Z_S (green) and Z_L (blue) one-supply configuration



Measured Z_S (green) and Z_L (blue) three-supply configuration

Load Impedance Model

NEAT Configuration

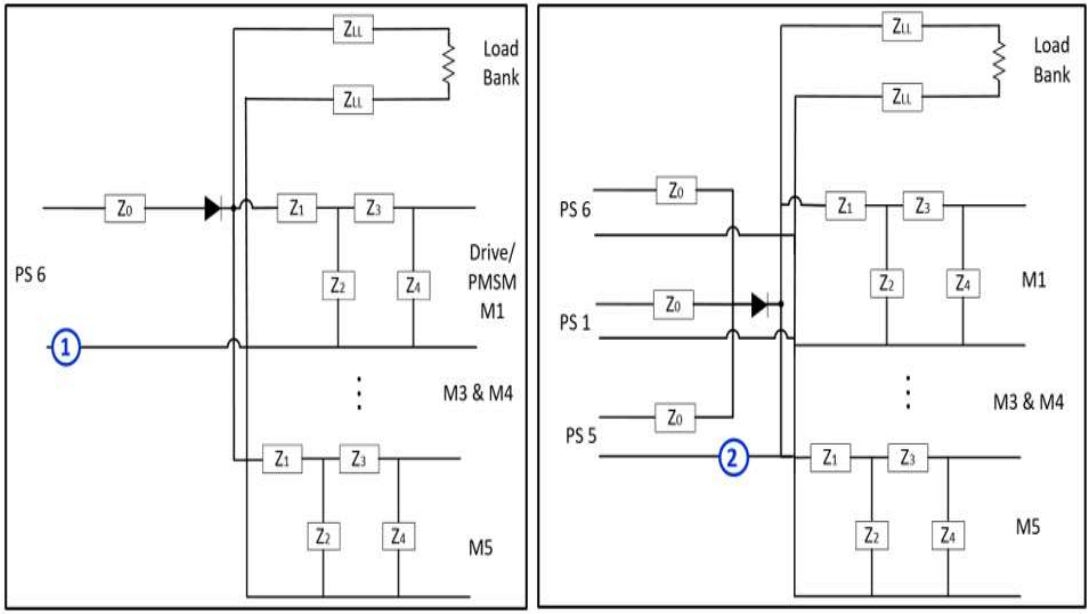
- components (supplies, drives, loads)
- connection via long lengths of cable

Load model

- Include line lengths, caps, load banks
- Use estimates of line parameters
- Updates
  - Latest NEAT configuration/test configuration
  - Format to plot alongside data

Approach

- Develop model, sweep frequency range
- Create Bode plot: 1- and 3-supply cases
- Compare to measured load Z data



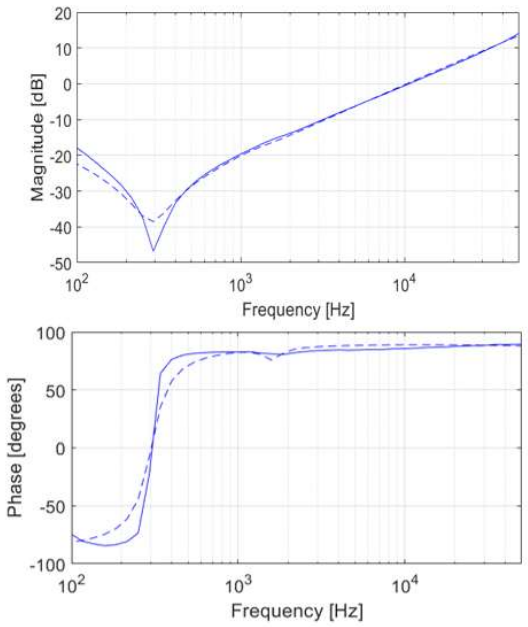
Load Impedance Model

Close match to measured impedance data

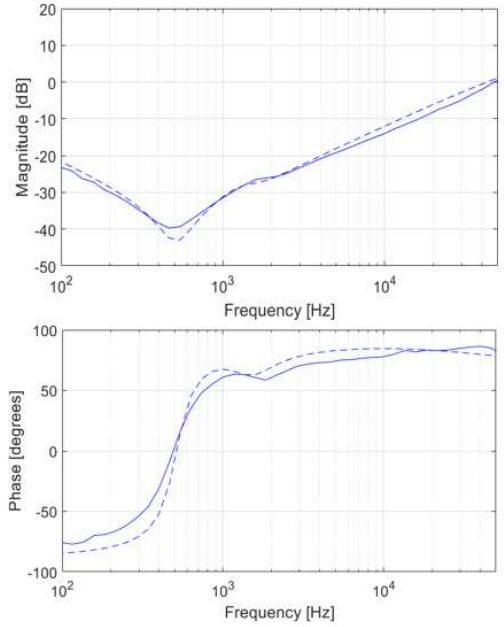
- lower frequencies capacitive
- higher frequencies inductive
- resonant points consistent

Future use in stability studies

- new facility EPS configurations
- vehicles



Z_L measured (solid) and model (dashed)
one-supply configuration



Z_L measured (solid) and model (dashed)
three-supply configuration

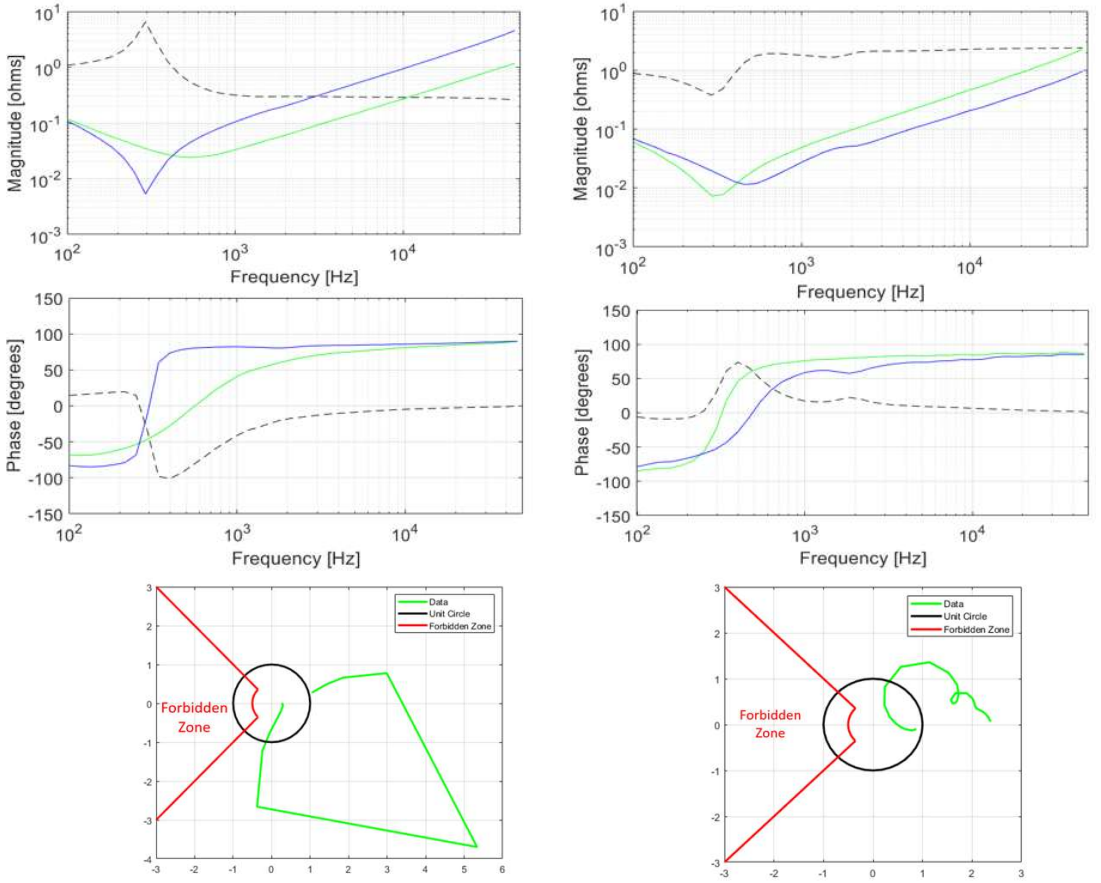
Stability Analysis

Approach

- Representative data: sources and loads
- Arbitrary stability margin of 6 dB and 45°

Impedance plots source (Z_S) & load (Z_L)

- Bode: no stability issues are anticipated (<135° given 45° margin)
- Nyquist plot consistent: avoids forbidden zone
- Analysis consistent with the observations: no stability issues observed during test



Conclusions

1. First impedance measurements at NASA GRC NEAT
    1. Companion to paper describing measurements in NASA's SPEED Testbed
    2. Machines, drives, supplies, load banks, connected over long leads
    3. Specifics of the impedance measurement process & testing configurations
    4. Measured impedance data for the loads and sources
2. Load impedance model of the NEAT power system
3. Stability analysis of the NEAT EPS
4. Future work discussed (wider frequency, higher power)

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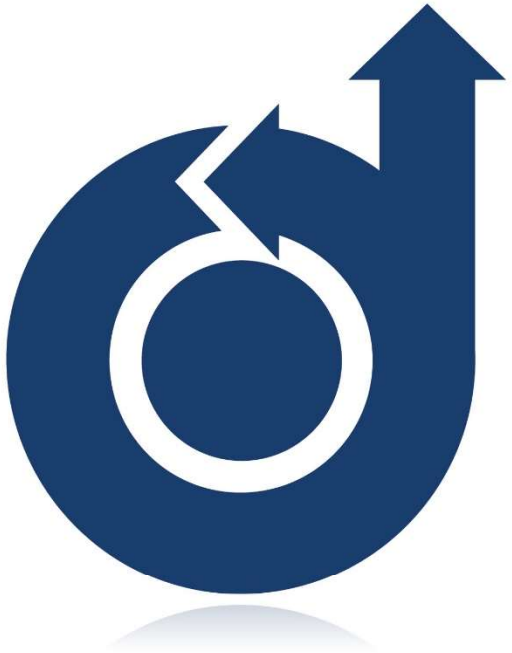

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