

GRID EMT

SIMULATION INITIATIVE

EMT Models: From Development to Application

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U.S. DEPARTMENT
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Motivation

The increasing penetration of power-electronic loads requires a better understanding of their dynamic interaction with the grid. EMT models provide the fidelity necessary. This presentation illustrates several applications of EMT modeling for modern electronic loads:

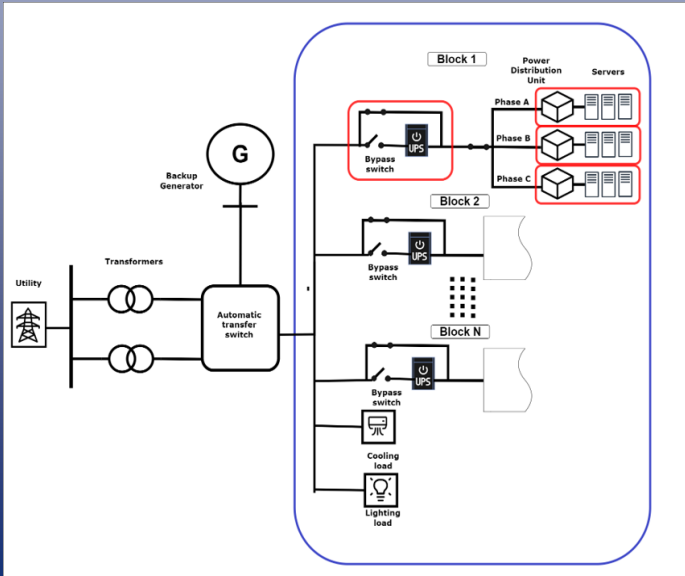
- Understanding response to grid disturbances and voltage sags.
- Assessing the validity of existing planning models.
- Developing simplified representations suitable for large-scale stability studies.
- Ensuring design requirements meet performance needs
- Investigating control interactions and oscillatory behavior



EPRI Large Load EMT models

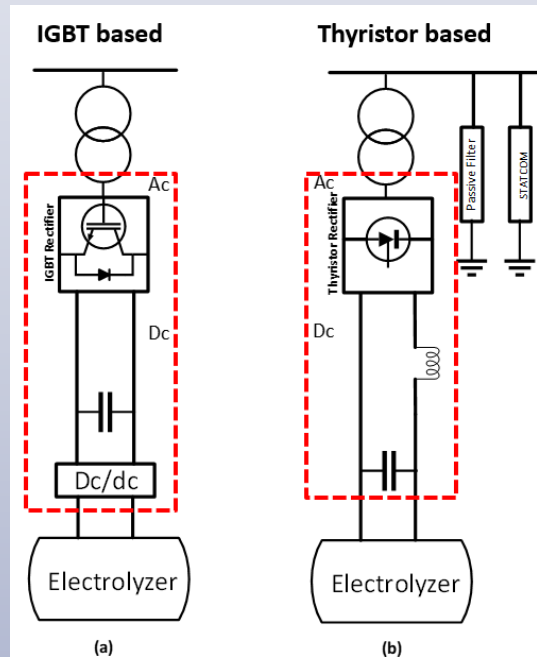
Data Centers

- 3 Φ UPS models
- 1 Φ PSU mode
- VFD



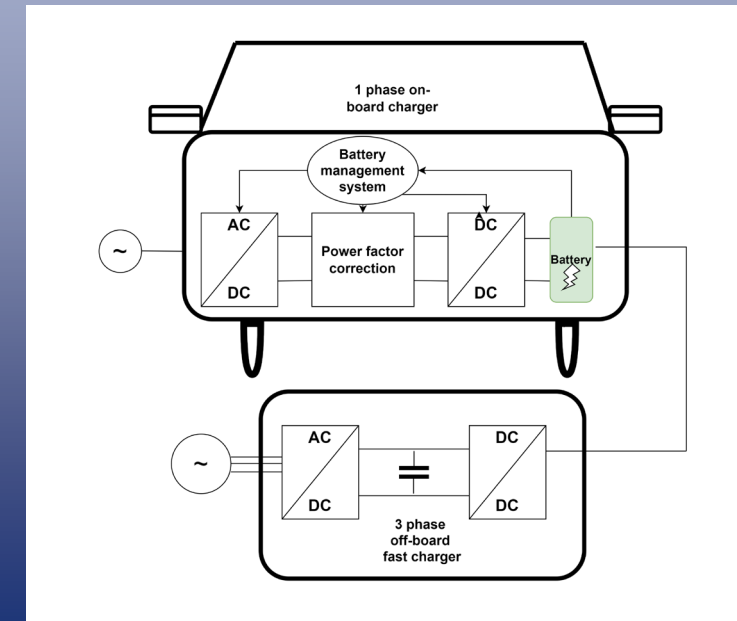
Hydrogen Electrolyzer

- IGBT based rectifier
- Thyristor based rectifier



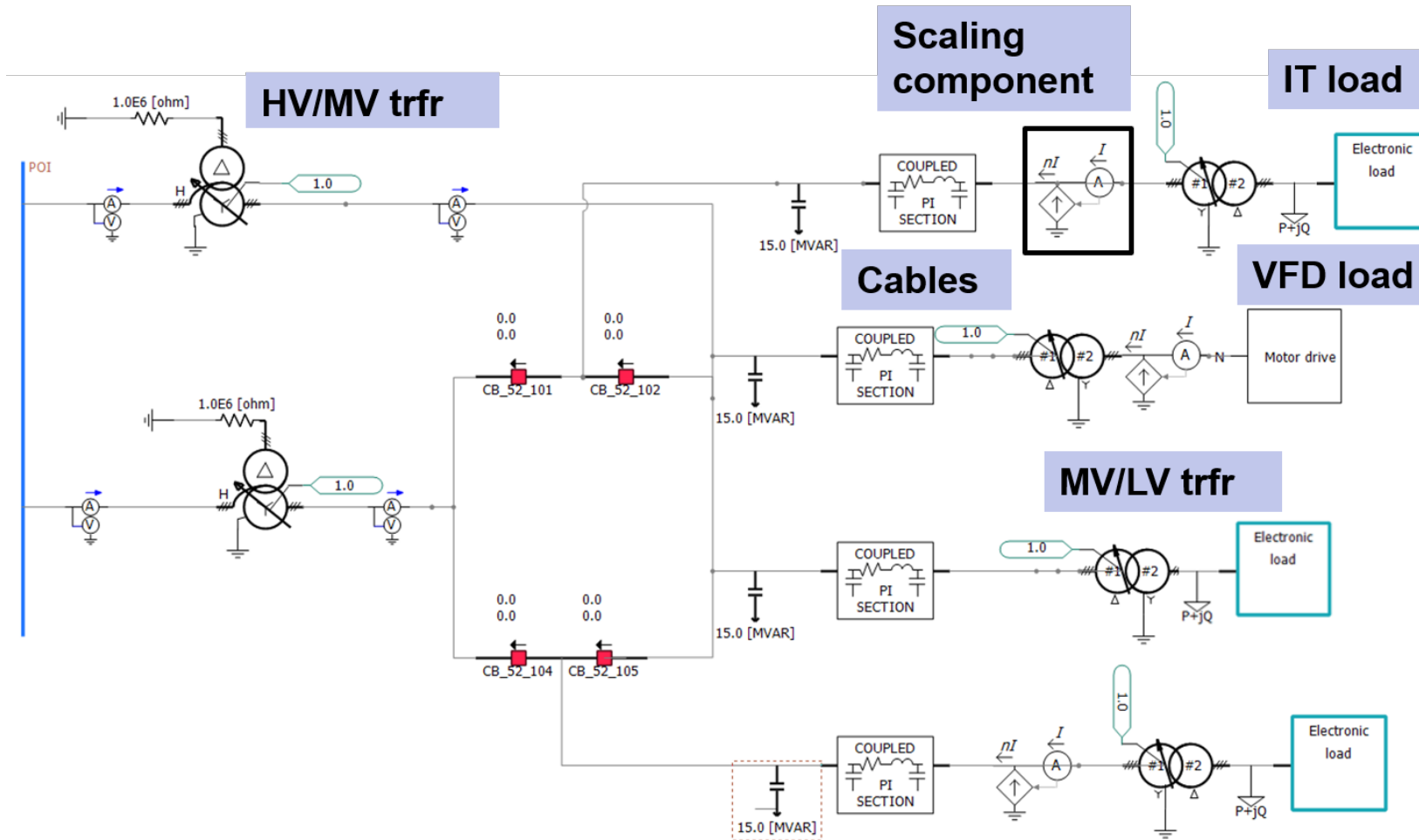
EV chargers

- 1 Φ Chargers
- 3 Φ Chargers



Primary use case has been screening and scoping studies, and verification of phasor modeling

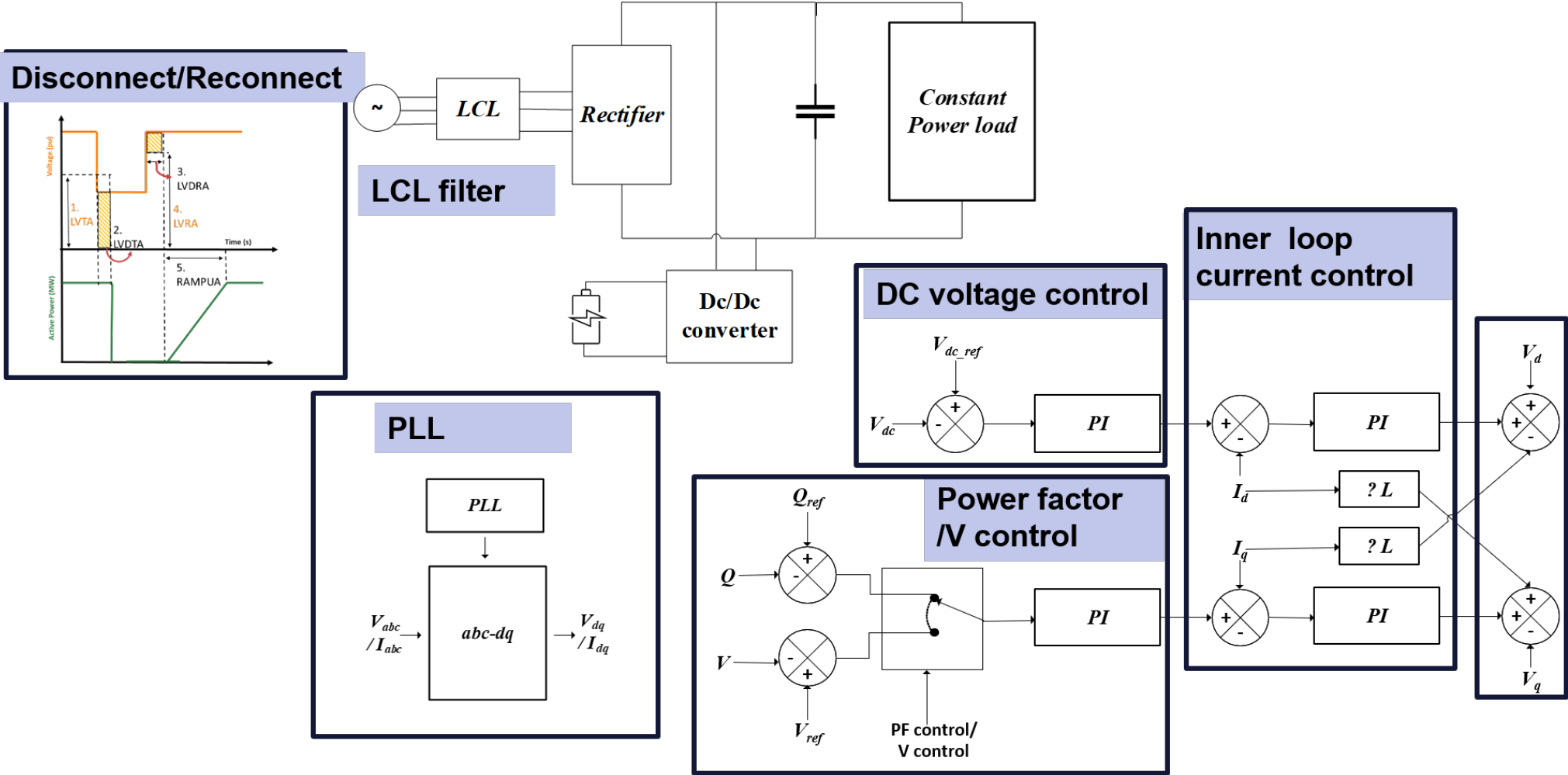
EMT model of data center



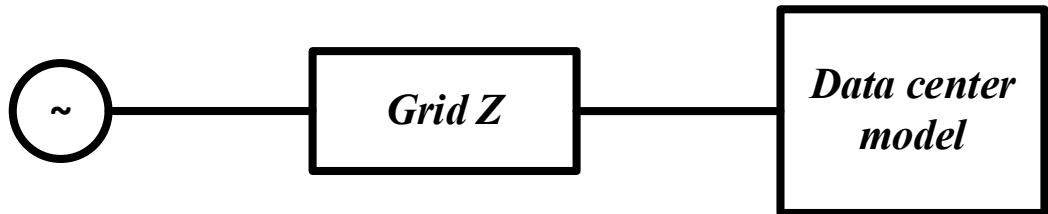
Customizable settings

- **MVA ratings (IT load, motor, VFD components, Static load)**
- **Control gains of the rectifier**
- **Cable parameters**
- **HV/MV voltage levels**
- **Scaling components to aggregate the response of multiple components**
- **Shunt capacitors**

Key control loops (UPS rectifier)



Simulation results



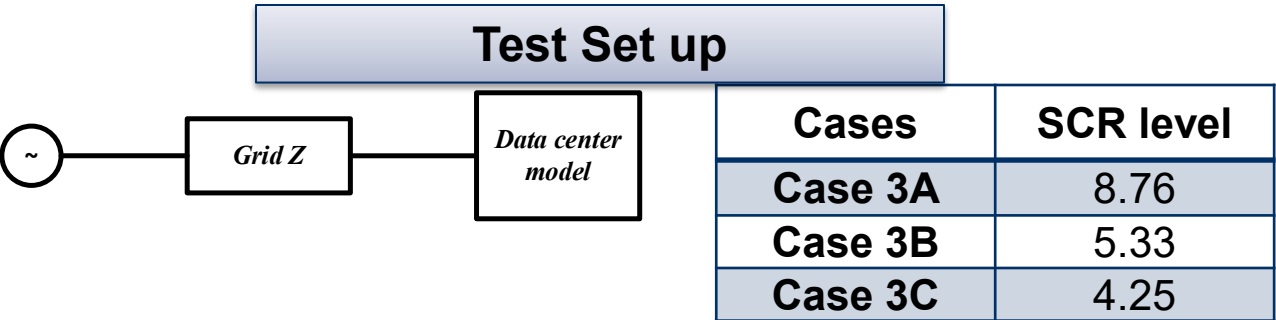
The robustness of the EMT model was tested using the single bus test system for the following conditions.

Test conducted	Performance
Voltage drop to 0.9 pu	Stable
Voltage drop to 0.7 pu	Stable
Voltage drop to 0.2 pu	Stable
3 Phase fault	Stable
1 phase fault	Stable
Low SCR condition	Stable
Phase jump of 45 degrees	Stable
Frequency change of 1 Hz	Stable

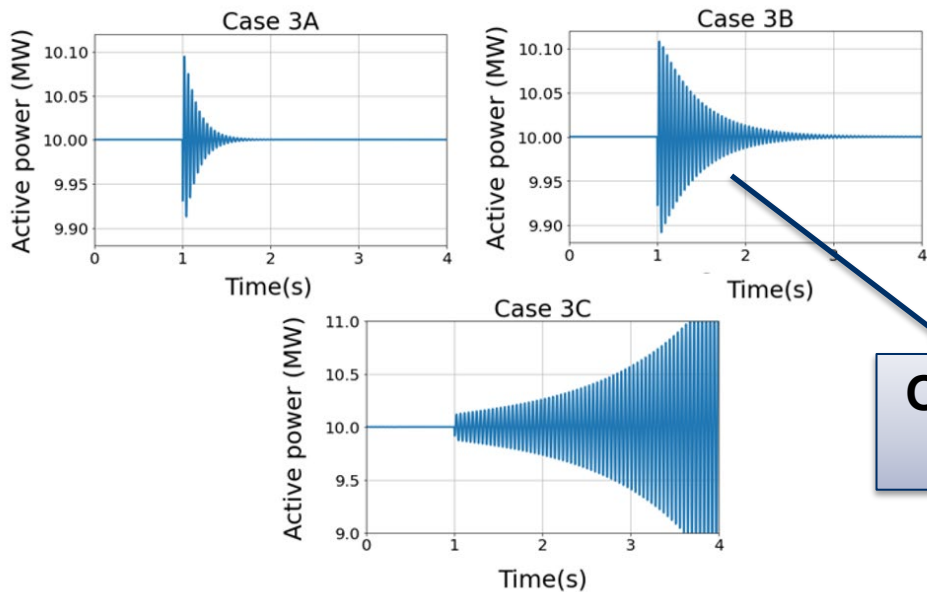
Parameter list

Basic	
MVA	11
Pref	10
Qref	0
Vref	1
C_dc	500000
VLL	0.48
Vdcb	800
Frequency	60
Battery	
Vbatt	1
Kp_batt_I	6
Ki_batt_I	9000
Kp_batt_V	11
Ki_batt_V	1500
Protection	
V_cease	0.2
T_cease	0.01
Ramp rate	2
V_reconnect	0.95
T_reconnect	0.01
T_delay	0.01
Rectifier	
Imax	1.1
Kp_dc	0.4
Ki_dc	5
Kp_Q	1
Ki_Q	10
Kp_I	0.5
Ki_I	20
Kp_V	0.6
Ki_V	0.25
Q control	Q control

Impact of SCR on data center response



Time Domain Simulation

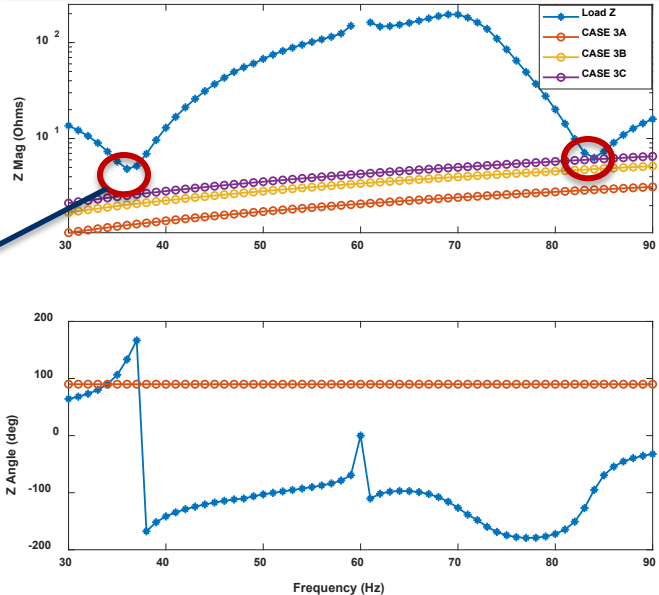


Oscillations at 23 Hz

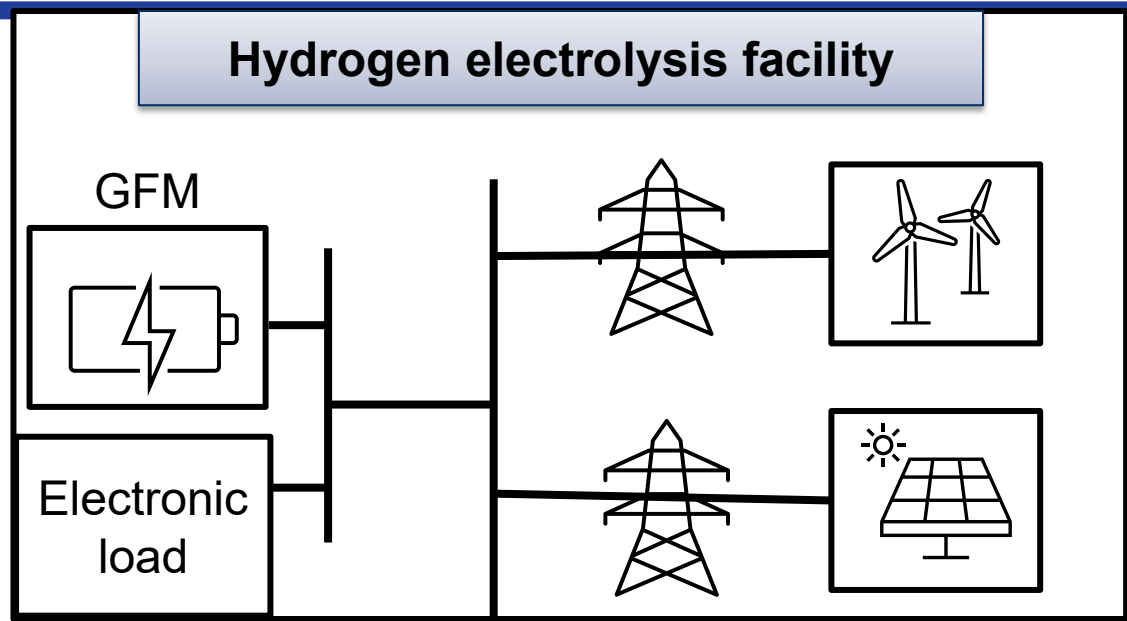
Eigen Value Analysis

Cases	Natural frequency	Damping ratio
Case 3A	23.14	5.5%
Case 3B	22.41	2.2%
Case 3C	21.71	-0.01%

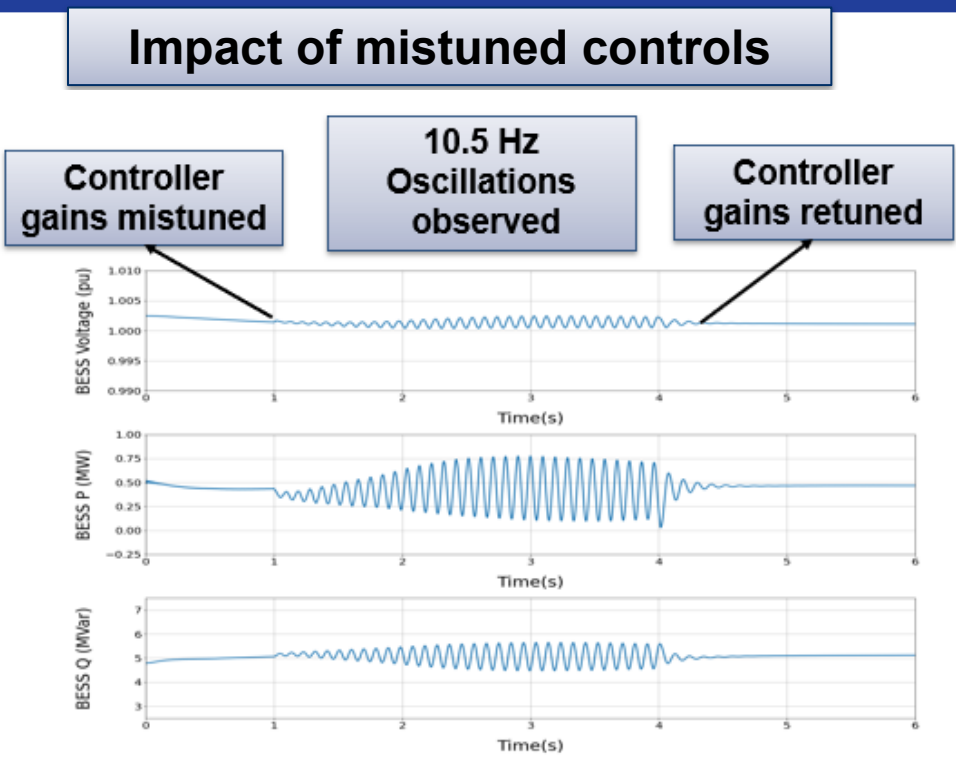
Frequency domain Analysis



System Details



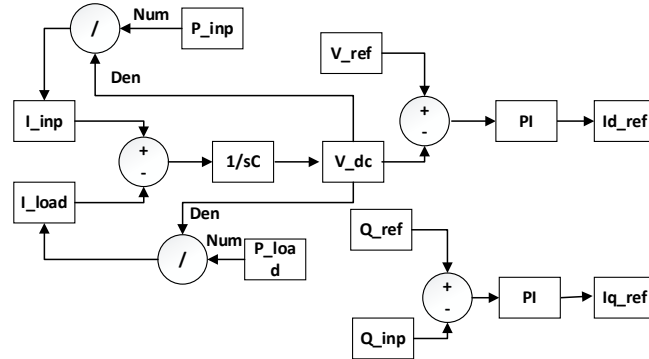
Name	Specifications
Generation	0.5X PV 0.5X Wind
EMT models used	Average models
Size of GFM	0.2X rated MVA
Size of load	XMVA



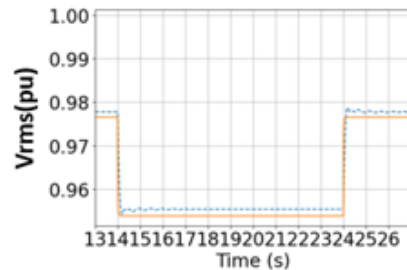
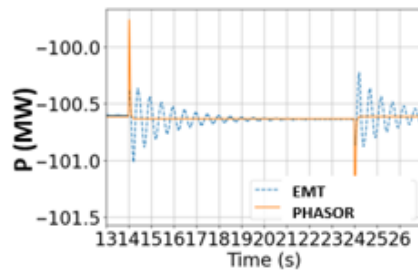
Identify control interactions and hidden instabilities
Validate retuned settings before field implementation

Development and Validation of Phasor Models

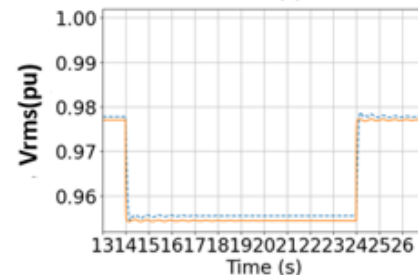
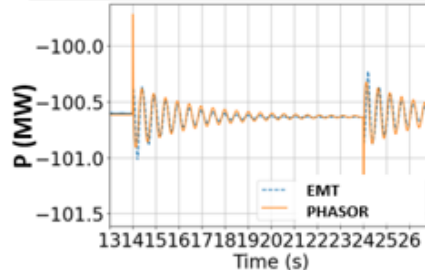
Improved Phasor Model



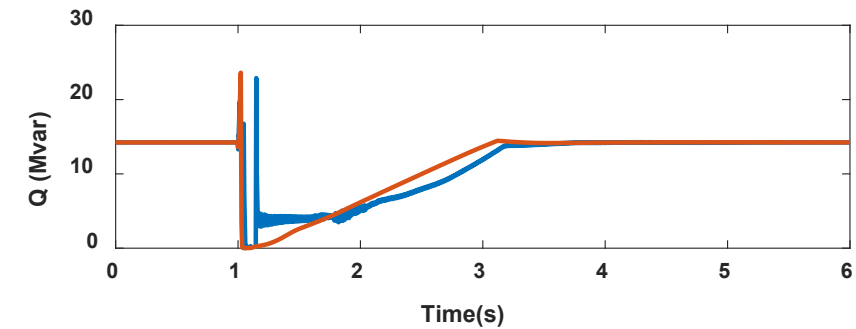
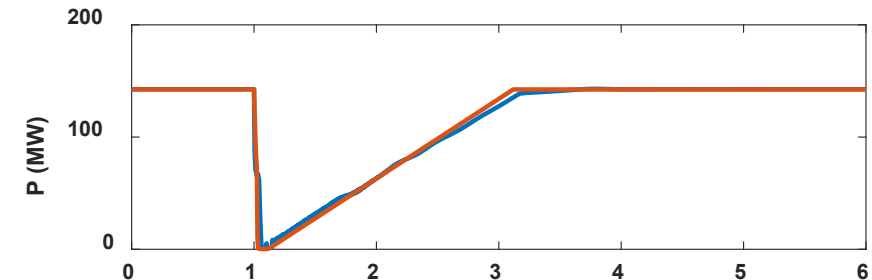
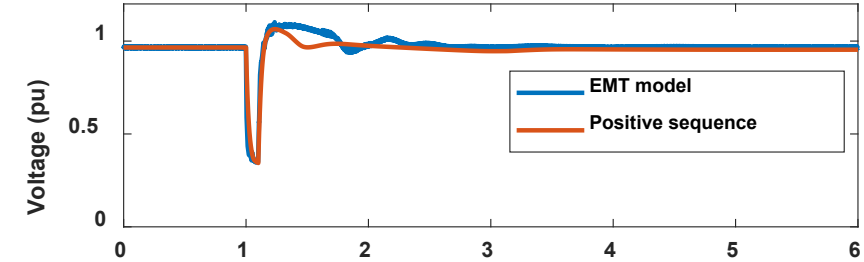
Without DC bus dynamics modeled



With DC bus dynamics modeled



Deep sag response



Conclusions/Next Steps

- EMT models can be used for several complementary purposes:
 - Evaluating disturbance response and ride-through behavior.
 - Verifying the adequacy of existing planning models and developing improved simplified models for bulk power system studies.
 - Diagnosing control interactions and oscillatory phenomena.
- Next Steps
 - Improve model parameterization using field and manufacturer data.
 - Apply validated simplified models in larger-scale transmission planning and stability assessments.





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