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WIND ENERGY TECHNOLOGIES OFFICE

Update on Grid-Forming Hybrid Control Inverter model and Plant Controller Model—REGFM_C1 and REPCGFM_C1

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WECC MVS Annual Meeting - May 2025

WECC-Approved Standard Library GFM Models

- REGFM_A1 and REGFM_B1 have already been approved and released in commercial tools
- The model specs of REGFM_C1 and REPCGFM_C1 have been approved by WECC on Jan. 30th, and software vendors are implementing the models
- The model specs have been updated to reflect a few minor changes recommended by software vendors
- Tesla Energy completed the comparison between REGFM_C1/REPCGFM_C1 and their black-box PSCAD model

WECC-Approved Standard Library GFM Models

REGFM_A1	REGFM_B1	REGFM_C1 and REPCGFM_C1 (*Model specs approved*)
GFM Droop Control	GFM Virtual Synchronous Machine	GFM Hybrid Control

Area II - Technical Achievements

REGFM_C1 and REPCGFM_C1 Contributors

Standard Library Grid-Forming Hybrid Control Inverter-based Resource Model Specification (REGFM_C1)

Wei Du[1], Sai Gopal Vennelaganti[2], Deepak Ramasubramanian[3], Jinho Kim[1], Udoka Nwaneto[1], Quan Nguyen[1], Ali Mohammadpour[2], Sarah Walinga[2], Lilan Karunaratne[2], Mostafa Mahfouz[2], Mohammed Nassar[2], Sushrut Thakar[3], Chengwen Zhang[3], Sheik Mohammad Mohiuddin[1], James Weber[4], Mengxi Chen[5], Jayapalan Senthil[6], James Feltes[6], Pouyan Pourbeik[7], Fred Howell[8], Jeff Bloemink[8], Song Wang[9], Doug Tucker[10], Songzhe Zhu[11], Juan Sanchez[12]

1 Pacific Northwest National Laboratory
2 Tesla Energy
3 Electric Power Research Institute
4 PowerWorld
5 GE Vernova
6 Siemens
7 Power and Energy, Analysis, Consulting and Education (PEACE®) PLLC
8 PowerTech Labs
9 Portland General Electric
10 Western Electricity Coordinating Council
11 GridBright, a Qualus Company
12 GE Vernova (retired)

Standard Library Plant Controller Model Specification for a Grid-Forming Hybrid Control Inverter-based Resource (REPCGFM_C1)

Wei Du[1], Sai Gopal Vennelaganti[2], Deepak Ramasubramanian[3], Jinho Kim[1], Udoka Nwaneto[1], Quan Nguyen[1], Ali Mohammadpour[2], Sarah Walinga[2], Lilan Karunaratne[2], Mostafa Mahfouz[2], Mohammed Nassar[2], Sushrut Thakar[3], Chengwen Zhang[3], Sheik Mohammad Mohiuddin[1], James Weber[4], Mengxi Chen[5], Jayapalan Senthil[6], James Feltes[6], Pouyan Pourbeik[7], Fred Howell[8], Jeff Bloemink[8], Song Wang[9], Doug Tucker[10], Songzhe Zhu[11], Juan Sanchez[12]

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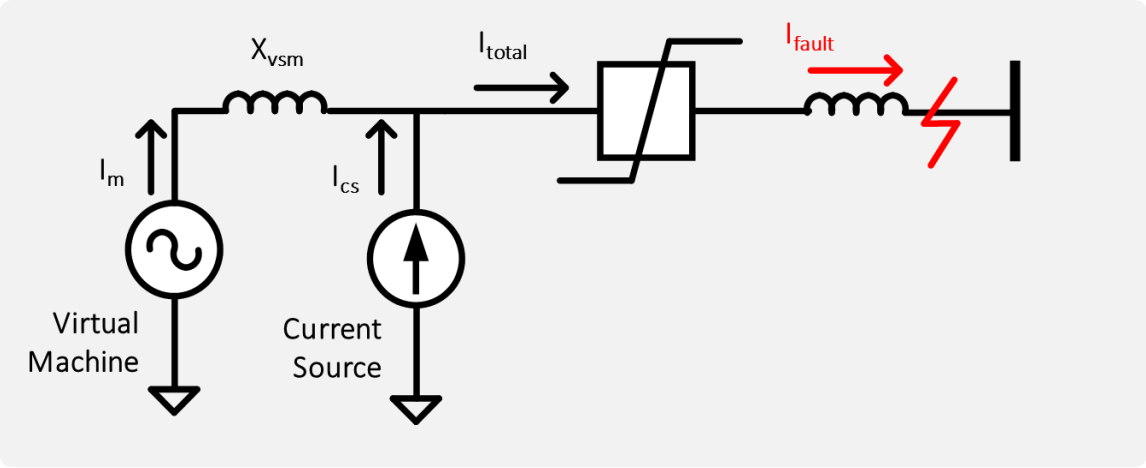
REGFM_C1 and REPCGFM_C1 Principle

- The GFM hybrid control implements both the GFM control and GFL control simultaneously inside one inverter. Both controls work in parallel, and they do not switch between the GFM and GFL controls
- The steady state P and Q of the GFM branch is regulated to be 0, and the GFL branch provides the steady state response



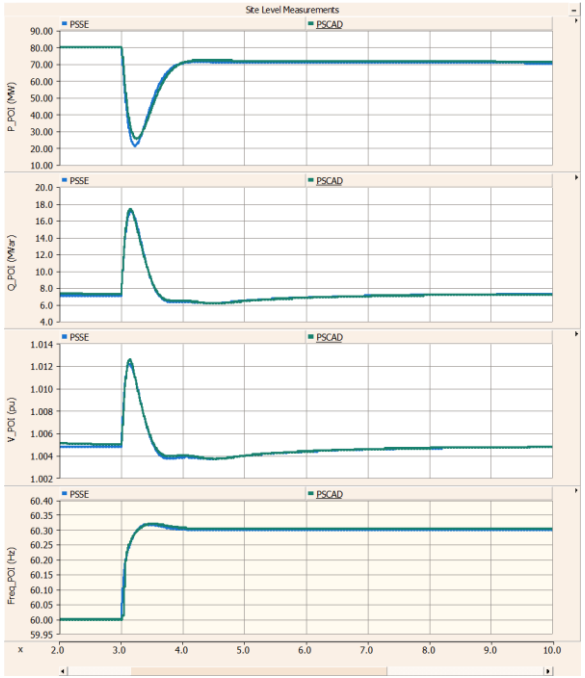
Source: Tesla PESGM 2024 Presentation

REGFM_C1 and REPCGFM_C1 Model Validation

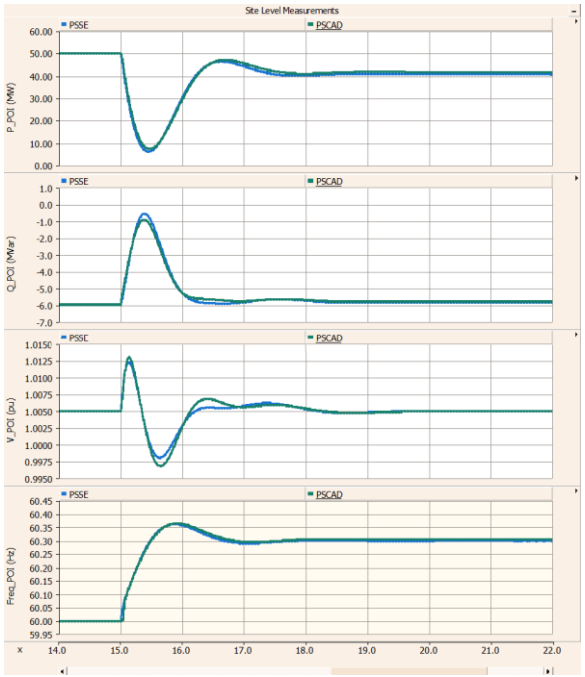
- Grid frequence step up

Blue Line: REGFM_C1 + REPCGFM_C1 PSS/E Model
Green Line: Tesla's black-box PSCAD Model

High SCR and X/R
SCR = 10, X/R = 10



Low SCR and X/R
SCR = 1.5, X/R = 3



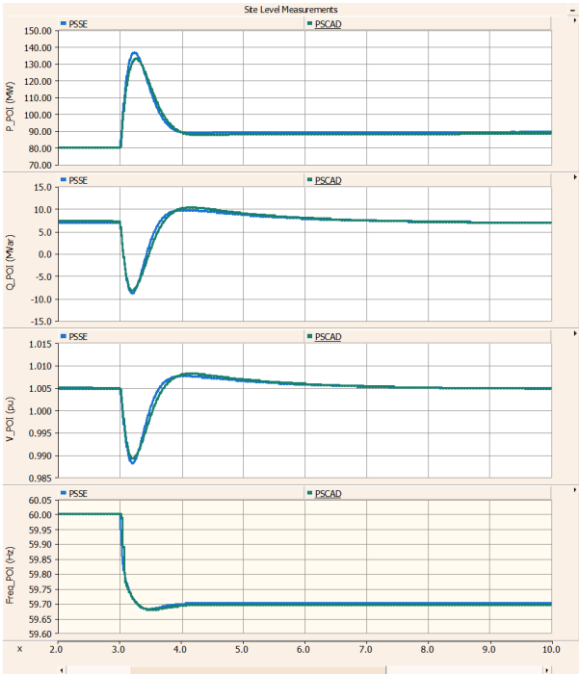
Simulation credit: Tesla Energy

REGFM_C1 and REPCGFM_C1 Model Validation

- Grid frequence step down

Blue Line: REGFM_C1 + REPCGFM_C1 PSS/E Model
Green Line: Tesla's black-box PSCAD Model

High SCR and X/R
SCR = 10, X/R = 10



Low SCR and X/R
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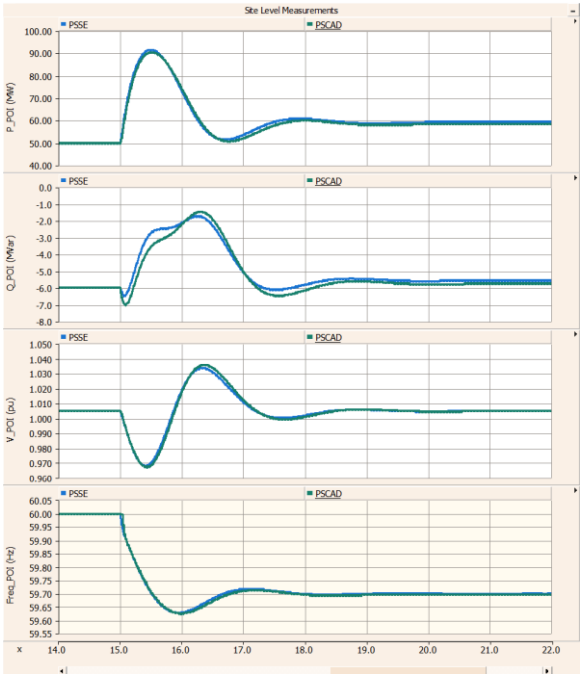


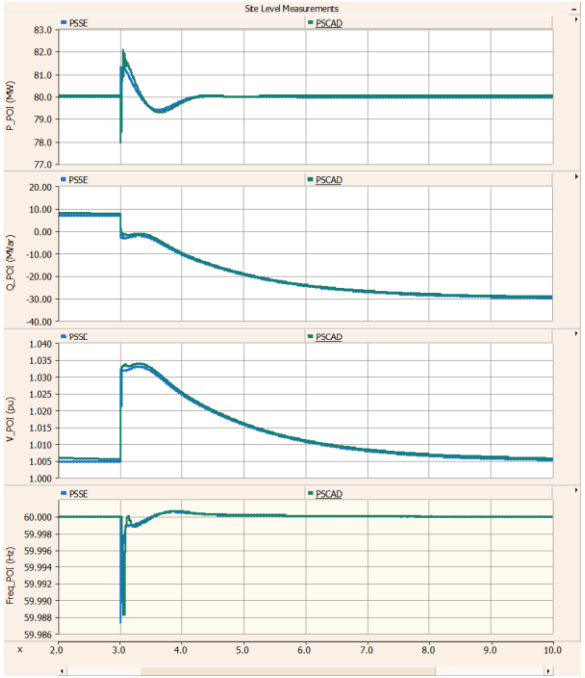
Simulation credit: Tesla Energy

REGFM_C1 and REPCGFM_C1 Model Validation

- Grid voltage step up

Blue Line: REGFM_C1 + REPCGFM_C1 PSS/E Model
Green Line: Tesla's black-box PSCAD Model

High SCR and X/R
SCR = 10, X/R = 10



Low SCR and X/R
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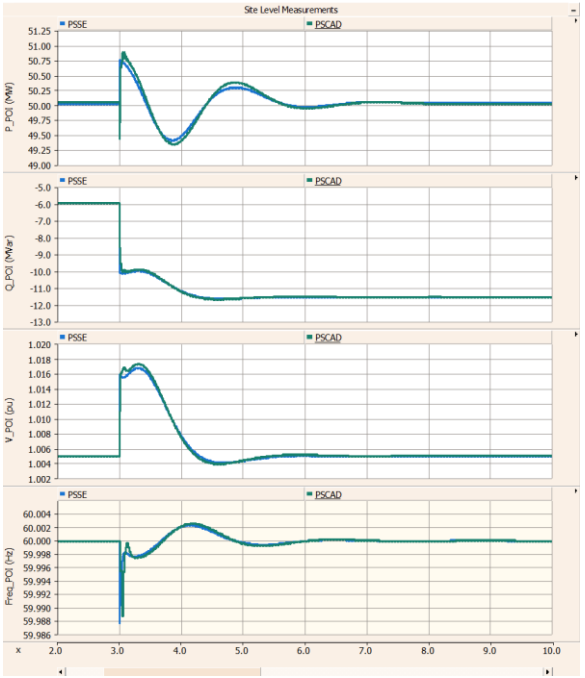

Simulation credit: Tesla Energy

REGFM_C1 and REPCGFM_C1 Model Validation

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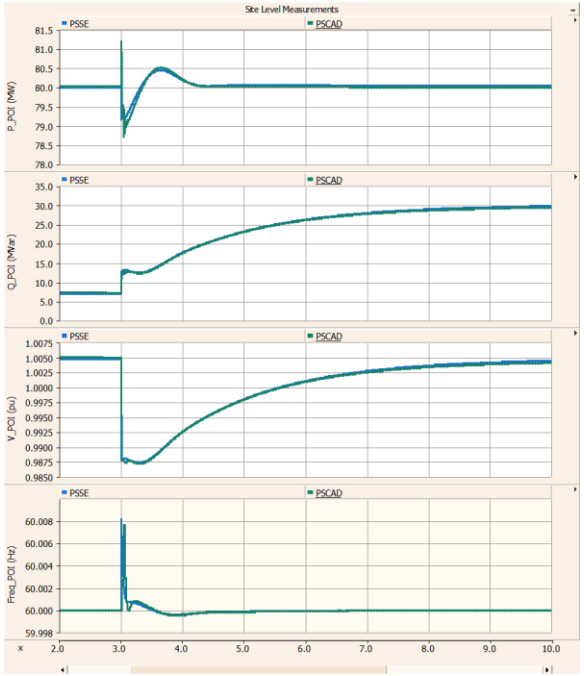

Low SCR and X/R
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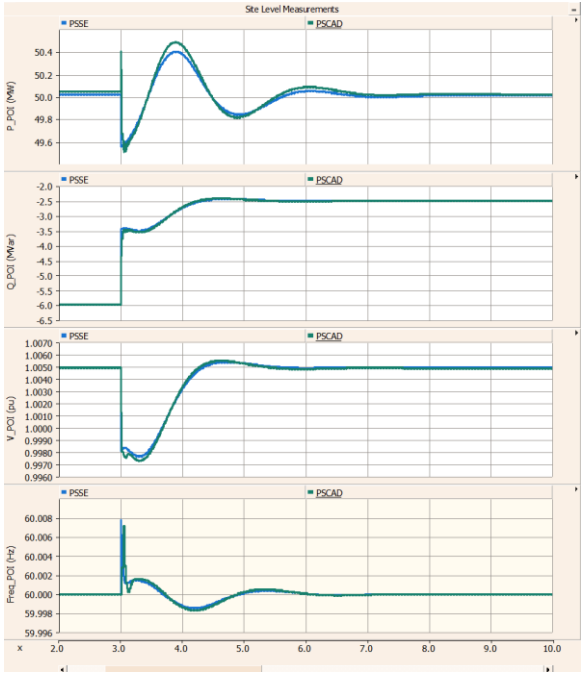


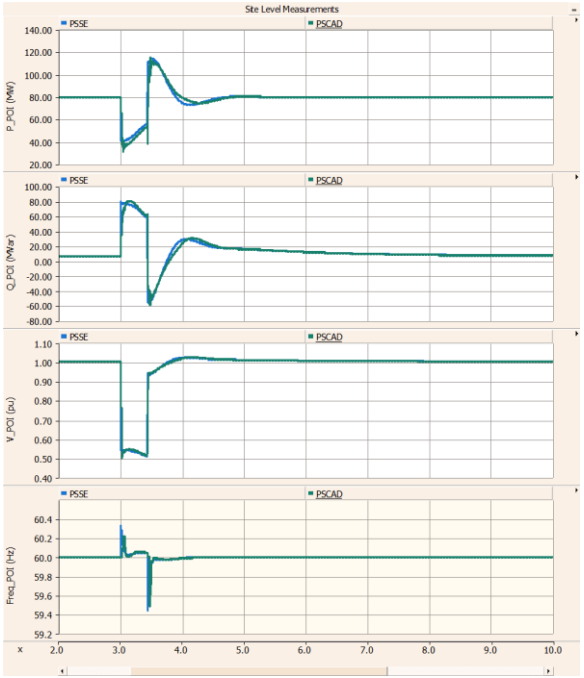
Simulation credit: Tesla Energy

REGFM_C1 and REPCGFM_C1 Model Validation

- High impedance fault at POI

Blue Line: REGFM_C1 + REPCGFM_C1 PSS/E Model
Green Line: Tesla's black-box PSCAD Model

High SCR and X/R
SCR = 10, X/R = 10



Low SCR and X/R
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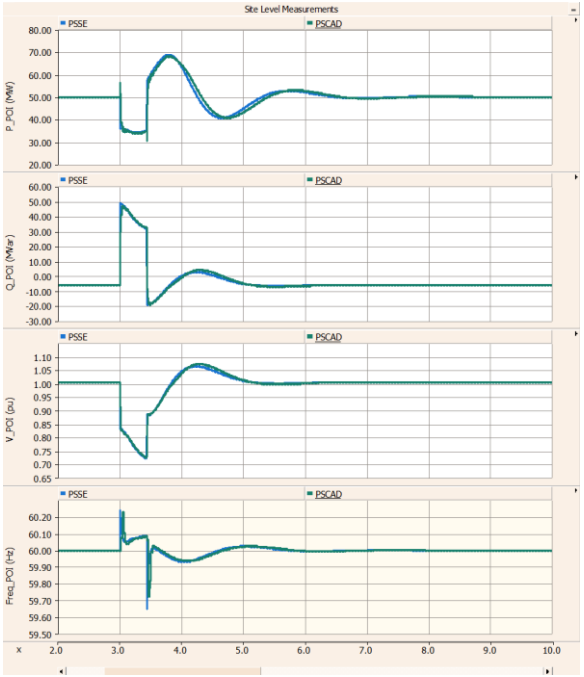

Simulation credit: Tesla Energy

REGFM_C1 and REPCGFM_C1 Model Validation

- Bolted Fault at POI

Blue Line: REGFM_C1 + REPCGFM_C1 PSS/E Model
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High SCR and X/R
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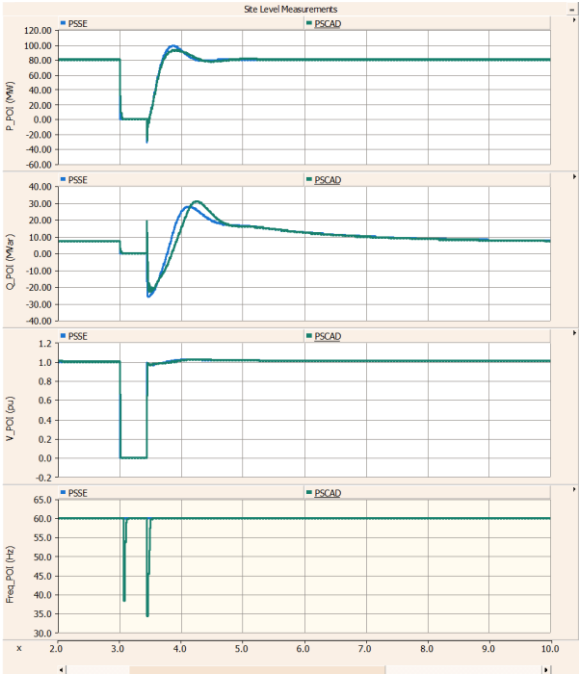

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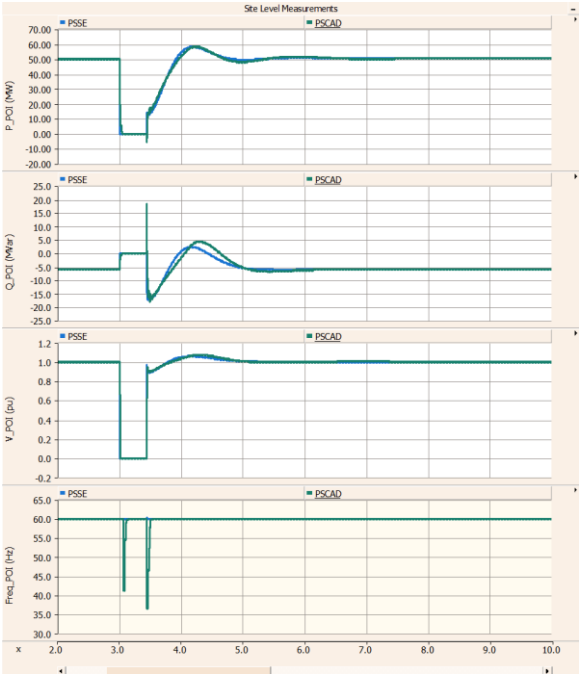

Simulation credit: Tesla Energy

Conclusion

- Updates of REGFM_C1 and REPCGFM_C1 model specs have been presented
- Validation of REGFM_C1 and REPCGFM_C1 against an OEM black-box EMT model has been presented
- ***GFMs can work in both strong and weak systems without the need to tune parameters***
- ***For GFMs, positive-sequence models are accurate enough to capture their dynamics for transient stability studies***

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THANK YOU