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DEVELOPMENT OF EMT MODELS FOR IBRS IN TRANSMISSION NETWORKS: NYPA EXPERIENCES

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NEW YORK POWER AUTHORITY

2023 North American RTDS TECHNOLOGIES INC. APPLICATIONS & TECHNOLOGY CONFERENCE

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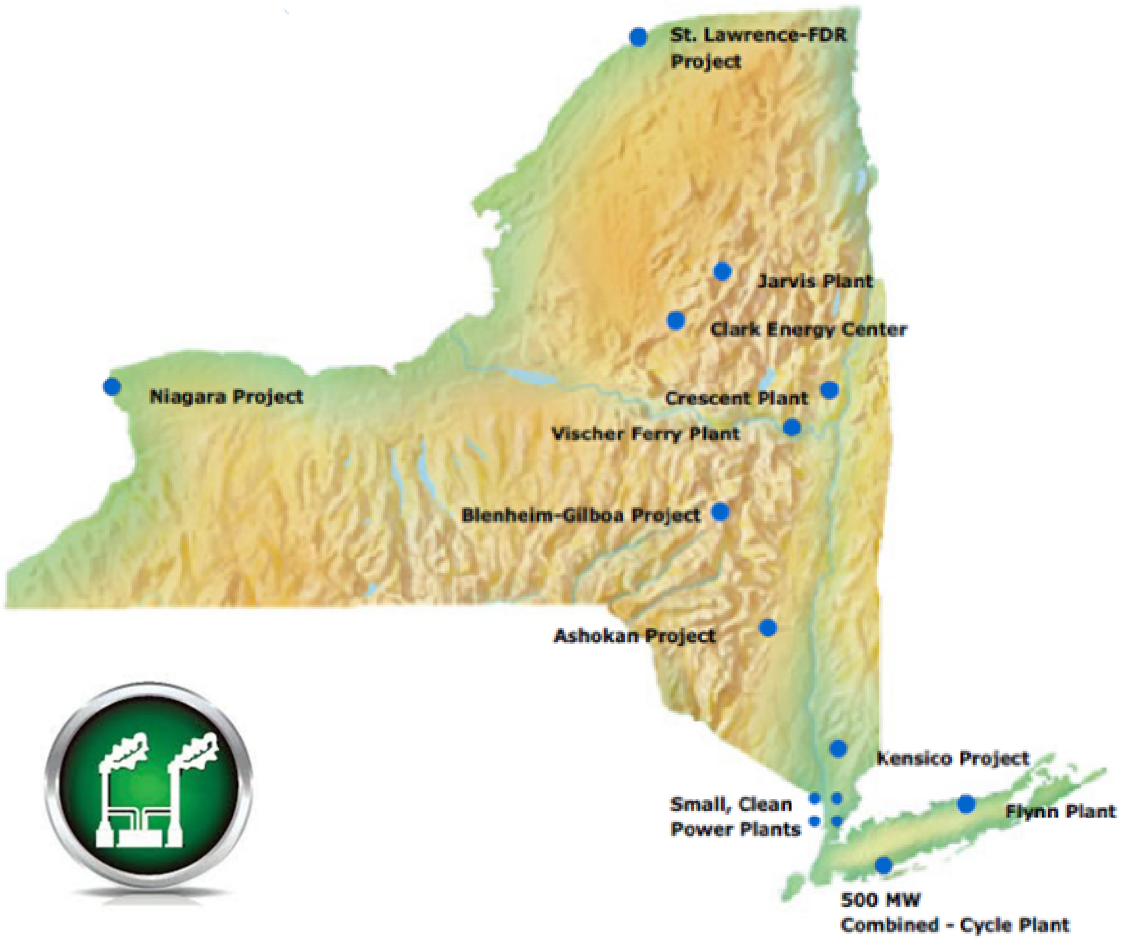
RTDS Technologies AMETEK

NYPA OVERVIEW - GENERATION ASSETS



16 hydro and natural gas generation plants (~6GW, 80% hydro and 20% gas):

- Niagara Power Project **~2,675 MW**
- St. Lawrence Power Project **~800 MW**
- Blenheim-Gilboa **~1,160 MW**
- Flynn Power Plant **~167 MW**
- Astoria CC Plant **~500 MW**
- Small Hydro Plants **~83 MW**
- Small Clean Power Plants **~461 MW**

NYPA OVERVIEW - TRANSMISSION ASSETS

1400 circuit miles:

- 765 kV **~155 circuit miles**
- 345 kV **~928 circuit miles**
- 230 kV **~338 circuit miles**
- 115 kV **~35 circuit miles**
- Substations **21 substation**
- Portion of Bulk NYS Grid

~13% (>115kV)
~34% (>230kV)

NYPA's AGILe

Enabling an Affordable, Reliable, Low-Carbon Future

New York's Low- to No-Carbon Future: State Targets

2025

6,000 MW of solar

185 trillion BTU energy use reduction

2030

70% renewables

6,000 MW of energy storage

2035

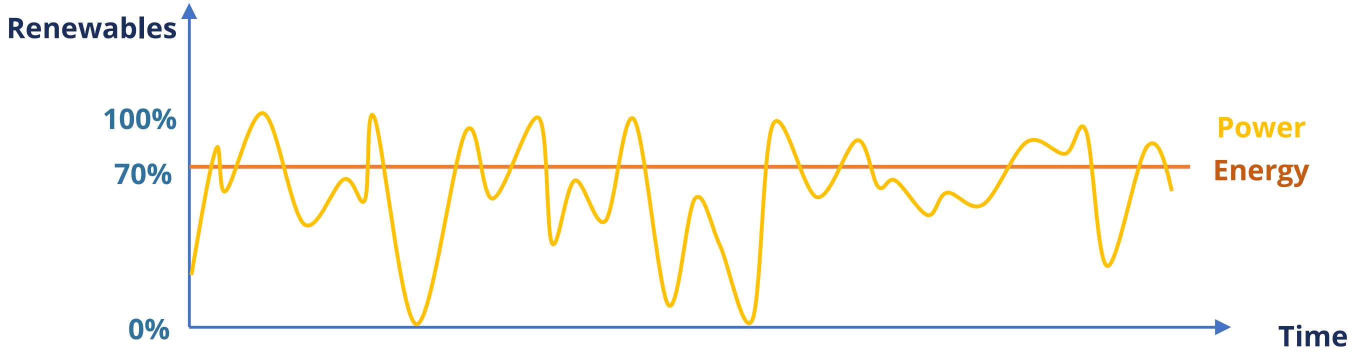
9,000 MW of offshore wind

2040

100% emission-free electricity

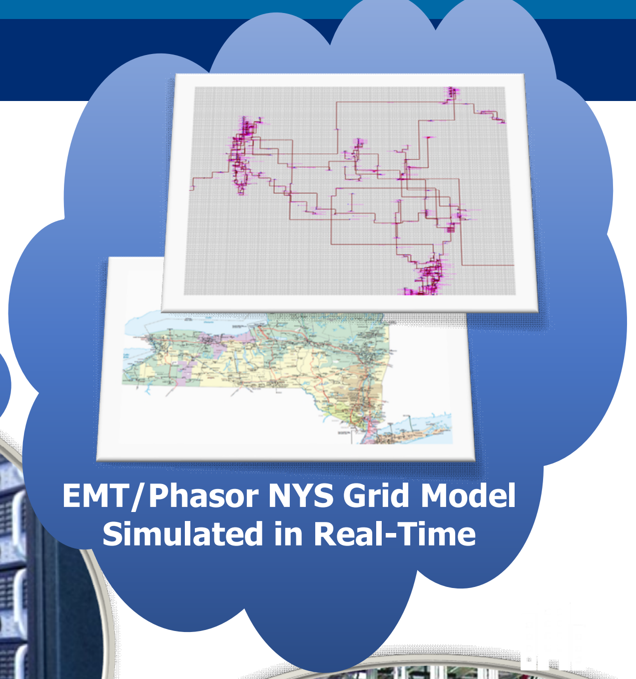
2045

100% economy-wide net-zero carbon emissions



NYPA's AGILe

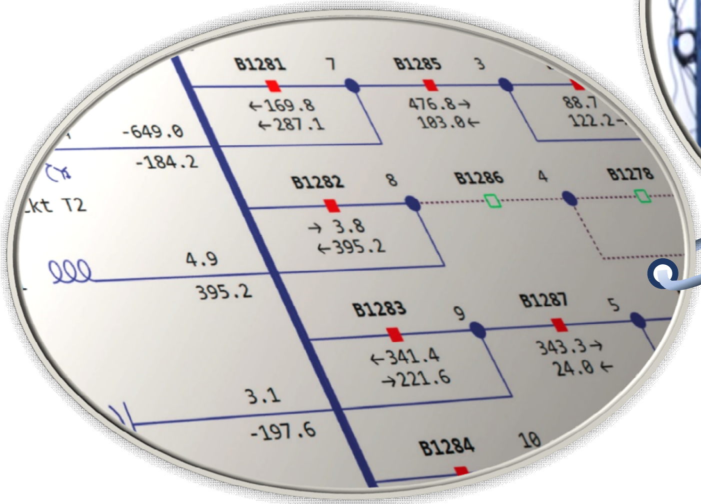
Enabling an Affordable, Reliable, Low-Carbon Future



Realistic Testing

AGILe

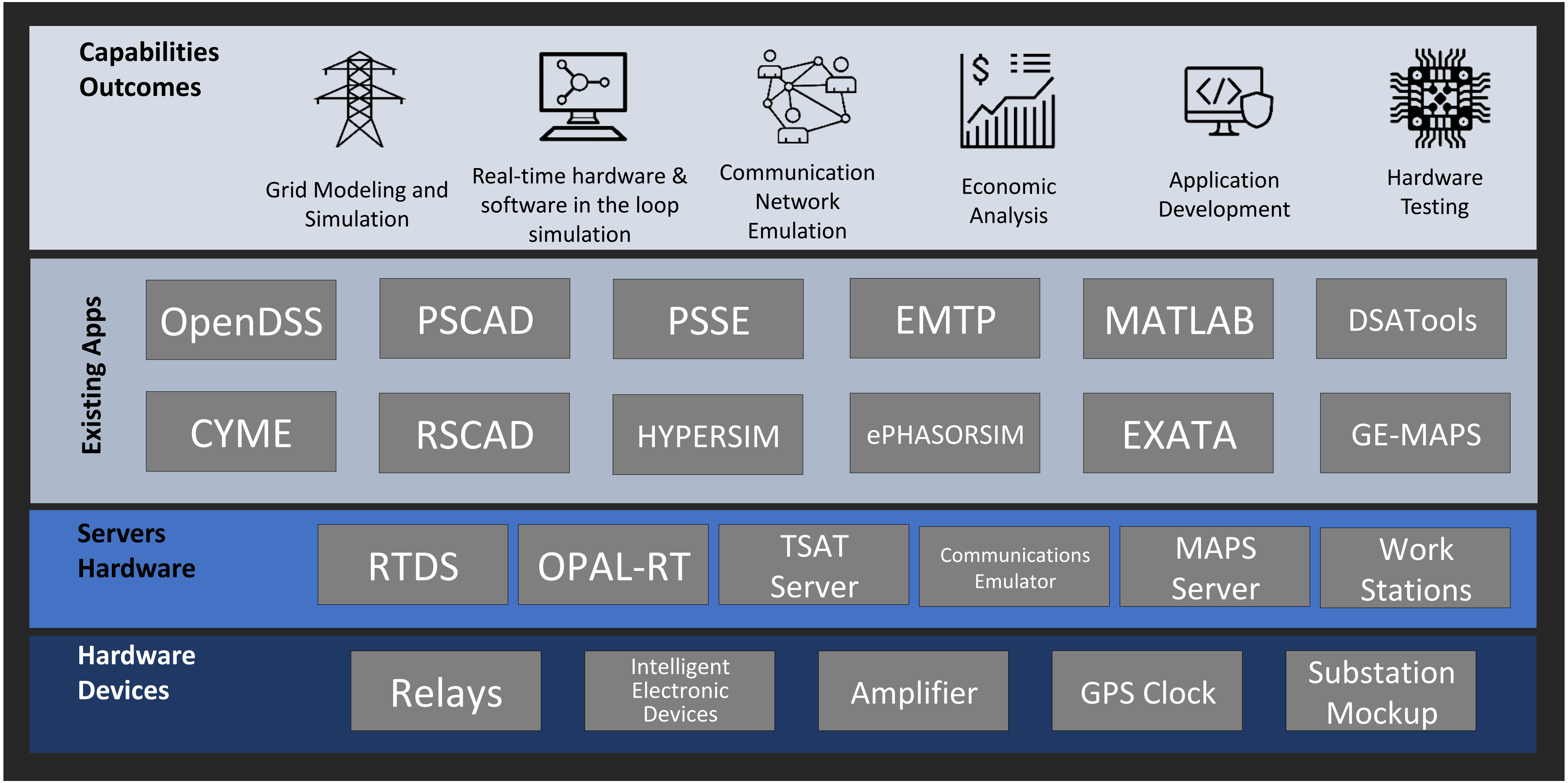
Model Validation



Applied R&D

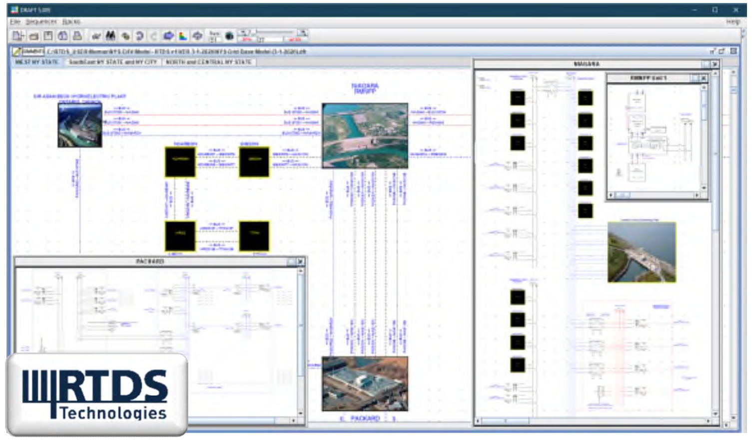
New & Off-The-Shelf Technologies

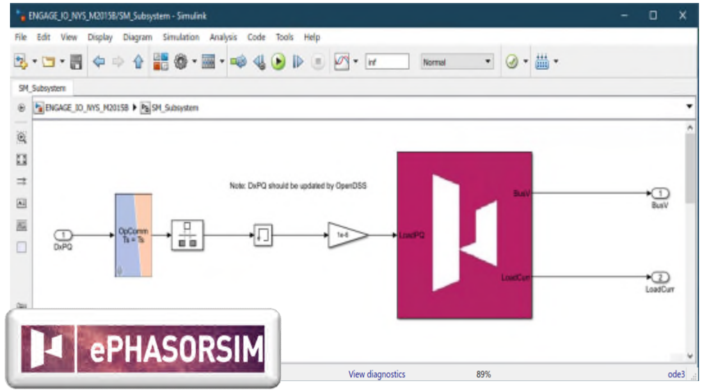
Field

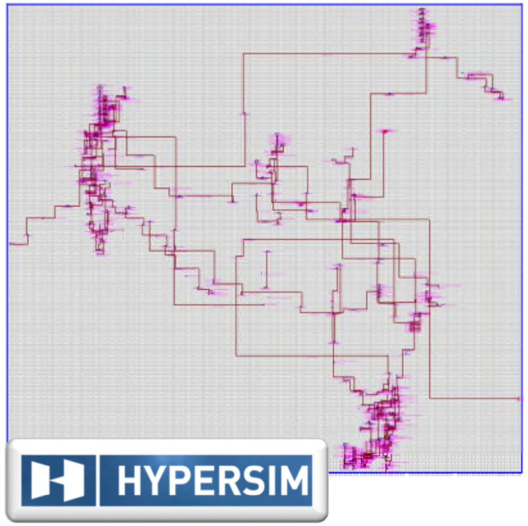

Capabilities Outcomes
Grid Modeling and Simulation
Real-time hardware & software in the loop simulation
Communication Network Emulation
Economic Analysis
Application Development
Hardware Testing
Existing Apps
OpenDSS
PSCAD
PSSE
EMTP
MATLAB
DSATools
CYME
RSCAD
HYPERSIM
ePHASORSIM
EXATA
GE-MAPS
Servers Hardware
RTDS
OPAL-RT
TSAT Server
Communications Emulator
MAPS Server
Work Stations
Hardware Devices
Relays
Intelligent Electronic Devices
Amplifier
GPS Clock
Substation Mockup

NEW YORK STATE GRID SUITE OF MODELS

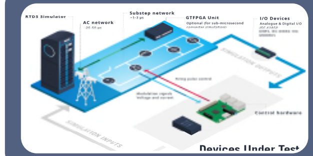
- **NYS Transmission Grid Model (34.5-765kV)** :
  - EMT and Phasor Models (~5500 bus)
  - Include FACTS and Wind plant models
  - Can be used in hybrid EMT-Phasor simulation
- **NYS Distribution Grid Models:**
  - Selected distribution feeders (up to 20,000 buses)
- **NYS Communication Network Models:**
  - Substation level communication models







AGILe Use Cases and Applications

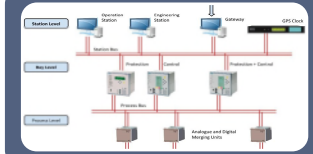


Equipment Configuration and Testing

- Test equipment in realistic field conditions
- Validate the performance of novel technologies

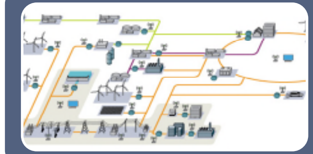
Novel System Protection Schemes

- Validate protective relaying behavior and settings
- De-risk novel protection schemes



Digital Substation and IEC 61850

- Create replicas of substation intelligent electronic devices
- Perform closed-loop testing using communication protocols



Distribution Automation and DERMS

- Simulate the performance of distribution automation system
- Integrate distributed energy resources and storage

Cyber Security

- Create testbeds used for tabletop exercises
- Evaluate and test intrusion detection and mitigation schemes

DEVELOPMENT OF EMT MODELS OF TYPE 4 WIND TURBINE GENERATORS

- Joint research project by Clarkson University and NYPA, funded by NYSERDA.

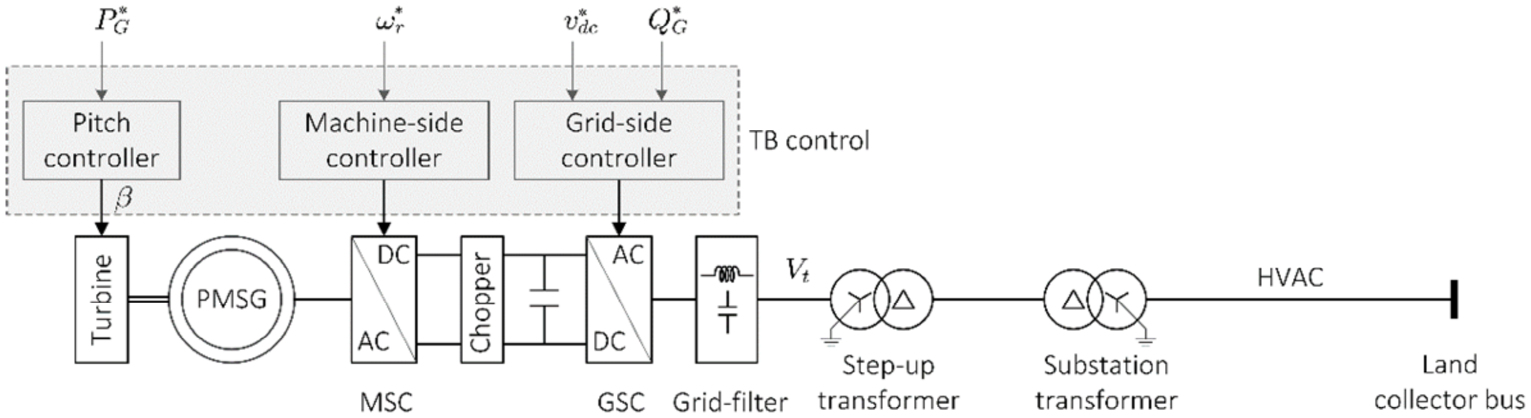
Smart Power Systems and Controls Lab

Advanced Grid Innovation Laboratory for Energy

- Develop models of wind turbines and wind power plants.
- Develop HIL-interface to perform real-time co-simulation between RTDS and Opal-RT.
- Study impacts of 9GW offshore wind on NYS power grid.

- EMT models of NYS power grid in both RTDS and Opal-RT systems.
- Real-time simulators:
  - RTDS (60 cores): 6 NovaCor Chassis
  - Opal-RT (40 cores)
- Perform impact studies.

WTG CONTROL SYSTEM

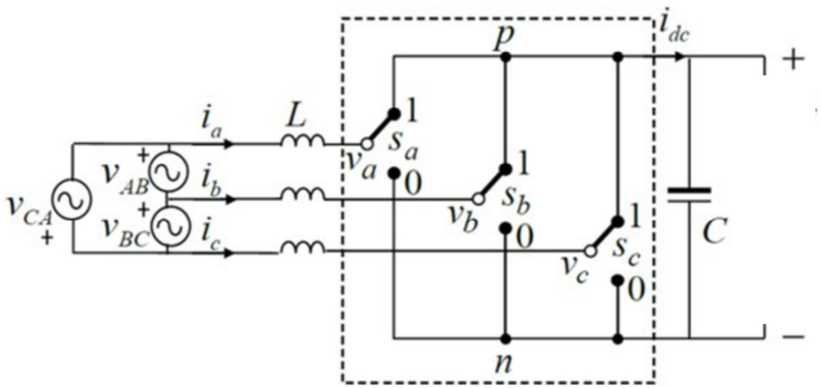


Configuration of wind turbine generator

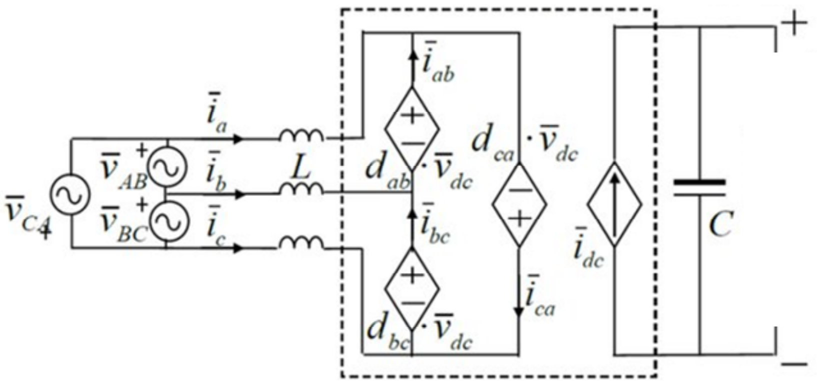
- Control functions:
  - Power curtailment
  - MPPT
- Protection functions
- Advanced functions
  - Low or high voltage ride through
  - Negative sequence injection

CONVERTER MODELS

Detailed Switching Model (DSW)



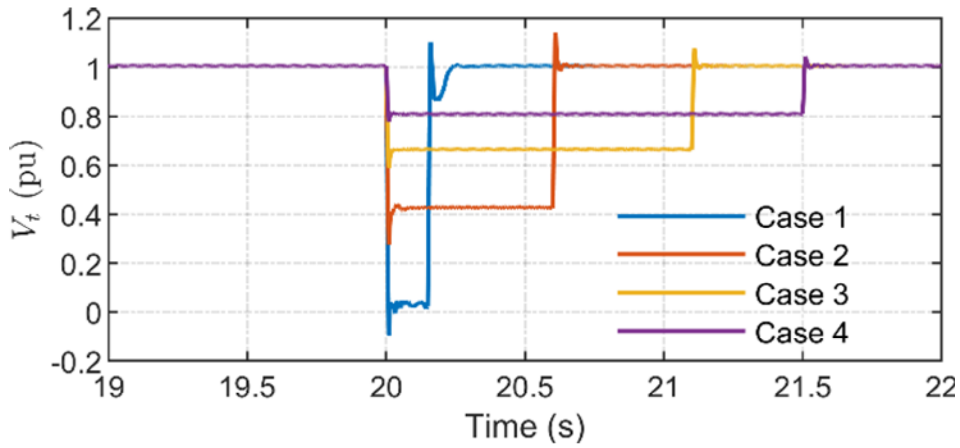
Average-Value Model (AVG)



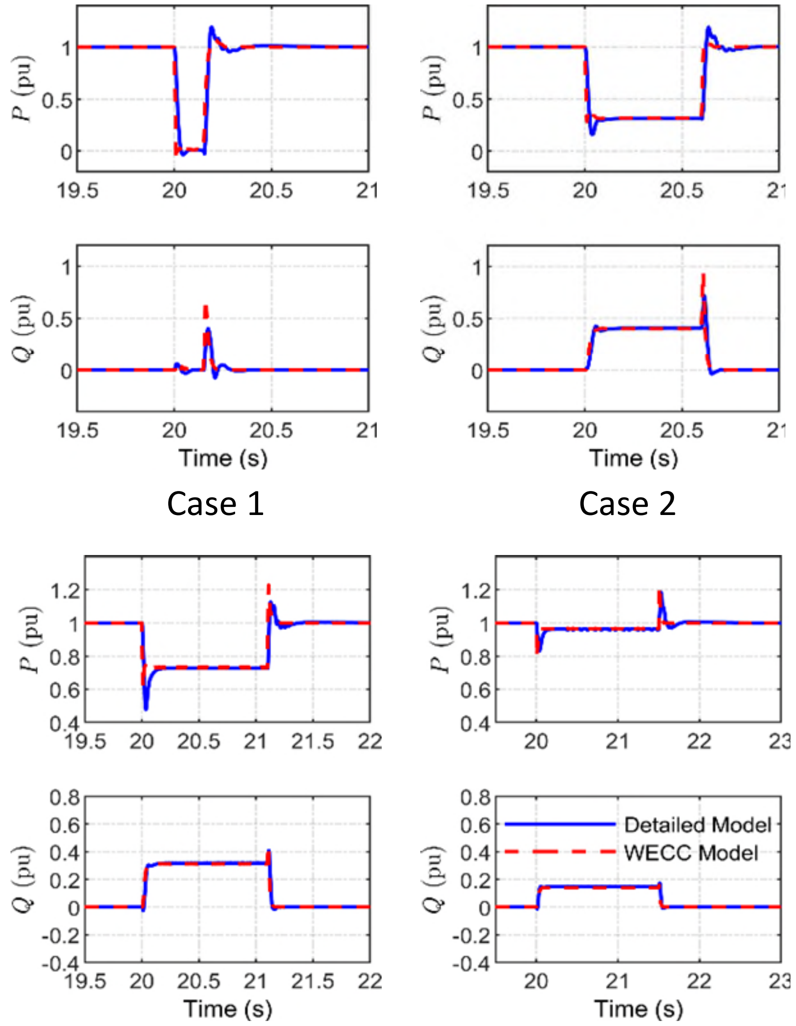
	DSW	AVG
Advantage	• Detailed representation of power electronic converter	• Low computational resource
Disadvantage	• High computational resource	• Lack of high-frequency harmonic representation
Application	• High-frequency harmonic studies • Dynamic performance over short periods of time	• Low-frequency interaction studies (e.g. control interactions) • Dynamic performance over long periods of time

TB MODEL VALIDATION

- Validate EMT models against WECC* generic models [1] under 4 cases.
- Performance of proposed and generic WECC models matches well.



Voltage dip cases



Case 1 Case 2

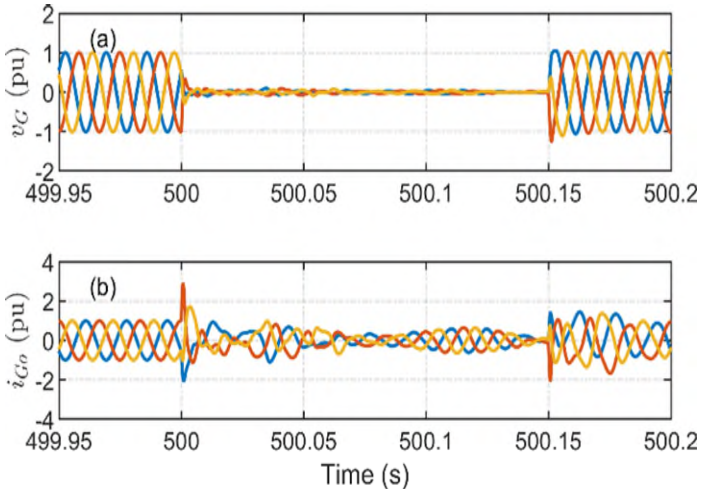
Case 3 Case 4

[1] W. REMTF, “WECC second generation of wind turbines models guidelines,” WECC, USA, 2014.

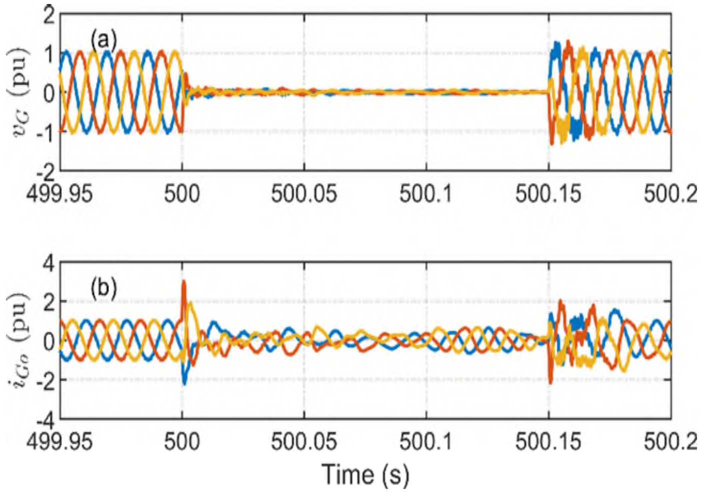
* Western Electricity Coordinating Council

BALANCED FAULT STUDIES

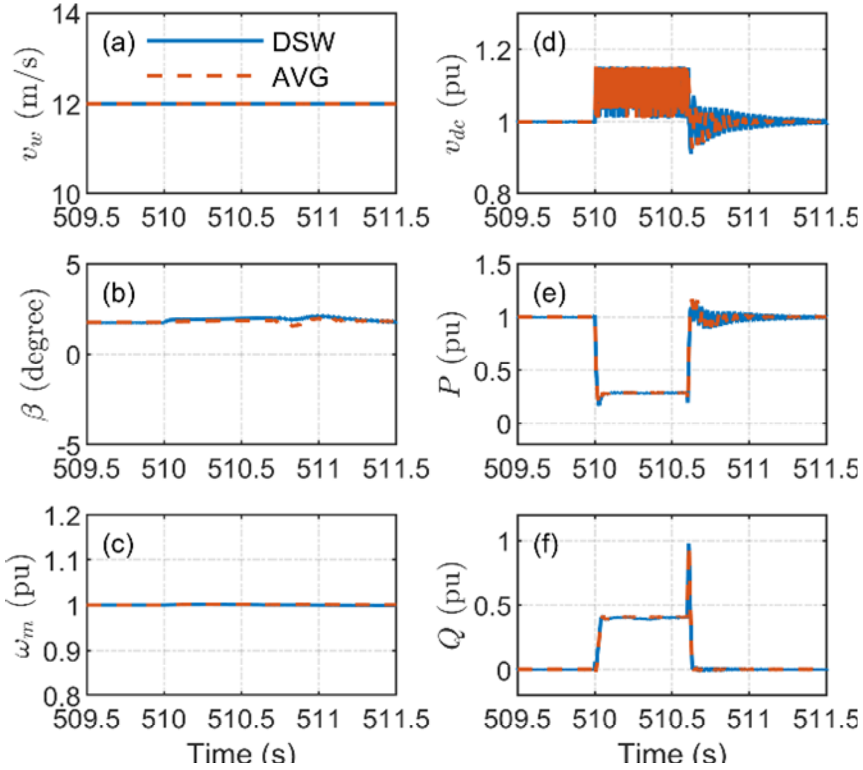
- Three-phase-to-ground fault at grid side is tested.
- AVG model well-captured dynamic response of DSW model.



Voltage and current of AVG model



Voltage and current of DSW model

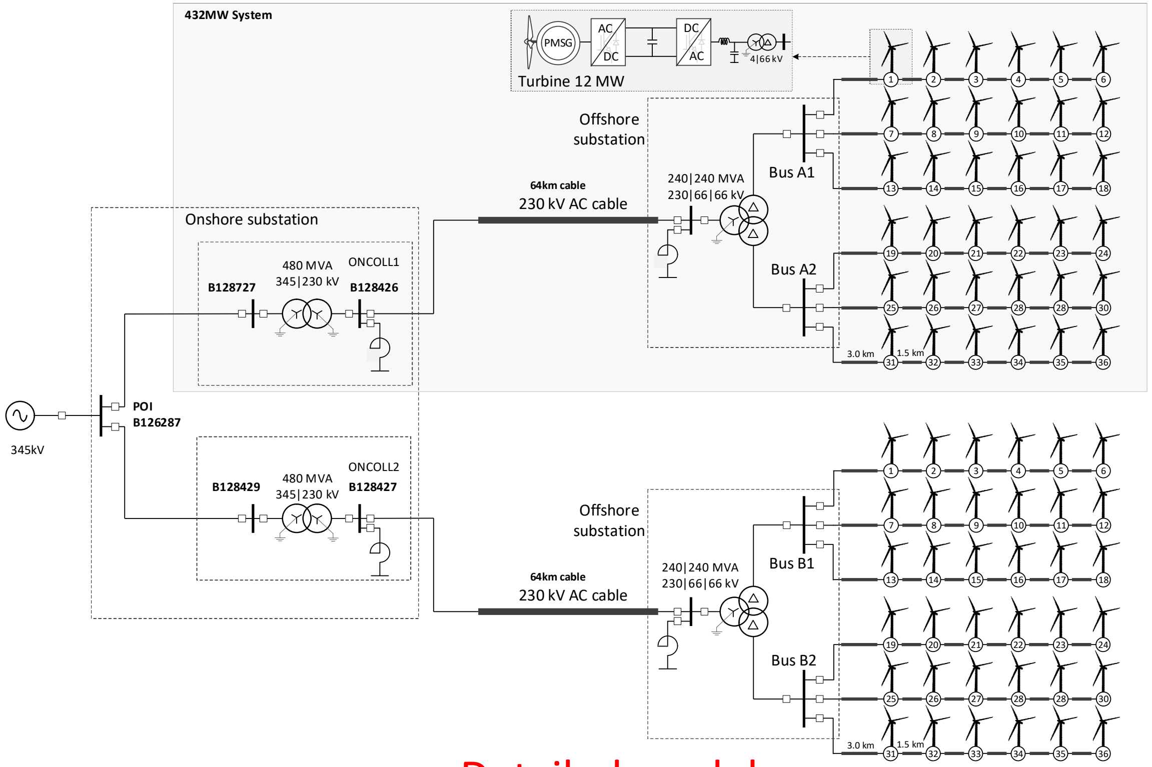


Turbine performance

EMT MODEL OF WIND FARMS

- Two types of WF models: detailed model and aggregated model.

34 turbines × 12MW



Detailed model

Series-connected equivalent network of each array.

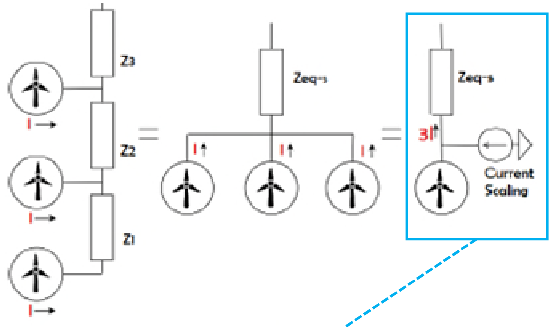
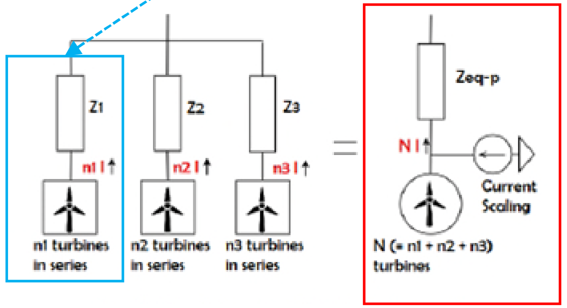


Fig. 6. Series-connected equivalent network.

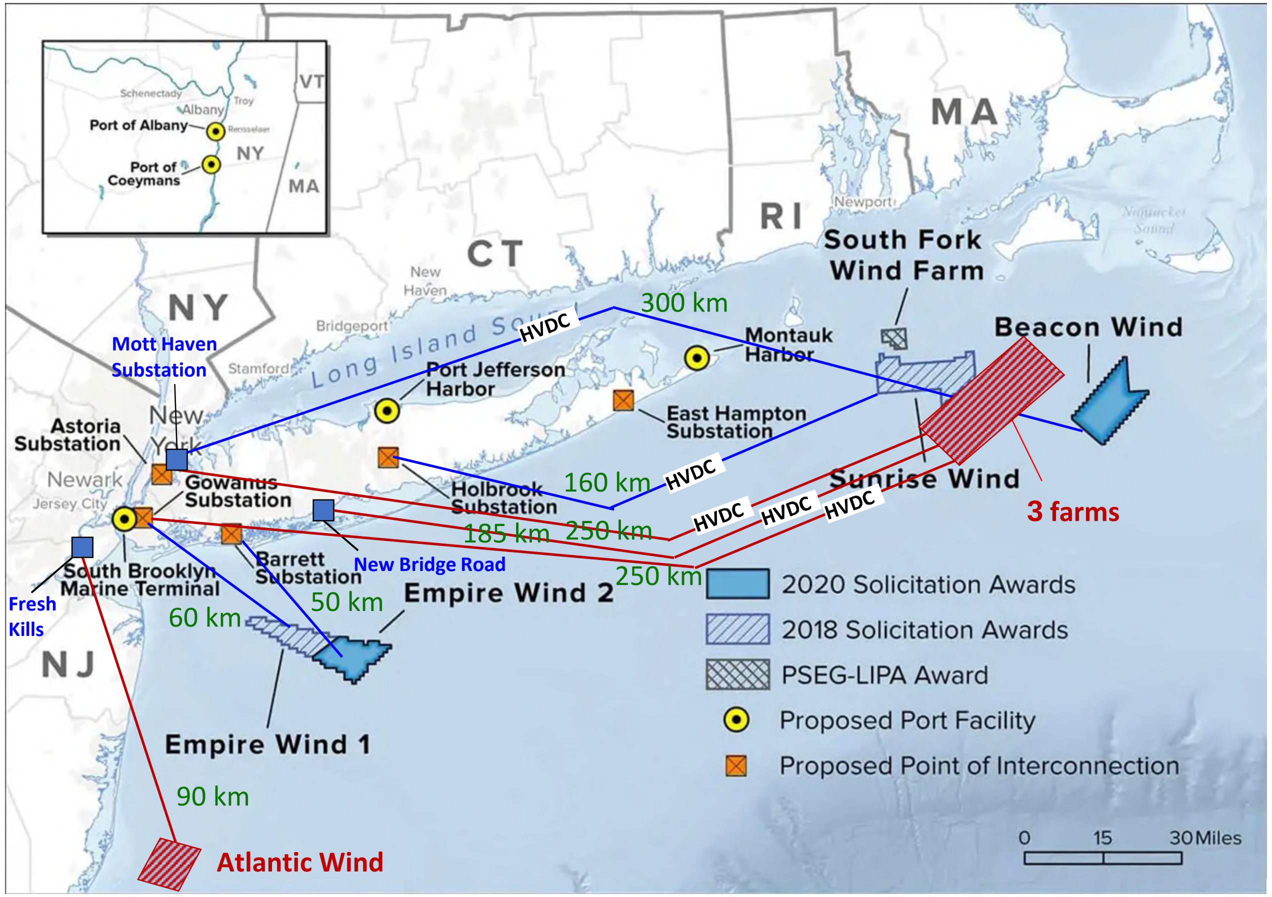
Aggregated model



Parallel-connected equivalent network of wind farm.

9GW OFFSHORE WIND

- 3 HVAC and 5 HVDC farms.
- Empire Wind 1 (816 MW) includes 68 DSW turbines.
- Remaining 7 farms are aggregated models.
- All HVDC converters are switching models.



[New York Bight Task Force Wind Developer Project Summaries (boem.gov)]

Real-Time EMT Simulation Modeling Strategy

NYS Grid Base
230kV+
~300 buses

Long Island
~345 buses

Central-West
~390 buses

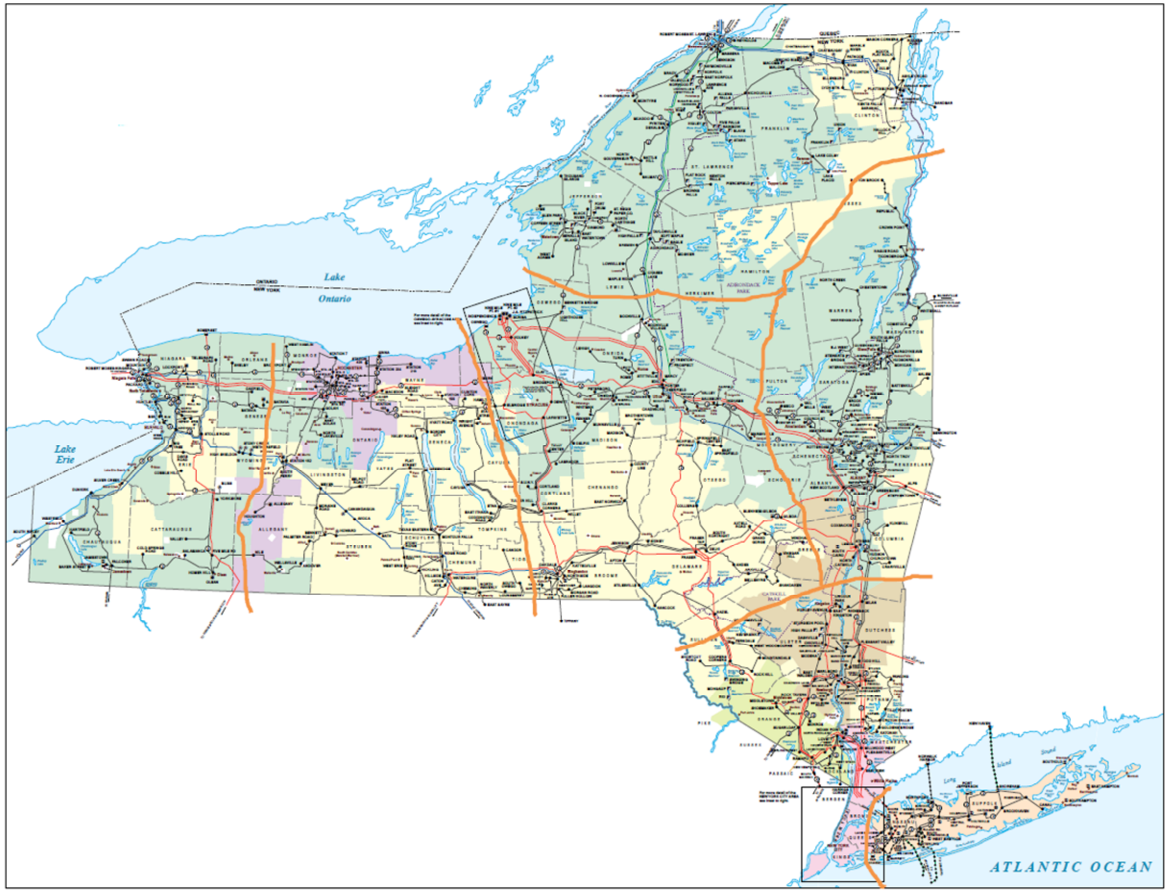
Central-East
~530 buses

Northern
~225 buses

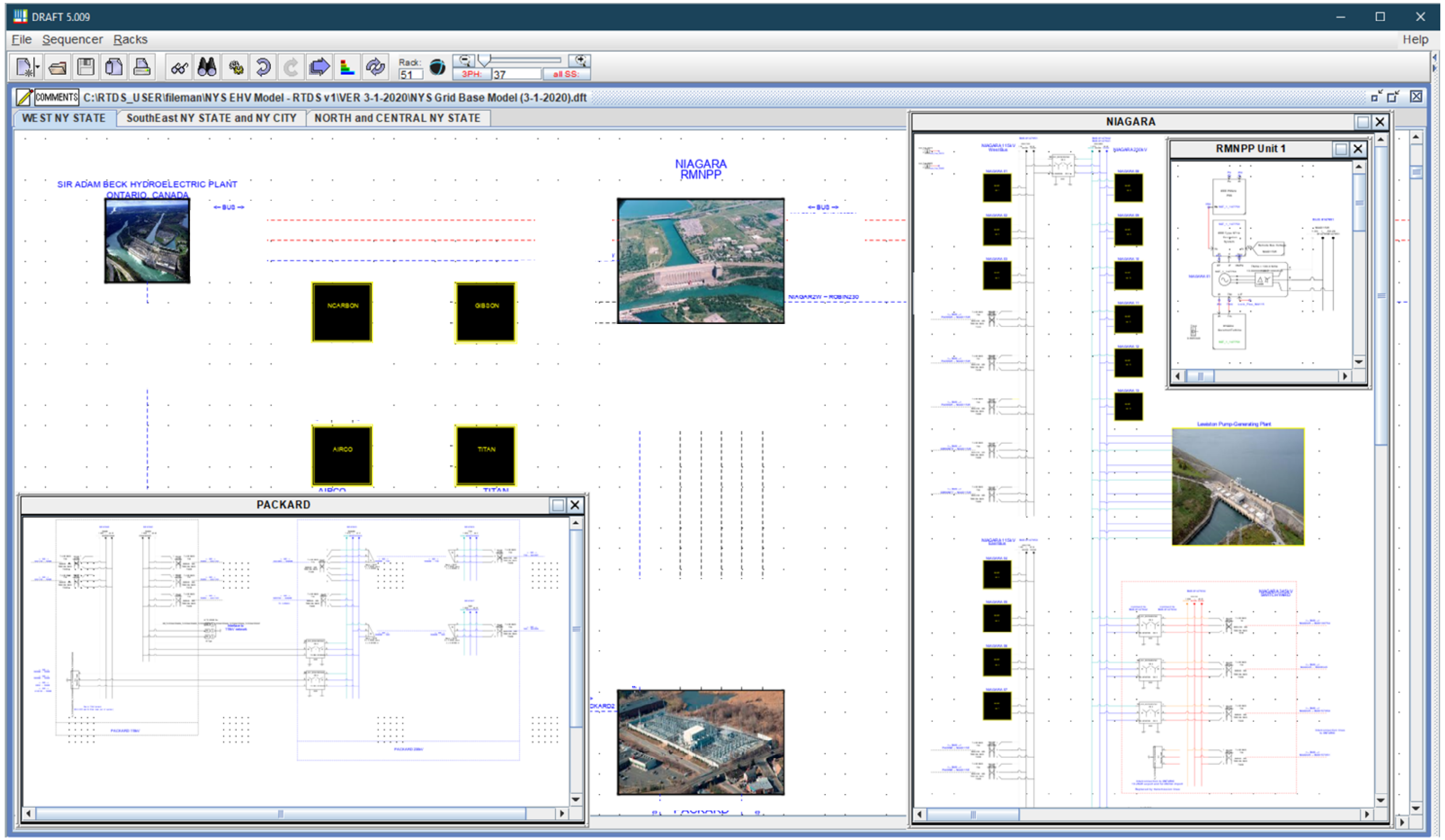
Western
~510 buses

Eastern
~350 buses

South-East
~870 buses



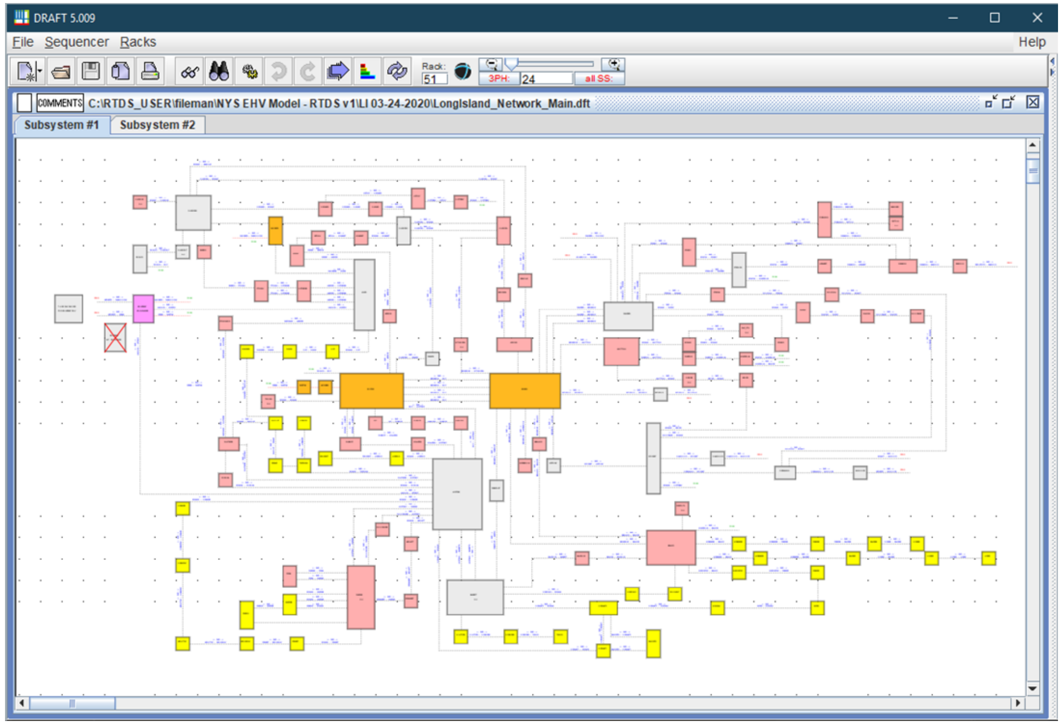
Real-Time EMT Simulation - RTDS: 230 kV + Grid Model

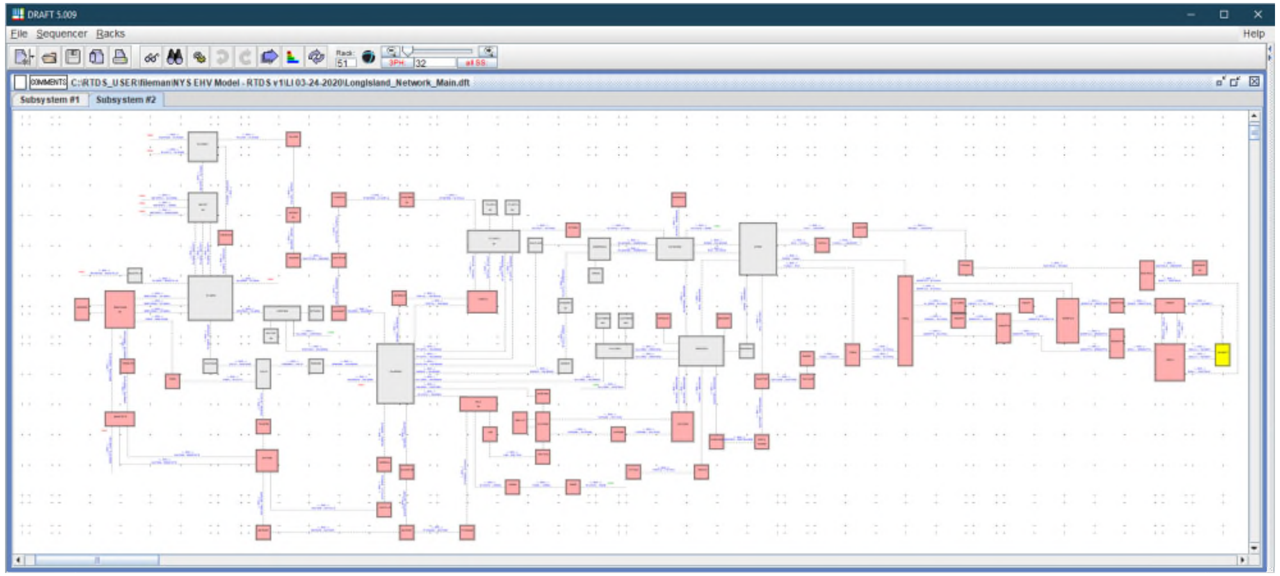


- Use of hierarchy boxes to facilitate component organization.
- Utilization of color coding for different voltage levels.

RT EMT SIMULATION - RTDS: REGIONAL GRIDS MODELS

- Regional models cover all voltage levels down to lower transmission and sub-transmission levels.
- Ability to utilize as stand alone "pieces" or in an RTDS-TSAT co-simulation environment.





RTDS MODEL MANAGEMENT

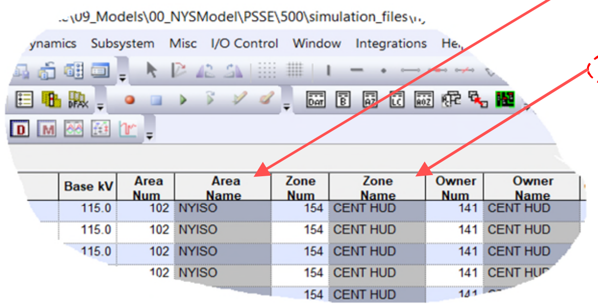
- Converting PSS/E models to RSCAD is a demanding task.
- NY State PSS/E model is updated few times a year by NYISO.
- Updating the RSCAD model of the NY State grid is required to keep the model consistent with the PSS/E models (i.e. current state of the grid).
- To address this issue, a Python based tool was developed to perform the automatic update by reading the PSS/E Raw file and overwriting the parameters of the components in the RSCAD Draft file.
- Requirement: Components in the Draft file should be named following a predefined naming convention. For example: SGT_1_123123.

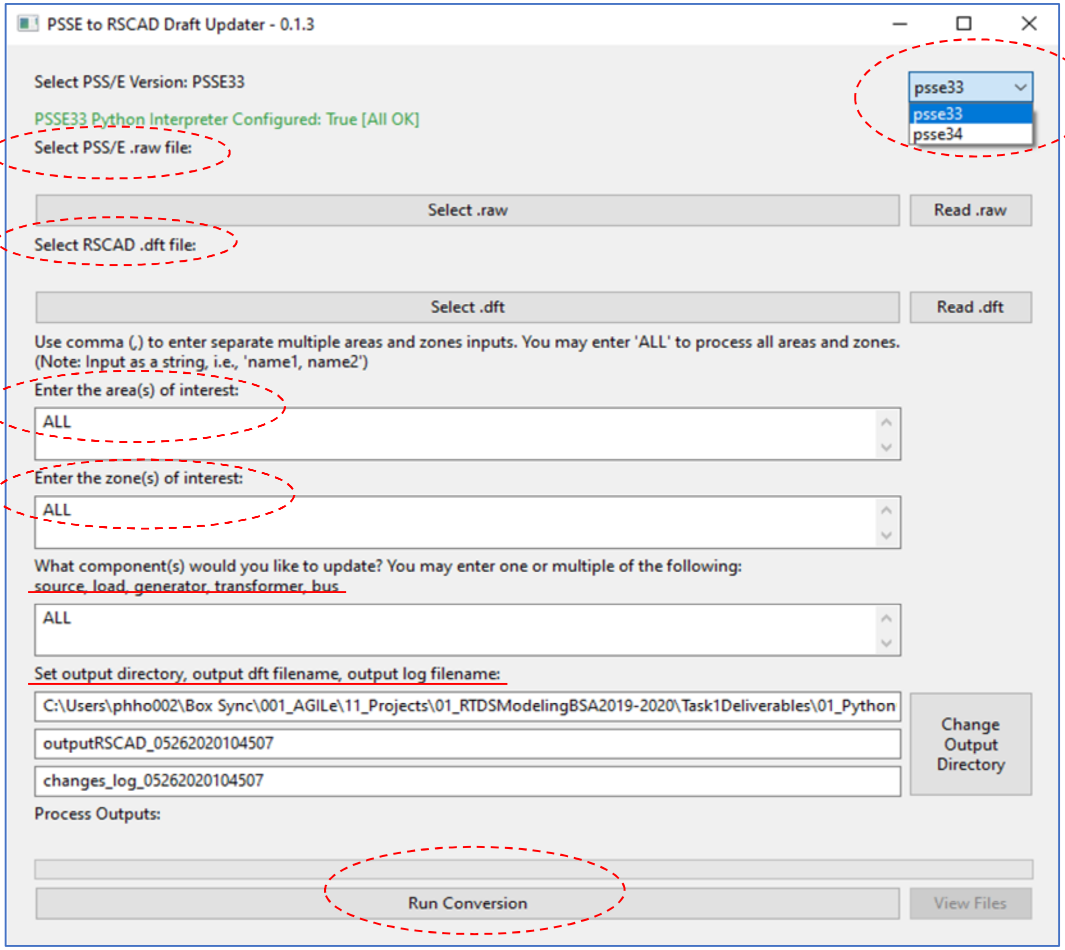
PSSE-TO-RSCAD PYTHON TOOL: GUI

Select the updated PSS/E Raw file

Select the to-be-updated Draft file

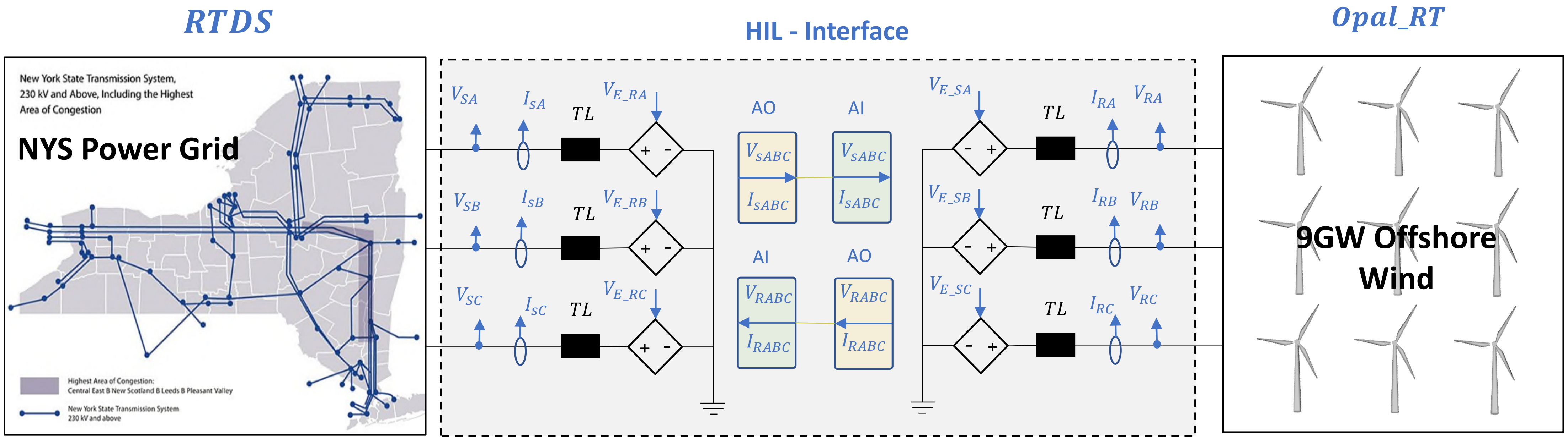
Verify PSS/E installation





INTERCONNECT WIND FARMS AND NYSPS

- NYS power system is modeled in RTDS ; 9GW offshore wind is modeled in Opal-RT.
- Real-time co-simulation between RTDS and Opal-RT is developed to test the interconnection.
- Hardware-in-the-loop (HIL) interface is developed to perform real-time co-simulation.



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RT CO-SIMULATION OF EMPIRE WIND 1

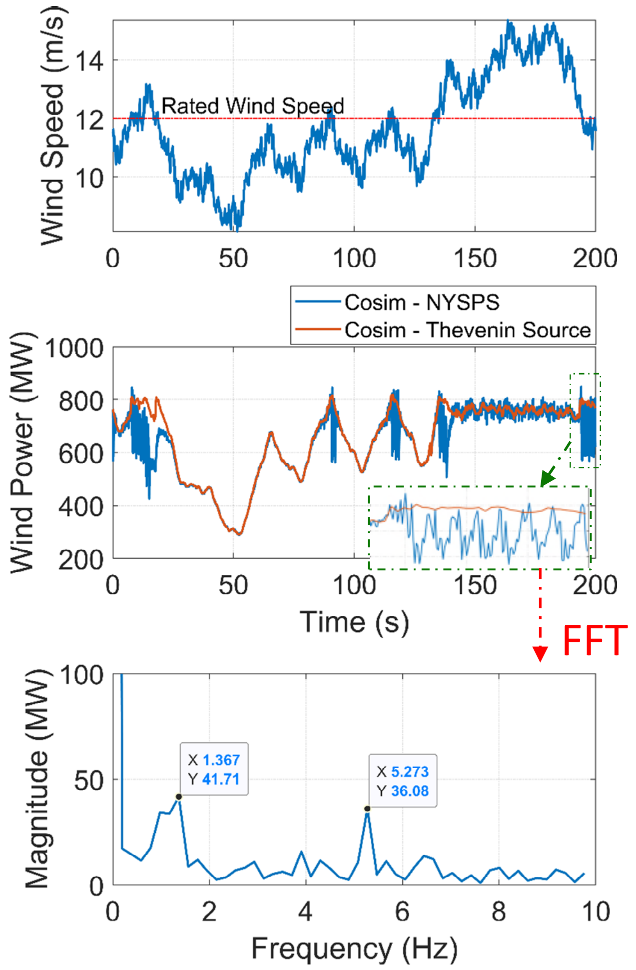
Two cases are conducted to verify the performance:

- Case 1: Empire Wind 1 connects to **Thevenin equivalent source** in RTDS. Short-circuit power is calculated by peak fault current at Gowanus bus.
- Case 2: Empire Wind 1 connects to full **NYSPS** model in RTDS.

Two cases are tested under condition of dynamic wind speed:

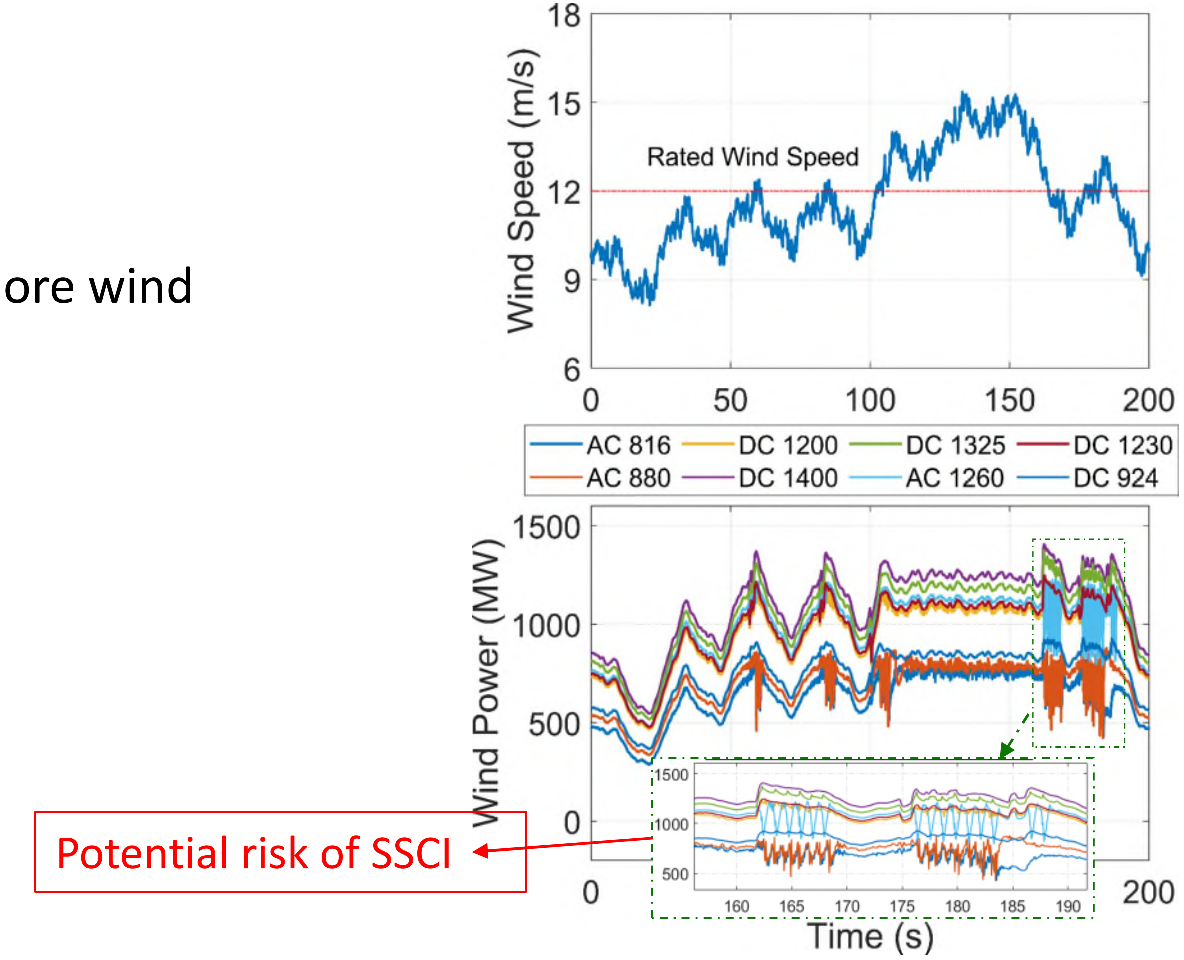
- Case 1 (Cosim – Thevenin Source) is working normally.
- Case 2 (Cosim - NYSPS): transition between regions 2 and 3 causes significant oscillation at frequencies of 1.4 and 5.3 Hz.

The risk of sub-synchronous control interaction is only revealed when wind farm connects to full NYS power grid model.



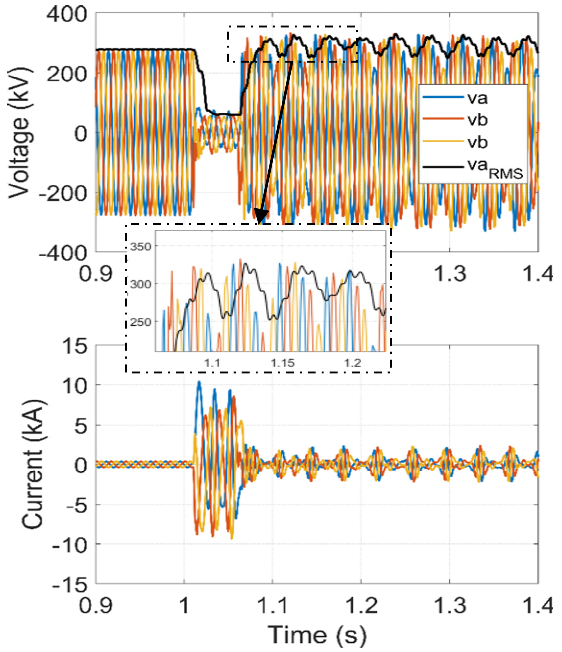
RT CO-SIMULATION OF 9GW OFFSHORE WIND

- Real-time co-simulation between RTDS and Opal-RT successfully operates.
- EMT models of both NYS power grid and 9GW Offshore wind are utilized.
- Wind speed varies from 8m/s to 16m/s to evaluate:
  - MPPT function
  - Power curtailment
- Potential risk of SSCI is found.

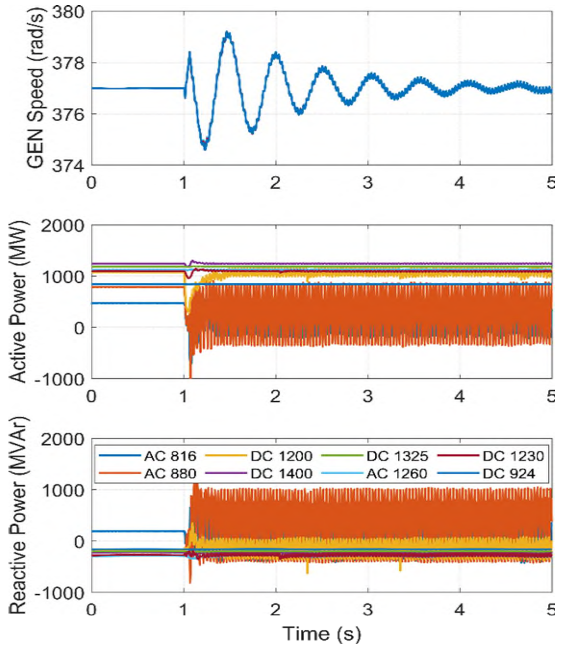


FAULT STUDIES – 8 FARMS

- Three-phase-to-ground fault at GOETHLS bus; fault impedance is 0.1Ω and fault duration is 3 cycles.
- Significant oscillation in three farms: AC816, AC880, and DC1200.
- Peak fault current is 10kA, resulting in short circuit power of 5GW. (SCR ≈1.2)

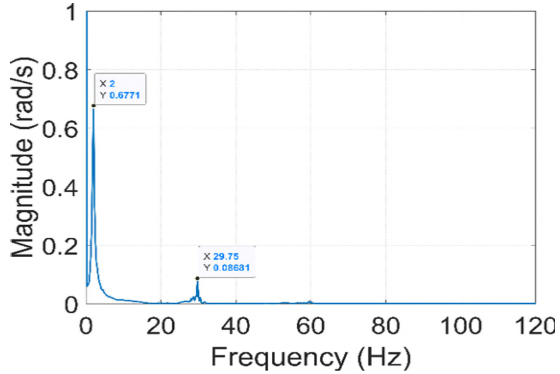


Gowanus bus voltage and current from GEOTHLS to GOWANUS



Output power of 8 farms

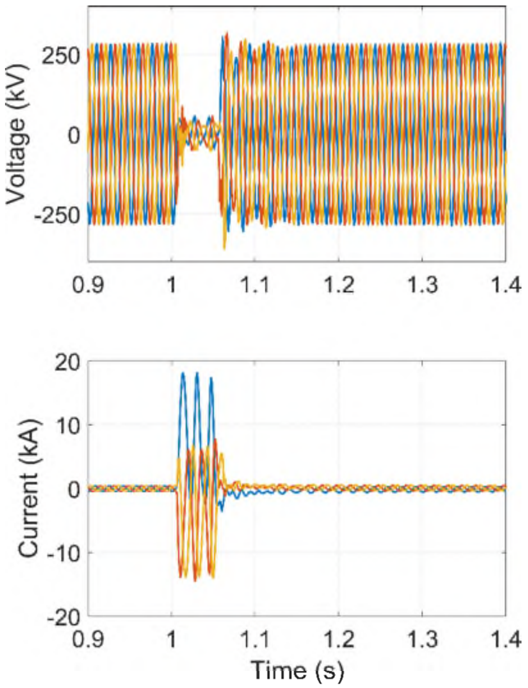
Oscillation frequencies: 2 and 30 Hz



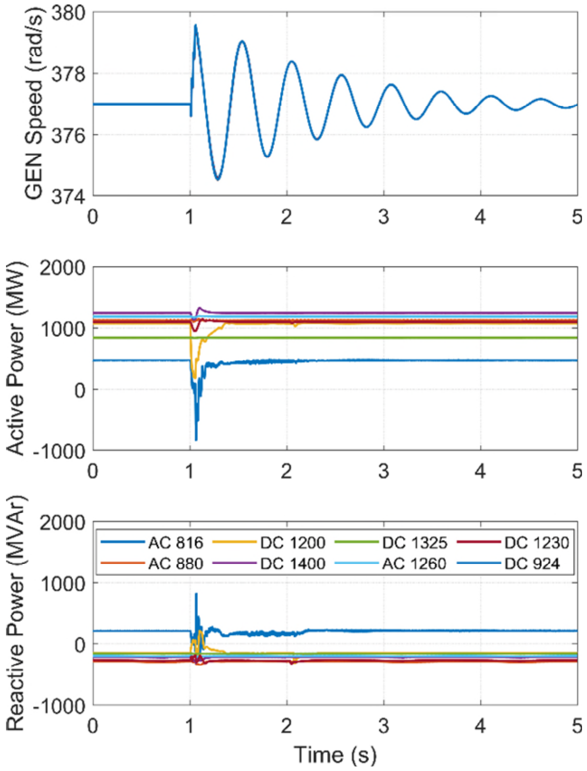
Frequency Spectrum of generator speed

FAULT STUDIES – 7 FARMS

- Disconnect farm AC880 connected to Fresh Kills (HVAC cable length of 95 km)
- 7 farms are restored to normal operation.



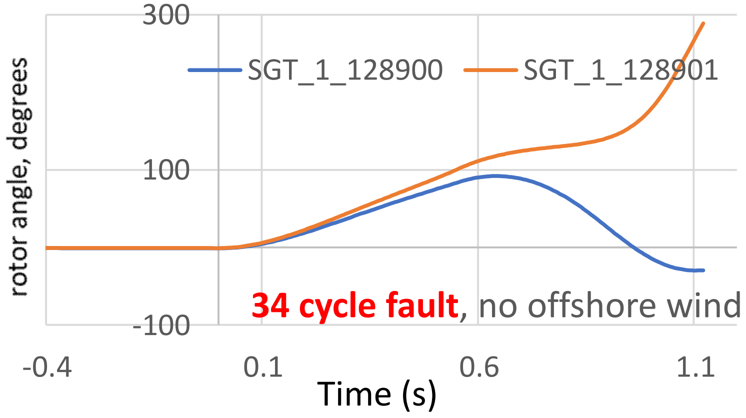
Gowanus bus voltage and current from GEOTHLS to GOWANUS

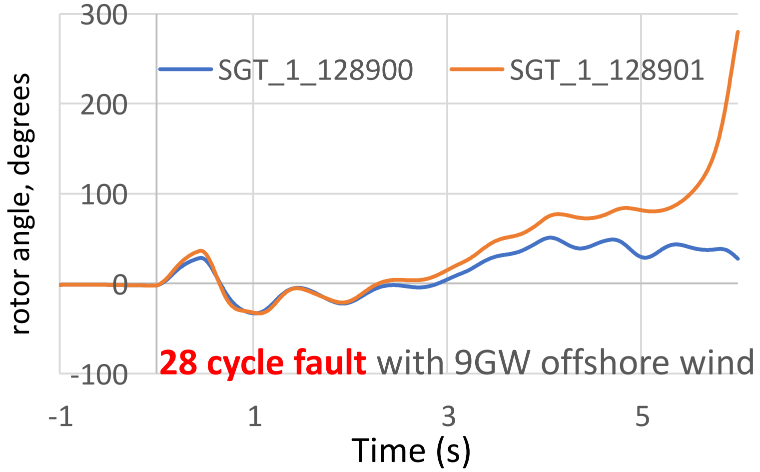


Output power of 7 farms

CRITICAL CLEARING TIME STUDY

- Fault at Freeport near Barrett substation.
- Two cases are tested to evaluate the critical clearing time: with 9GW wind and without 9GW wind.
- Measured rotor speed of 2 critical synchronous generators at Barrett substation for comparison of instability behaviors:
  - SGT_1_128900: 170 MVA
  - SGT_1_128901: 220 MVA
- Offshore wind reduced the critical clearing time.





Marginally unstable cases

CONCLUSION

- Various types of EMT IBR models are presented:
  - DSW and AVG single WTG models
  - Detailed and aggregated wind farm models
- Different EMT models can be combined to simulate large-scale IBR plants.
- Real-time co-simulation between Opal-RT and RTDS allows EMT simulation of both power grids and IBR plants.
- Various studies on large-scale power system can be performed on the RT co-simulation:
  - Balance and unbalance faults
  - Control interactions such as SSCI, SSR, etc.
  - Harmonic resonance

QUESTIONS?

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