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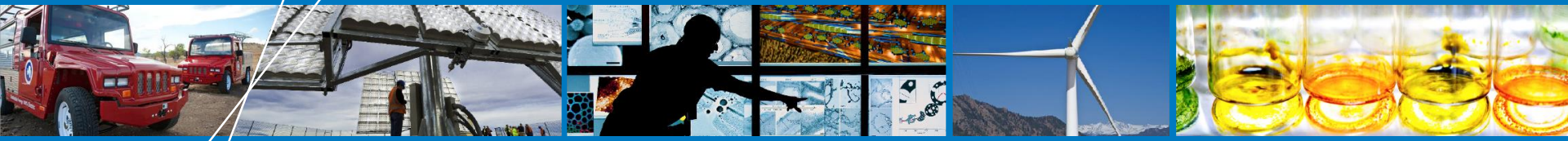
Investigating Power System Primary and Secondary Reserve Interaction under High Wind Power Penetration Using Frequency Response Model



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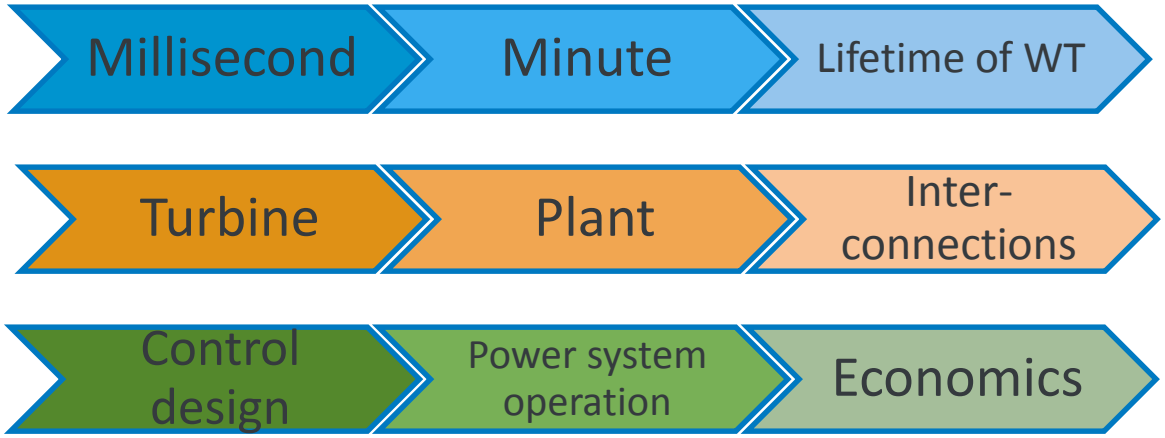
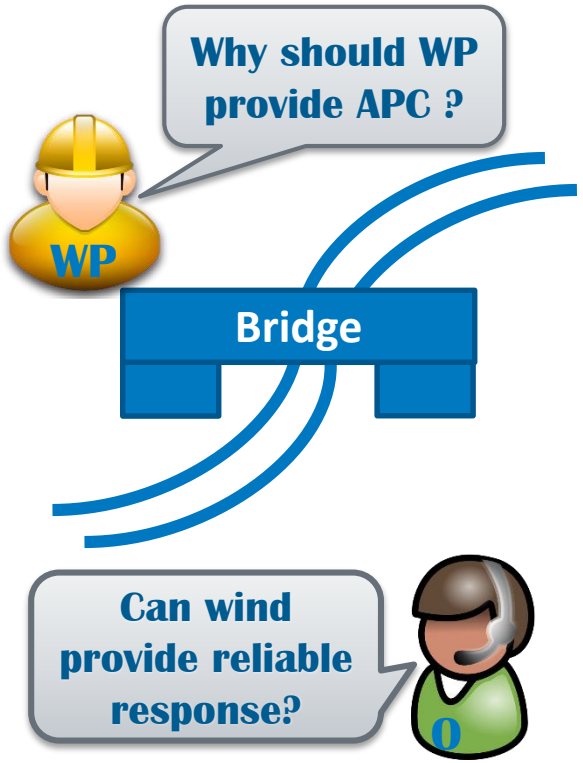
Outline

- Background
- Multi-area Frequency Response Integration Model (MAFRIM)
- A demonstration: “Primary and Secondary Reserve Interaction under High Wind Power Penetration”
- Conclusion

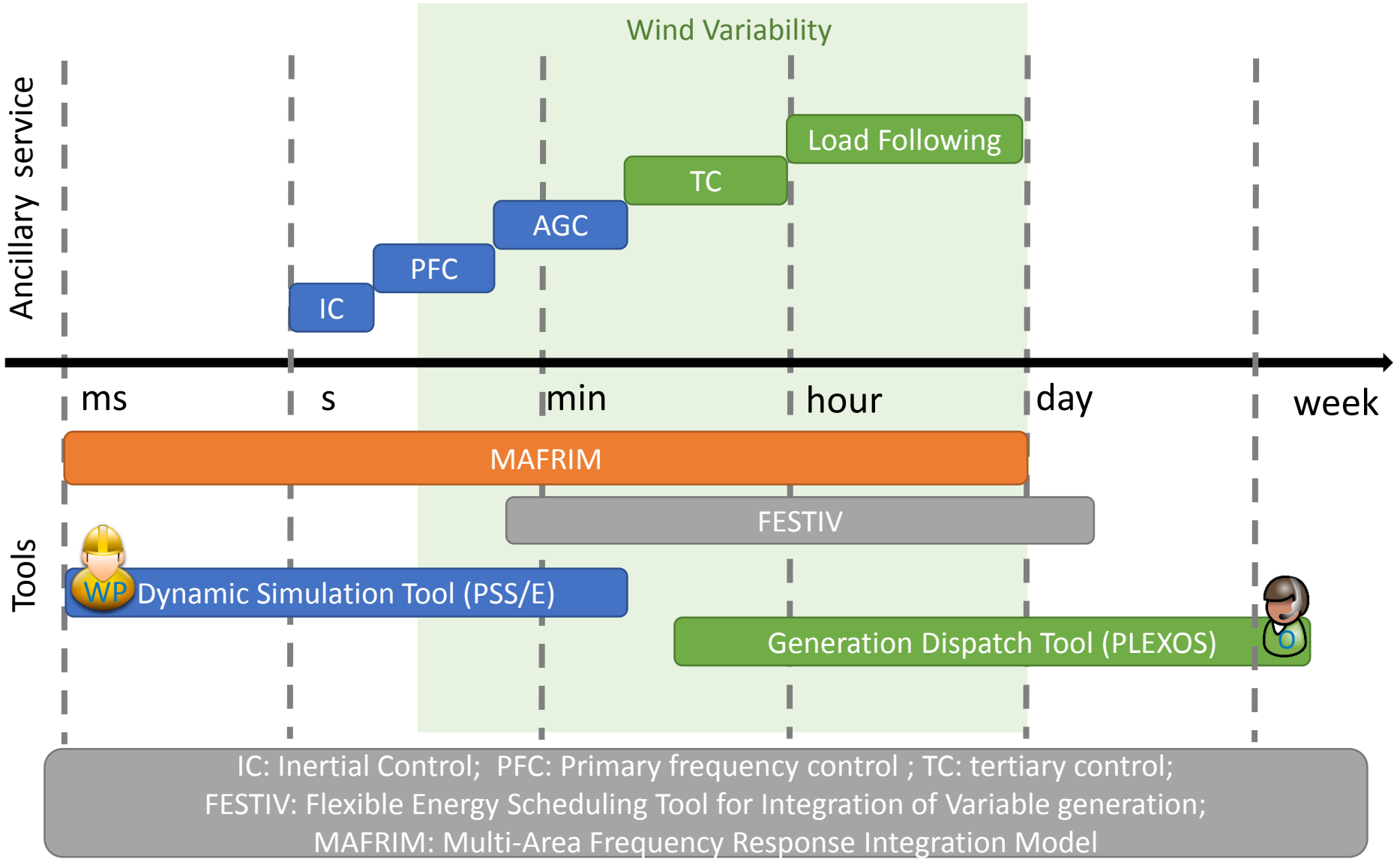
Background

- **Project: Active power control from wind power (DOE)**
- **Goal**
  - ✓ Adjust the wind power's active power in various timeframes
  - ✓ Improving power system reliability
- **Time scales, spatial scope and topics**



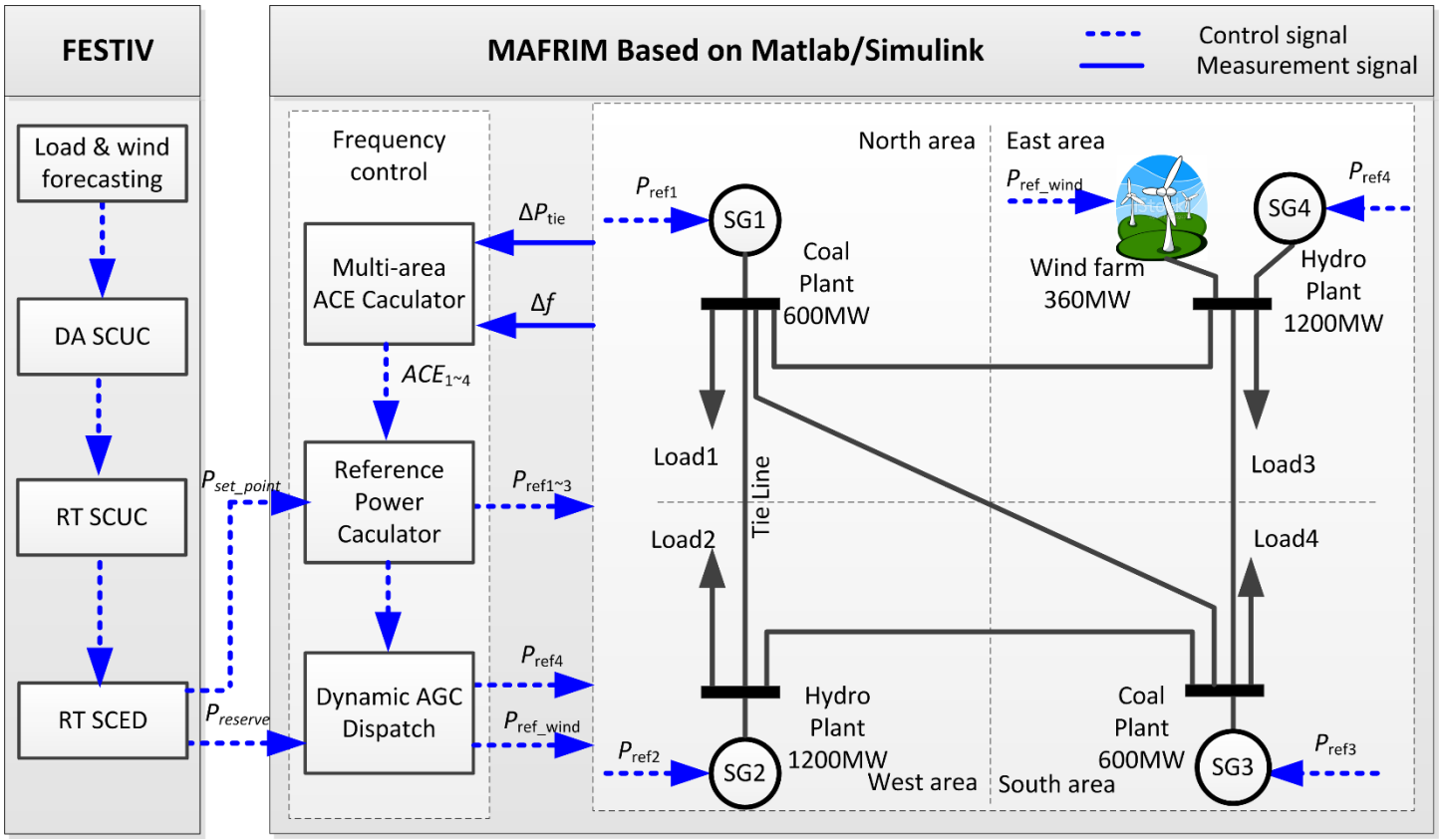


Services and Analytical Tools at Different Time-scales



IC: Inertial Control; PFC: Primary frequency control ; TC: tertiary control;
FESTIV: Flexible Energy Scheduling Tool for Integration of Variable generation;
MAFRIM: Multi-Area Frequency Response Integration Model

Multi-Area Frequency Response Integration Model



Key features:

- Bridge dynamic simulation & economic dispatch simulation;
- Response to 4-s AGC and 5-min dispatch ;
- Represent frequency dynamics from seconds to days level considering the variability of the wind.

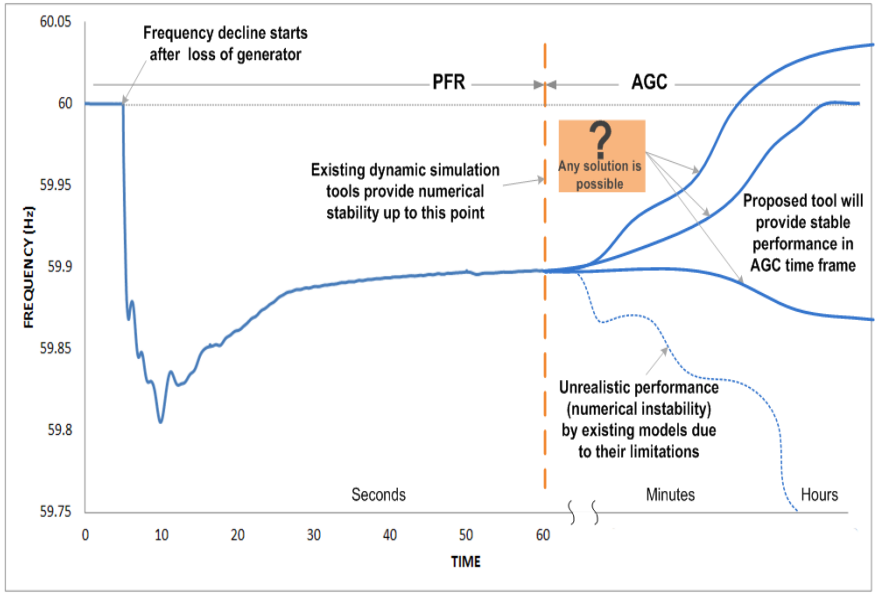
A demonstration: Primary and Secondary Reserve Interaction

Incentive

- *"There is no commercially available simulation tools that can realistically model the interactions between these two types of reserves (primary and secondary)"* [1]

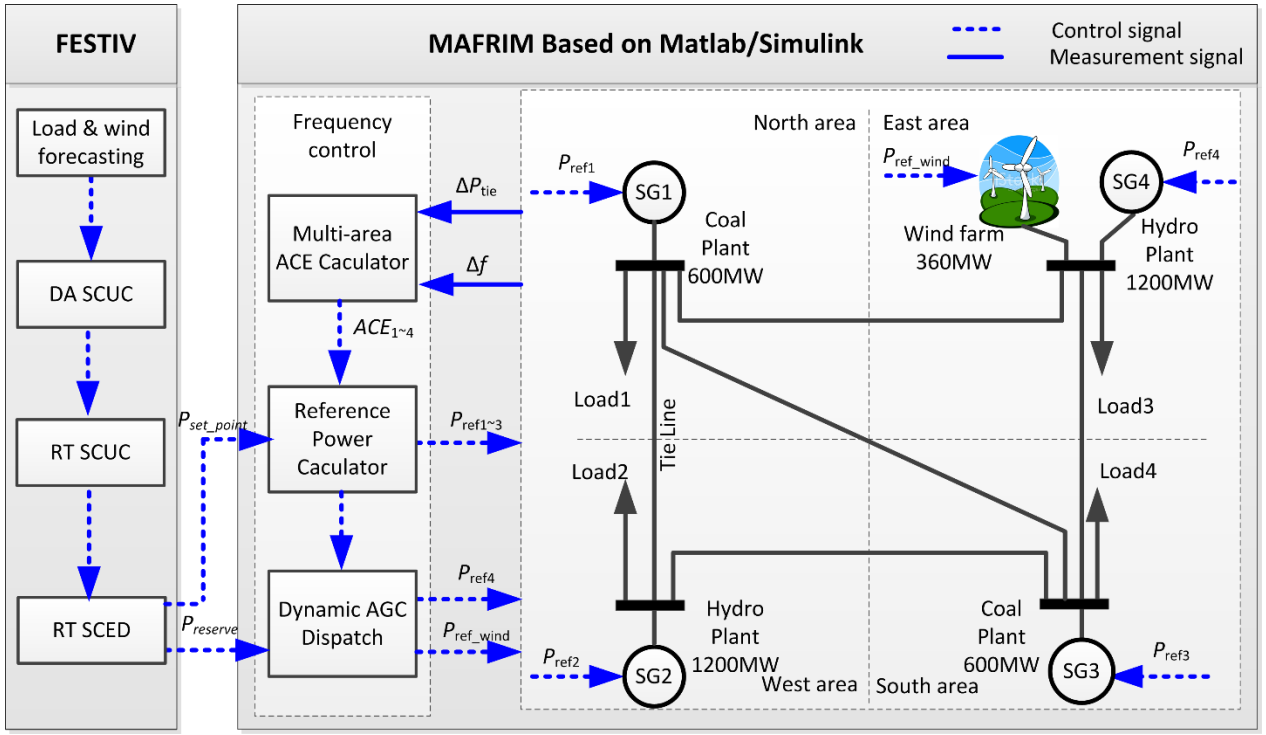
MAFRIM

- Provide a unique and comprehensive look at **primary and secondary reserve interaction** under high wind power penetration



[1] J. Eto, et al. "Use of Frequency Response Metrics to Assess the Planning and Operating Requirements for Reliable Integration of Variable Renewable Generation", FERC report prepared by LBNL, December 2010

Modelling



- ***FESTIV Model***
  - Wind and load forecasting model
  - Day-ahead security-constrained unit commitment model
  - Real-time SCUC and security-constrained economical dispatch model

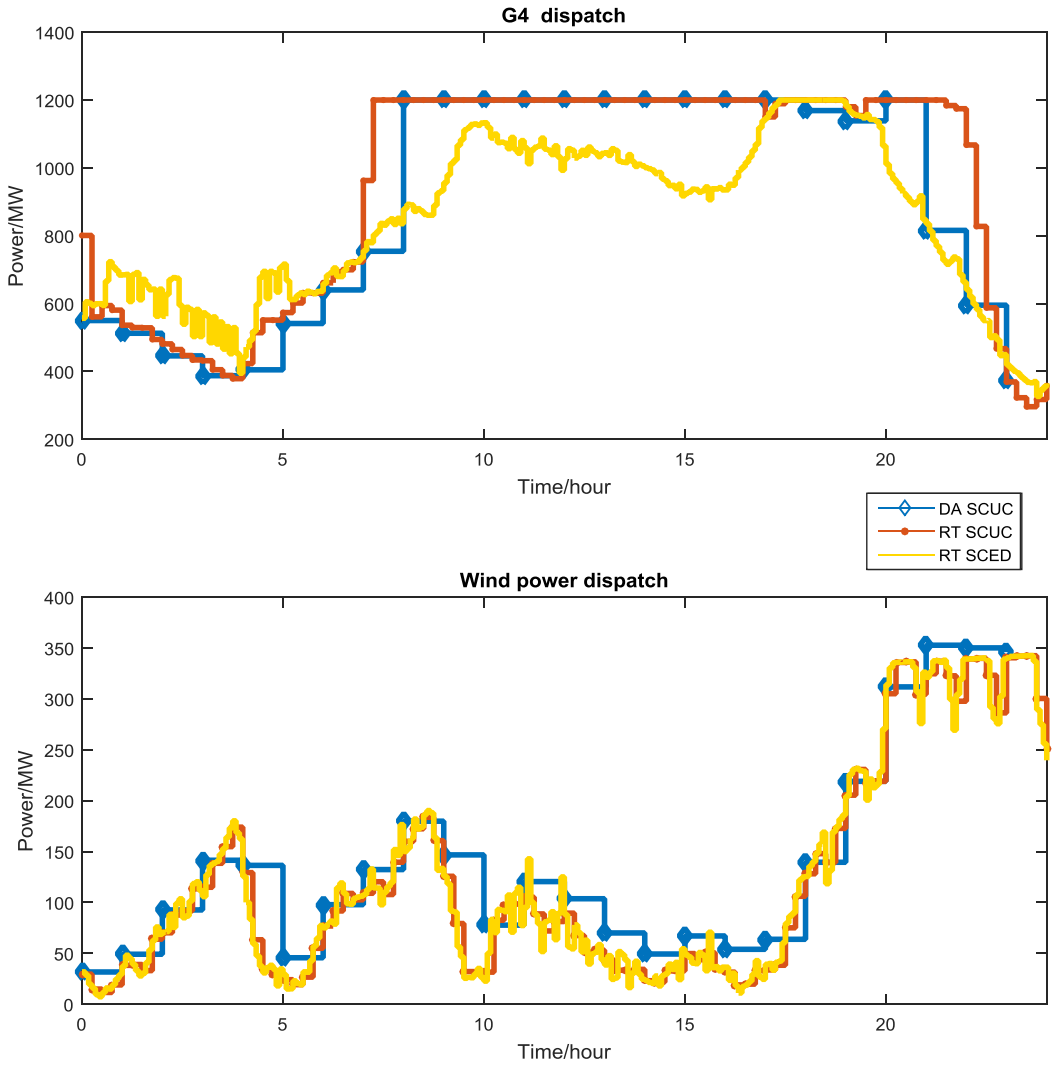
- ***Dynamic Grid Model***
  - Phasor-based grid Model
  - Four-area AGC model
  - Wind plant's PFC and AGC controller
  - Dynamic AGC dispatch model

Simulation

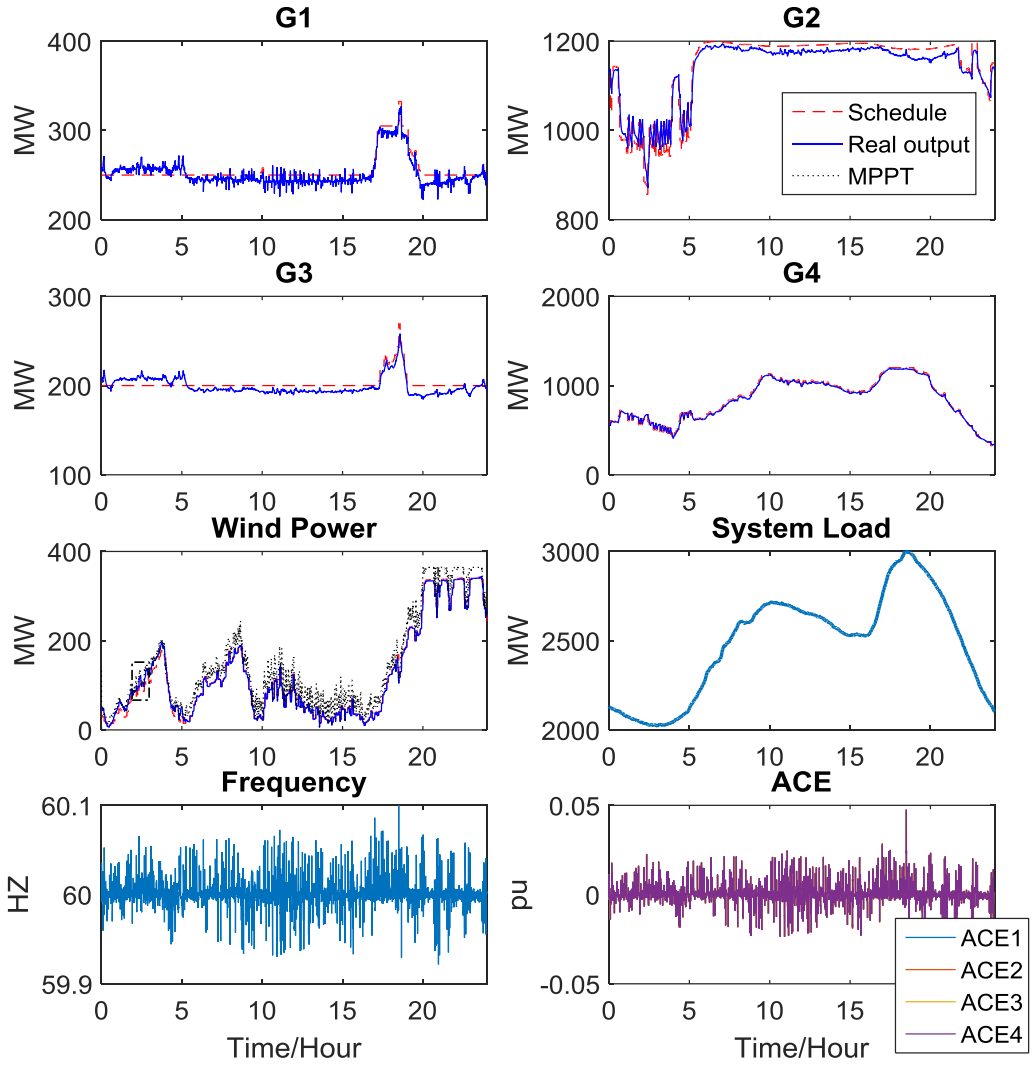
- FESTIV simulation
- 24-hour dynamic simulation
- Interaction between the PFC and SFC
- Effects of Wind AGC on long term frequency response performance

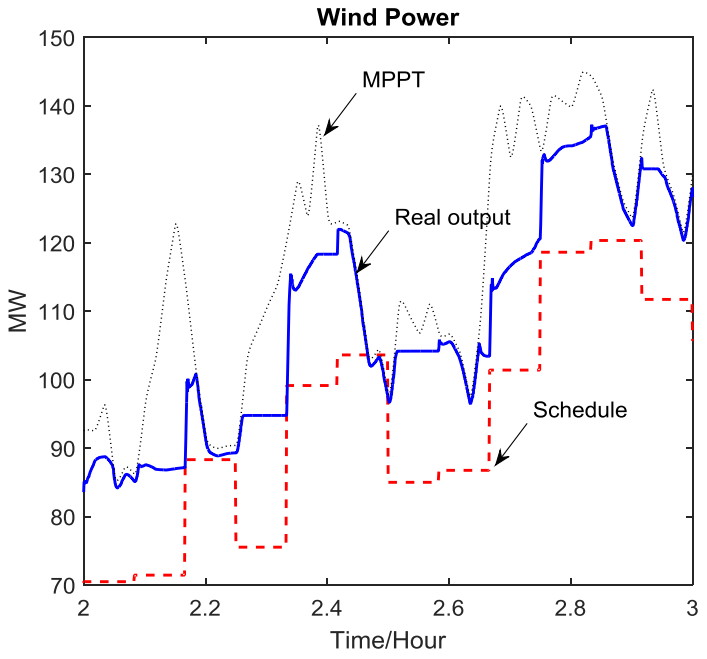
FESTIV Simulation

- Day-ahead unit commitment, real-time unit commitment, and economic dispatch for Wind and conventional generator's generation.
- Spinning and regulation reserve dispatch.
- Optimize the dispatch by considering the variability of the wind.



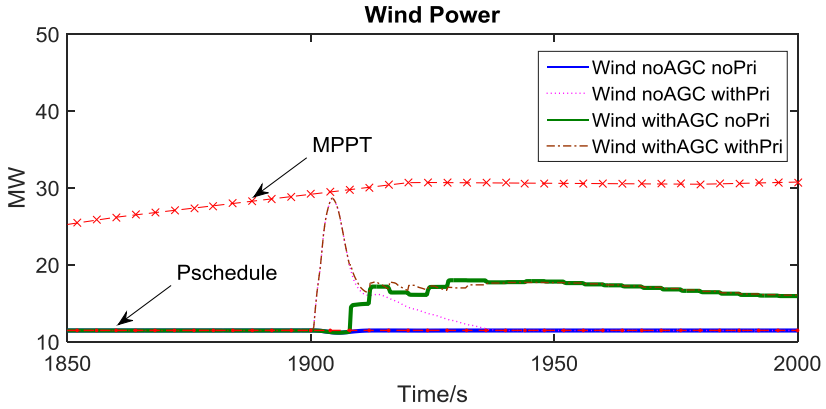
24-hour dynamic simulation

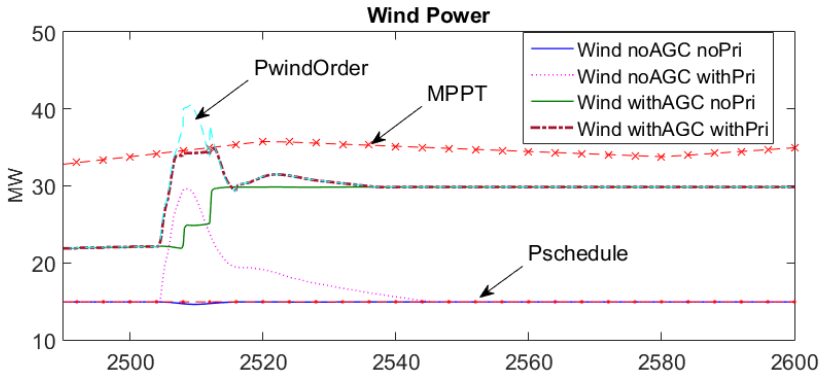


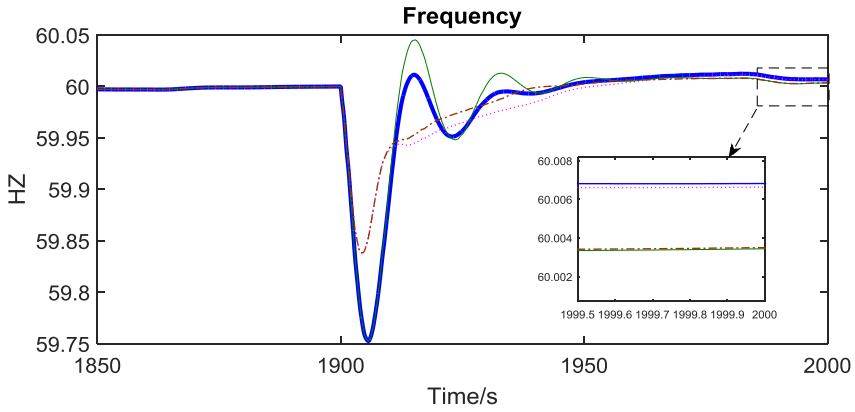


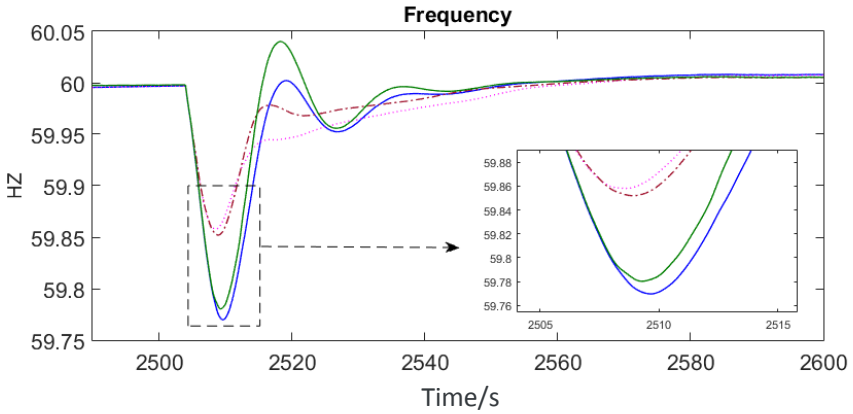
- 24 hour simulations
- Dynamic responses of conventional generators and the wind plant
- Frequency response of the interconnection grid

Interaction between the PFC and SFC



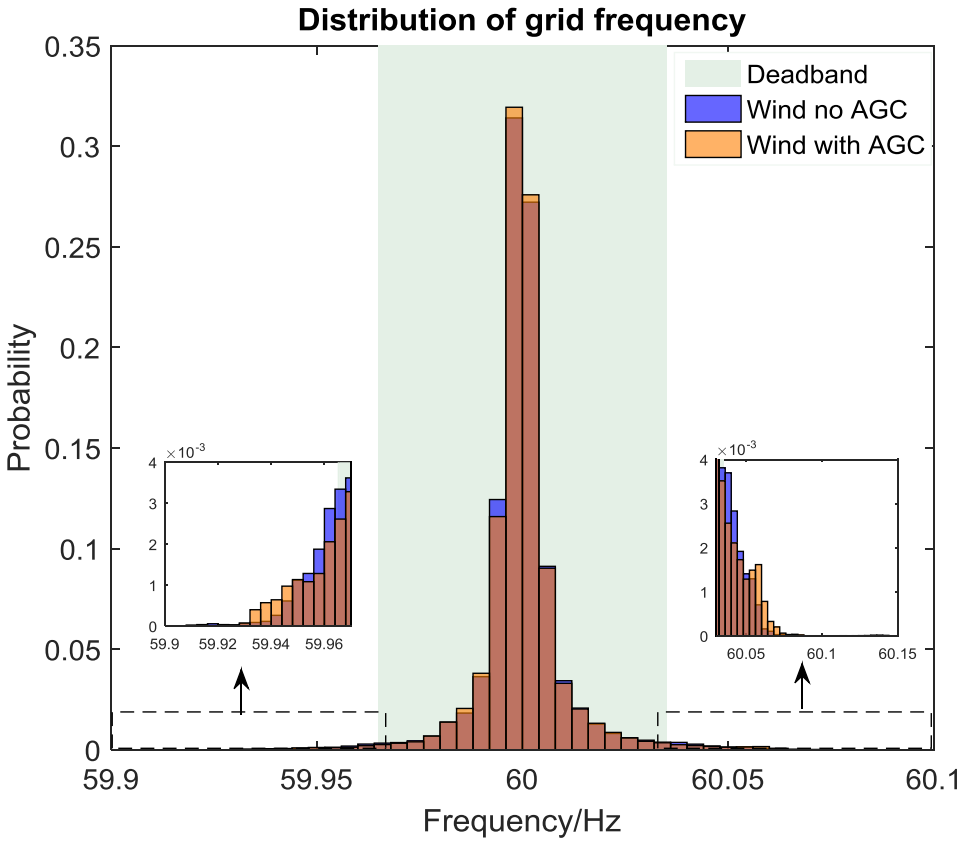






- Wind that provides primary response has a better frequency nadir.
- Wind that provides AGC has a faster response to restore frequency.
- When wind is providing SFR and an event happens, wind may not have enough headroom to provide a full-scale PFR.

Effects of wind AGC on long-term simulation-No event case

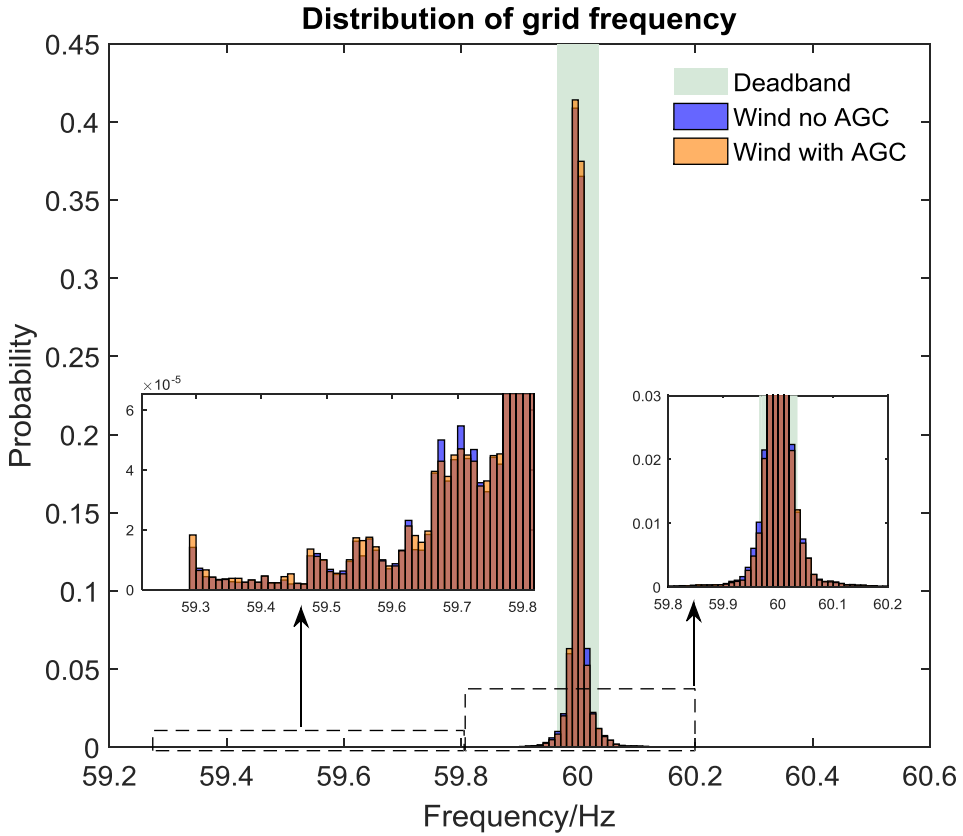


	Wind no AGC	Wind with AGC
RMSD of Fre (Hz)	0.0103	0.0105
MAE of Fre (Hz)	0.0059	0.0059
Energy of ACE (MWh)	146.9584	146.2710
Unavailability Time	---	6.50%

≈1.56 hours

- In the no event case, the wind plant with AGC has few impact on frequency performance of the grid compared with the wind plant without AGC.

Effects of wind AGC on long-term simulation-Event case



	no AGC	with AGC
RMSD of Fre (Hz)	0.0211	0.0206
MAE of Fre (Hz)	0.0090	0.0084
Energy of ACE (MWh)	221.2578	208.8844
Unavailability Time	----	6.06%

- In the event case, wind AGC is good to the frequency performance of the grid.
- Wind AGC can help the grid frequency return to the nominal frequency quickly.
- However, due to SFC may take some reserve during the operation, so when event happens, the performance of PFC may be limited by the limited headroom, as a result, the wind AGC is harmful to the frequency nadirs in some cases.

Conclusion

- Propose the MAFRIM to bridge the power system dynamics across different time-scales.
- A better understanding of the interactions of PFC and SFC and their reserves.
- Future investigation on different control strategies of enabling wind to provide ancillary services.
- Help industry to move forward on PFR market designs.

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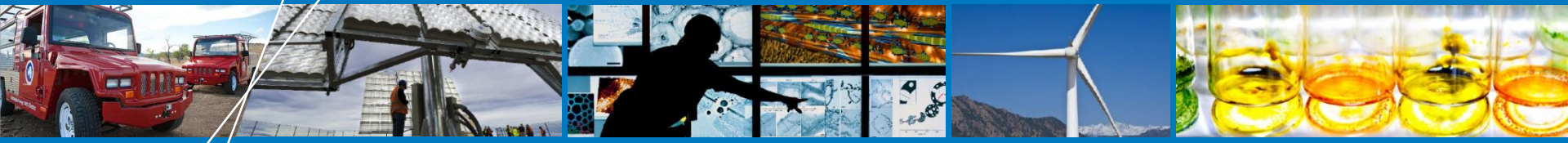

Thanks

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http://www.nrel.gov/electricity/transmission/active_power.html