2023 Title of Webinar: Off-Shore Wind Projects: Items to Study and Confirm

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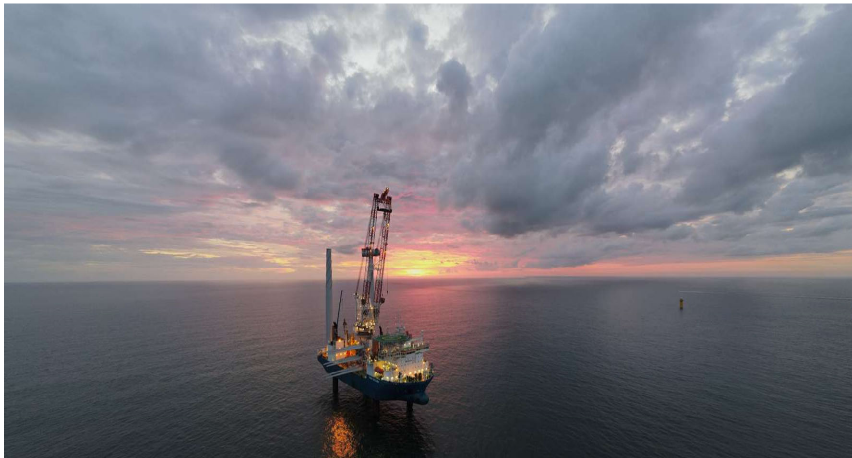
26 September 2023



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Offshore Wind Integration Considerations

By Mark McVey Principal Engineer ET Equipment & Technical Sr. Strategic Advisor, Dominion Energy

Offshore Wind Integration Considerations

Transmission Interconnection Check List

- Data Gathering/Review – Short-Circuit Analysis
- High Level Study Results
- Cycle #1 Cluster Study Results
  - Phase 1 Results – High Level Study (PSS/E or PSCAD, EMTP ect…)
  - Phase 2 Results – Detailed Direct Connection Results & High-Level Network Impacts
  - Phase 3 Results – Detailed Direct Connection & Network Impacts (including Dynamic Analysis) Results

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Task 01 – Data Gathering/Review – Short-Circuit Analysis
Task 02 – Power Flow Case Development
Task 03 – Reactive Power Capability (WTG or On Shore Interconnection)
Task 04 – Steady-State Contingency Analysis
Task 05 – Dynamic Model Review and Ride-Through/Small-Signal Stability Testing
Task 06 – Dynamic Stability Analysis
Task 07 – Dynamic Performance, Coordination, and Interaction Analysis
Task 08 – Harmonic Model Development of the Wind Farm
Task 09 – Frequency Scan of the Wind Turbine and Project
Task 10 – Harmonic Model Development of the Grid
Task 11 – Harmonic Sectors
Task 12 – Incremental Harmonic Emissions Analysis
Task 13 – Background Harmonic Amplification Analysis
Task 14 – Harmonic Performance Assessment
Task 15 – Harmonic Filter Design
Task 16 – Harmonic Interaction Screening Analysis
Task 17 – Harmonic Field Measurement Benchmarking Analysis at POI
Task 18 – Electromagnetic Transients (EMT) System Model Development

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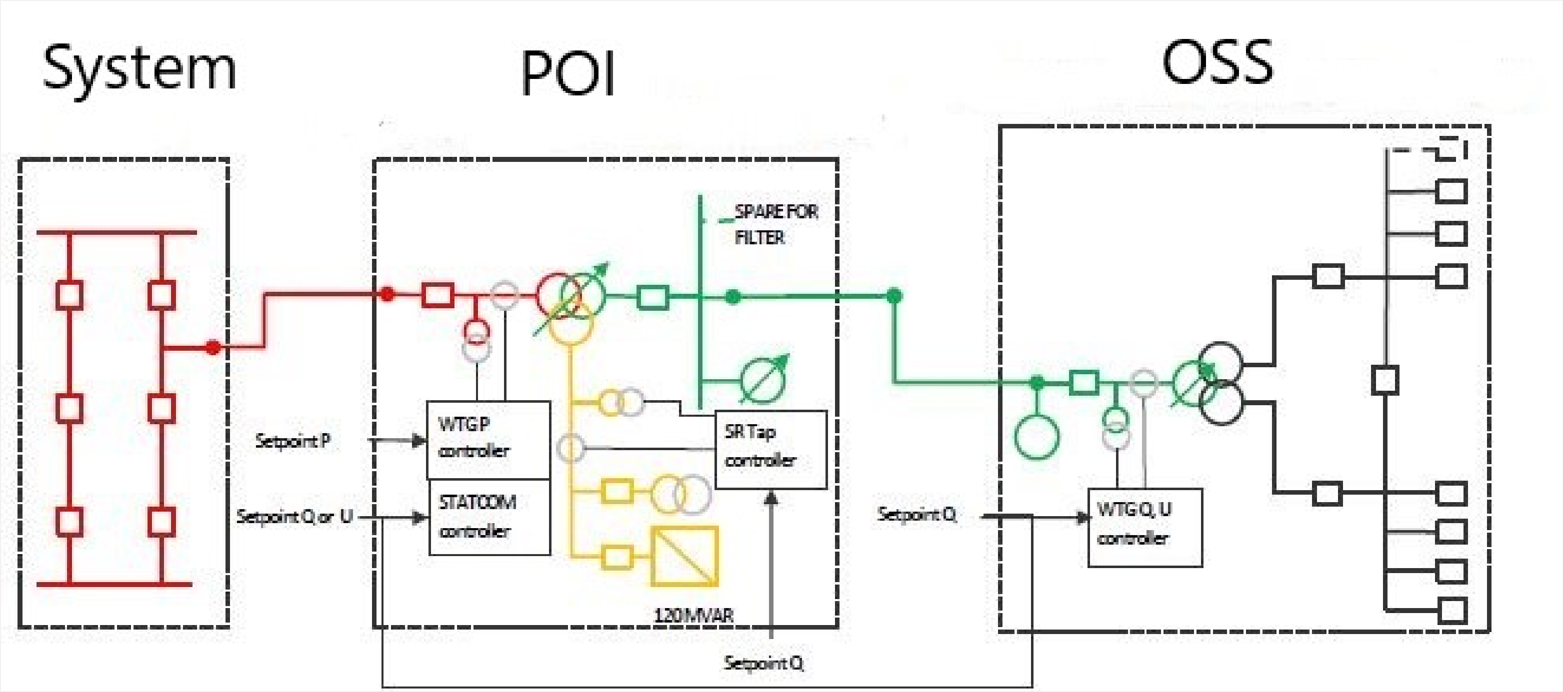
- Task 19 – EMT Model Review and Ride-Through/Small-Signal Stability Testing
- Task 20 – RMS-EMT Wind Farm Model Benchmarking Analysis
- Task 21 – EMT Switching and Internal Fault/Clear Analysis
- Task 22 – EMT Dynamic Performance Analysis
- Task 23 – EMT Project Stability Threshold Analysis
- Task 24 – EMT Short-Circuit Current Verification
- Task 25 – Wind Farm Flicker Analysis
- Task 26 – Multi-Frequency Stability Analysis
- Task 27 – SSTI and SSCI Screening Analysis
- Task 28 – Countermeasure and Mitigation Solutions If Required

Offshore Wind Integration Considerations

Typical Wind Park Oneline



Offshore Wind Integration Considerations

Week Grids

- Thermal Results
- Wind Park Operating Limits
- Dynamic Results
  - Short Circuit Impact Changes On Stability
  - **Example of SCR change based on N-1**
    - Blue is Strong SCR
    - Red is Weak SCR

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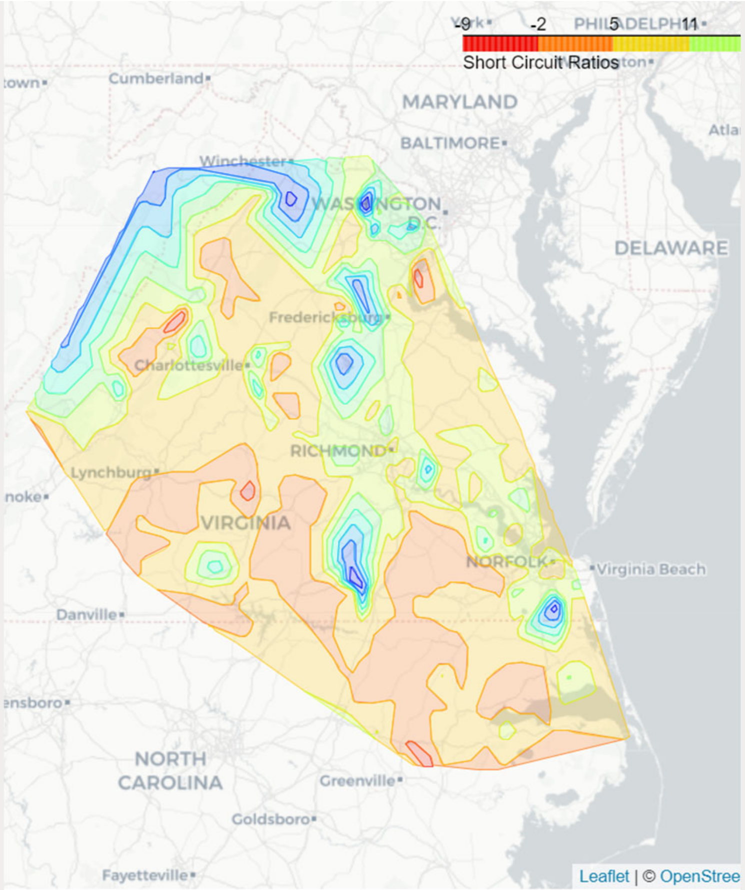
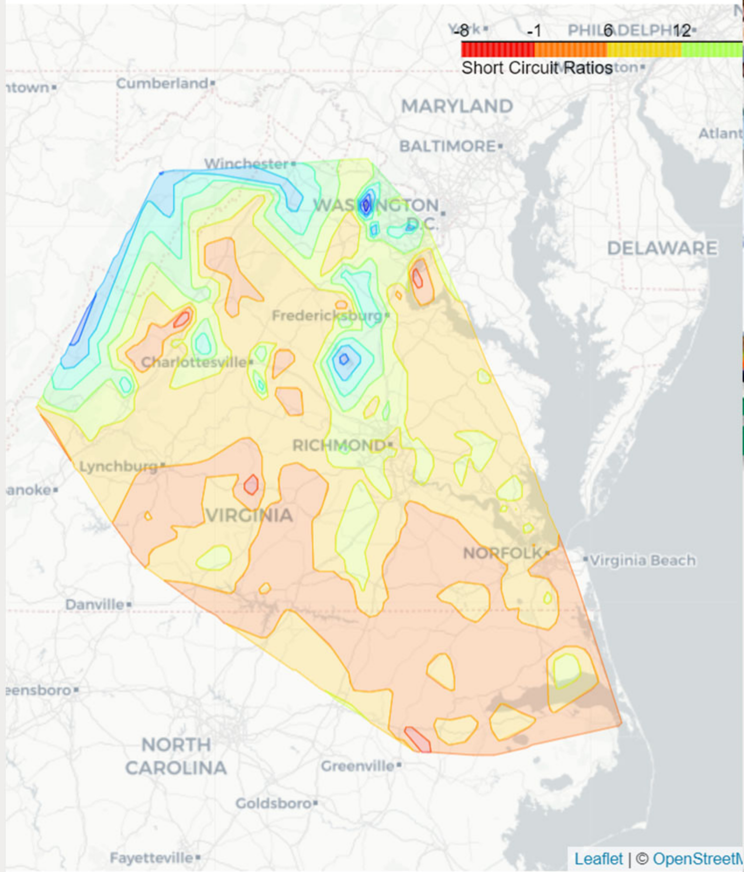
Example Short Circuit Ratio (SCR N-1)





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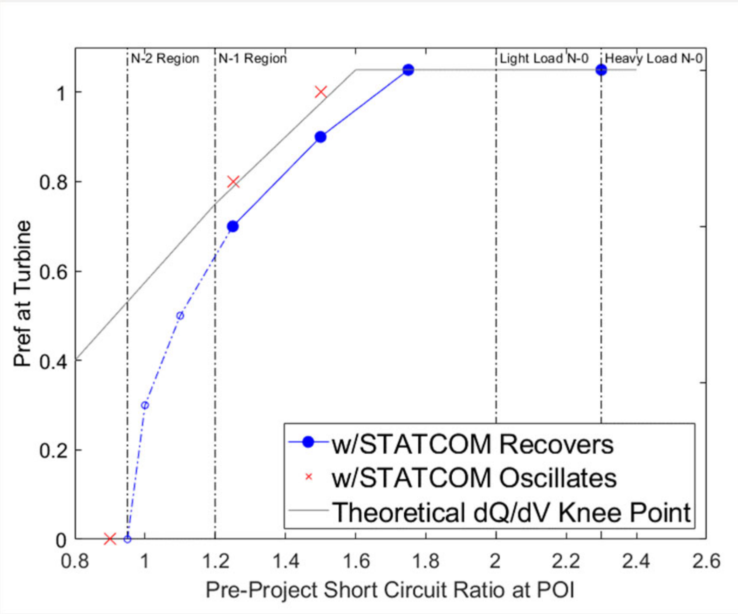
Offshore Wind Integration Considerations

- Example Week Grid Stability



- Direct Connect No Upgrades
- Light Load Generation Model
- Example of STATCOM for more than Voltage Compliance and PF
- Mitigation may be need or reduce the amount of WTG?

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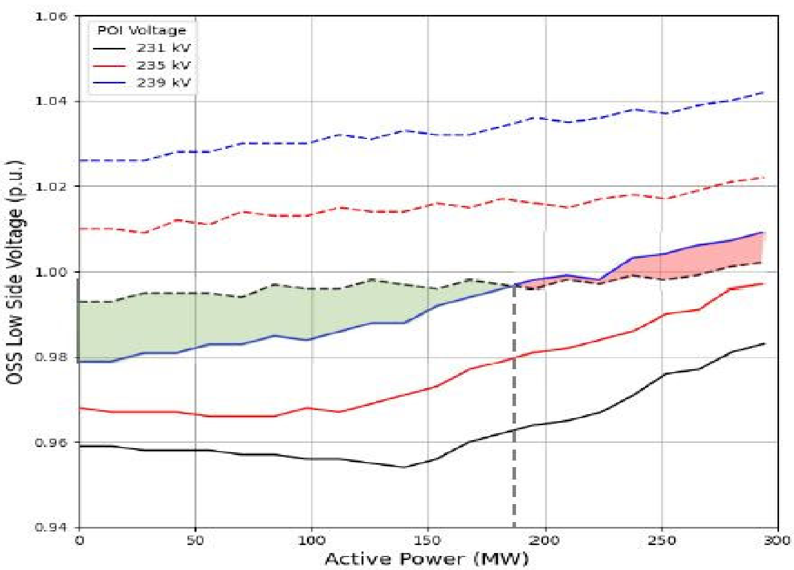
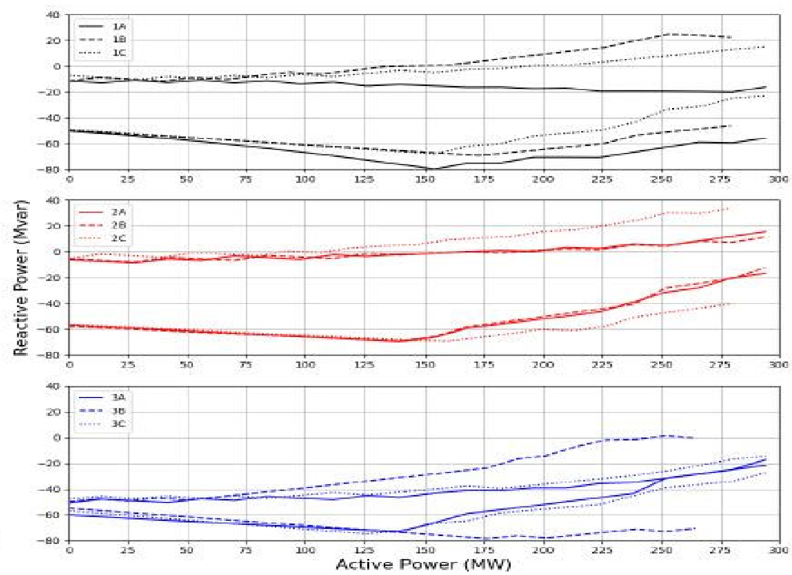
Offshore Wind Integration Considerations

- Cable Selection Considerations

- Wind Park Operating Limits
- Dynamic Support WTG to POI ?
- Thermal Results





Offshore Wind Integration Considerations

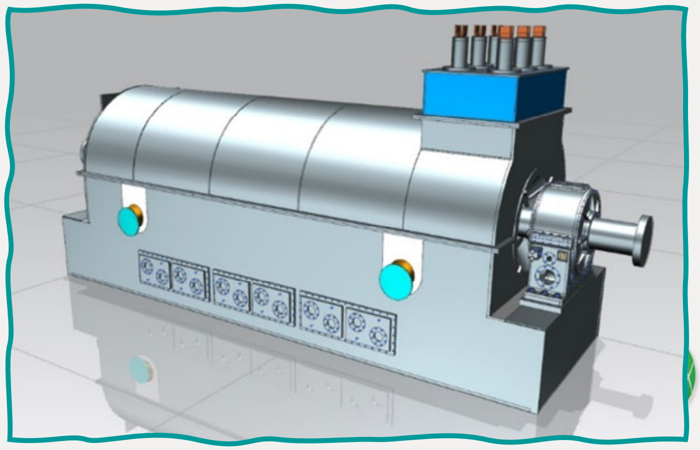
Critical Regulatory Drivers

- RTO will limit Wind Park output to what reliability studies indicate is an acceptable level.
- RTO will re-evaluate this limit every year as network improvements are completed.
- RTO will not allow a Remedial Action Scheme (RAS) or Runback Scheme as an alternative mitigation since any reliability impacts to Customers and the Transmission System can be solved by controlling generation dispatch.

Offshore Wind Integration Considerations

Power Factor Correction

- Reactors installed on Cable Ends to Limit Voltage and Balance Reactive Compensation of Underground Lines.
- Surge Impedance Loading (SIL) and Reactor weight may limit size of reactors
- Asset managers will require single design to reduce spares.
- FACTs devices can be used to balance power factor



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Synchronous Condensers and STATCOMS for Compliance Operation.

- STATCOM may be applied to satisfy FERC power factor requirements, where Synchronous Condenser (SC) rating to achieve necessary dynamic reactive power range would be excessive.
- Potential application of SC for Offshore wind driven by need for system reinforcement, where voltage sensitivity is high (low dQ/dV) for power injection into large system impedance, during network outage conditions.
- SC are synchronous machines without the prime mover.
  - Short-circuit characteristic determined by machine rating, reactance (sub-transient, transient, and synchronous), and transformer (reactance).
  - Continuous and dynamic reactive power response provided through excitation system.
  - Inertial response dictated by machine rotor’s moment of inertia (lesser than machine with prime mover, flywheel can be added to increase).
- Addition of SC will increase dQ/dV (based on the MVA/Xd” relationship of the machine), eliminating or reducing the voltage and power oscillations which develop for a given power injection into large system impedance, thereby increasing the amount of power injection possible for a given network outage condition.
- Additional transmission path cans provide enhanced dQ/dV improvement under high power injection. Application of SC alone cannot reinforce system to extent necessary to accommodate MFO of CVOW during outage conditions.
- Combination of mitigation options (additional transmission, SC, grid-forming converters, control tuning, and/or other network reinforcement) necessary for system to accommodate full power injection.

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Offshore Wind Integration Considerations

Additional Topics

- Controlled Switching of Under Water Cables
- Relay Protection is simple. Overcurrent and differentials
- Monitoring of equipment, WTG and Underwater Cables
- Harmonics – Filter Banks our STATCOM Harmonic Cancelation
- Flicker
- Sub Synchronous Oscillations

THANK YOU !

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Carbon Free Energy

Reliable and Sustainable

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Questions ???

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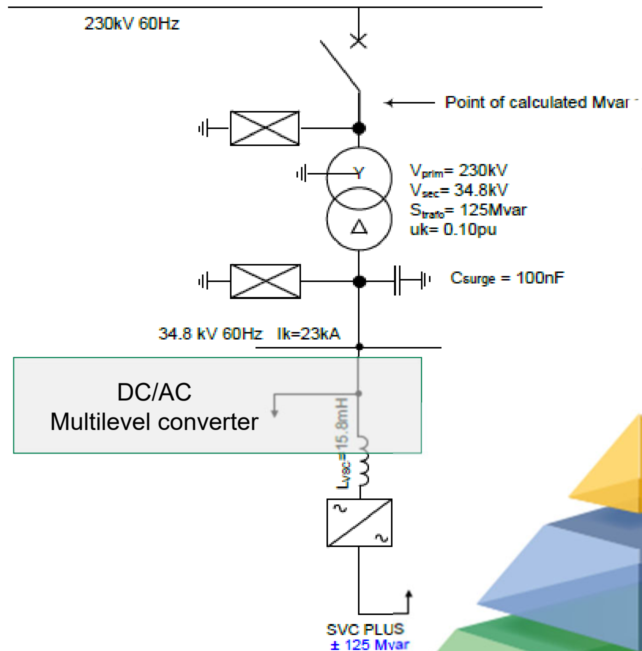
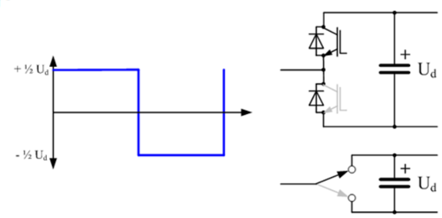
STATCOM

Static Synchronous Compensator



Two-level converter



Multilevel converter