Inverter-Based Integration Study (IBIS) Small-Signal and Transient Stability Studies of SPP

SPP Transient Stability and Small-Signal Security Analysis Studies

A transient stability study will be performed to determine a stability limitation based on wind penetration in the MDWG light load 2022 model based on two base case scenarios of N-0 (planning base case) and N-X (ops outages case). V&R Energy's Fast Fault Scan (FFS) tool will be used to determine the more severe N-1 fault locations in the SPP region for each case. These locations will be ranked according to critical clearing times. Stability analysis for disturbance events will be completed using DSATools Transient Security Assessment Tool (TSAT) for the FFS events with critical clearing times less than 9 cycles. During the stability simulations, monitored parameters will include rotor angle and speed, real and reactive power, bus voltages greater than 100kV in the disturbance area (more than one area may be monitored depending on proximity to the disturbance), transient voltage response, and machine angle rotor damping. Parameters will be compared with the *SPP Disturbance Performance Requirements* criteria.

A small signal analysis will be performed on the stability limited wind penetration cases as described above to determine the existence, modal frequencies, and damping levels of inter-area oscillations within the SPP footprint. The analysis will be completed using DSATools Small Signal Analysis Tool (SSAT).

Task 1 Model development, Benchmarking, Analysis

- **a.** Dynamic Model Development
- **b.** Fast Fault Scan Analysis
- **c.** Transient Stability Analysis

Task 2 Build and benchmark stability models against PSS/E models from Task 1a

Task 3 Perform a transient stability assessment for the identified contingencies in task 1b.

Task 4 Perform prony analysis to identify problematic frequencies of oscillations and associated damping ratios.

Task 5 Perform base case small-signal stability analysis.

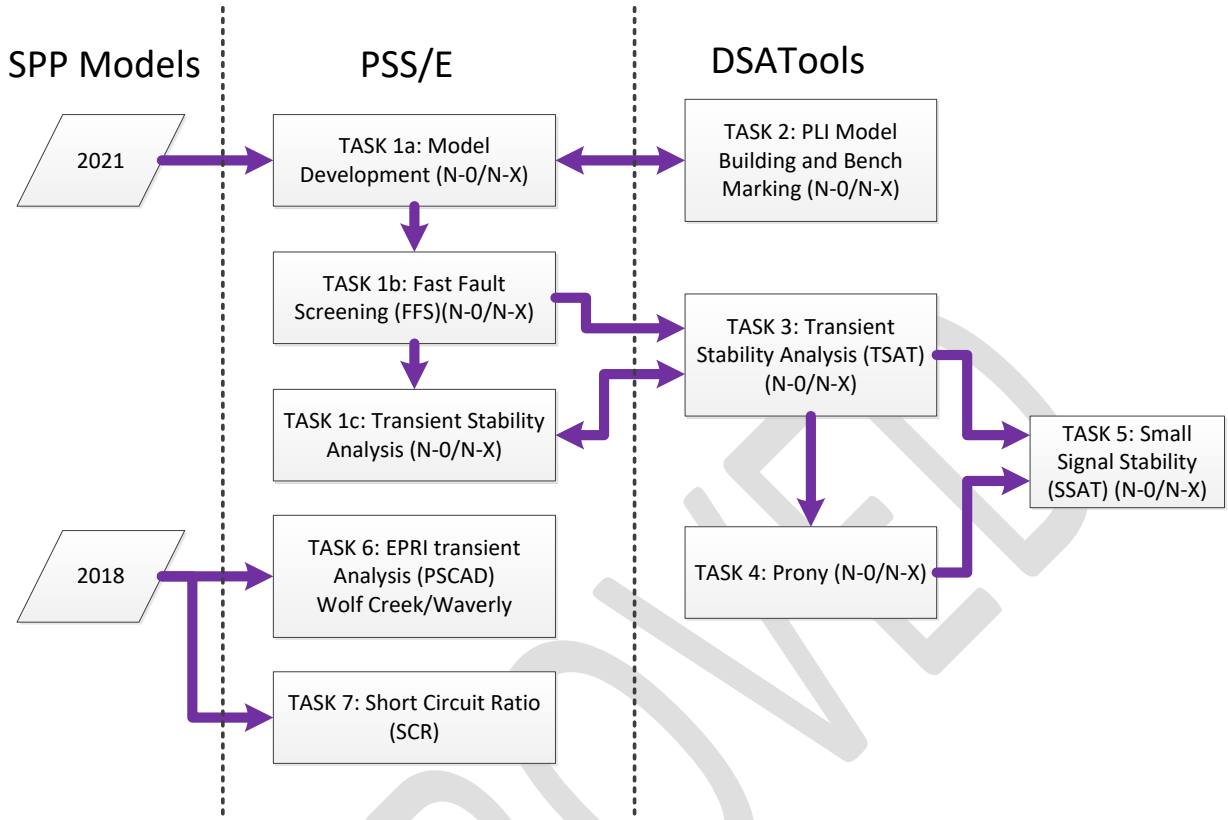
Task 6 EPRI to perform a Transient analysis (PSCAD) for areas of concern.

Task 7 Determine the short circuit ratio (SCR) for inverter-based generation interconnections at existing and new locations, and required minimum criteria.

Schedule of Activities

Activity	Resource	2017 Sept	2017 Oct	2017 Nov	2017 Dec	2018 Jan	2018 Feb	2018 Mar	2018 Apr	2018 May	2018 Jun	2018 Jul	2018 Aug	2018 Sep	2018 Oct	2018 Nov	2018 Dec	2019 Jan	2019 Feb
Scope Doc	OPS/RDSS	ϕ																	
SPP Review	SPP Planning/OPS/RDSS/Modeling		ϕ																
ORWG Scope Review	ORWG						ϕ												
TWG Scope Review	TWG						ϕ												
Solicit Consultant Bids	SPP OPS/RDSS/Purchasing/Legal					ϕ													
Finalize Consultant Contracts	SPP OPS/RDSS/Purchasing/Legal						ϕ												
TWG Project Review	ALL																		ϕ
ORWG Project Review	ALL																		ϕ
Task 1a Dynamic Model Development	SPP Modeling									ϕ									
Task 1b Fast Fault Scan Analysis	SPP RDSS										ϕ								
Task 1c Transient Stability Analysis	SPP RDSS											ϕ							
Task 2 build and benchmark models	PLI/SPP RDSS											ϕ							
Task 3 TSAT transient stability assessment	PLI/SPP RDSS												ϕ						
Task 4 Prony analysis	PLI/SPP RDSS												ϕ						
Task 5 Small-signal stability analysis.	PLI/SPP RDSS													ϕ					
Task 6 EPRI Transient analysis (PSCAD)	EPRI/SPP RDSS												ϕ						
Task 7 Short circuit ratio (SCR) analysis	EPRI/SPP RDSS/SPP GI												ϕ						
Draft Report and Stakeholder Review	ALL																	ϕ	
Final Report	ALL																		ϕ

Task Flowchart



Task 1 Model development.

Approach:

a. SPP Staff with TWG input and review will develop both N-0 and N-X dynamics models to simulate a specific operating condition with high renewable dispatch in a light load case using MDWG models. The existing first generation generic wind models will be replaced with newer second-generation wind models. The dynamic models will be developed using Siemens PTI PSS/E version 33.7.'

b. SPP Staff will use V&R Energy's Fast Fault Scan (FFS) tool to determine the more severe N-1 fault locations, above 100 kV, in the SPP region for the N-0 and N-X models. The severe faults will be ranked according to critical clearing times. SPP Staff will coordinate with affected system TO's to determine the field clearing times for those events identified in the FFS. The clearing times to be used in the time domain simulation performed in task 3 will be the greater of the FFS critical clearing time or the actual field setting clearing time.

c. SPP Staff will perform a transient stability analysis on the N-0 and N-X cases using PSS/E for the identified FFS events in task 1b, with critical clearing times less than 9 cycles. During the stability simulations, monitored parameters will include rotor angle and speed, real and reactive power, bus voltages greater than 100kV in the disturbance area, transient voltage response, and

machine rotor angle damping. These results will be provided for comparison with TSAT results in task 3.

Data Requirements:

The following data will be provided by SPP Staff.

- Siemens PTI PSS/E power flow cases, and dynamics data files
- List of operations outages (generation, lines, transformers) added to the base MDWG model
- Resource additions to obtain the desired wind penetration levels
- Resource dispatch modifications
- Data for converter technology for wind farms: either doubly-fed induction machines or full-converter interface.
- PSS/E transient stability results output data.

Deliverables: (Task 1)

A report of the model development.

- Updated Siemens PTI PSS/E dynamic models
- Dynamic data
- Load and generation levels
- Wind penetration levels
- Outages
- FFS results
- Events for time domain simulations
- Event clearing times to be used in the time domain simulations
- Up to 20 contingencies per case for PSS/E dynamic stability simulation purposes.
- PSS/E transient stability results output results.

Task 2 proposal details.

Approach:

SPP staff will provide the N-0 and N-X models, data, and simulation results as developed in task 1a to facilitate conversion into dynamic models into PLI DSA Tools TSAT, SSAT, and PSAT formats. Models will be benchmarked with the PTI models using a no fault and test fault simulation.

The quantities to be benchmarked are rotor angles of synchronous machines in SPP footprint with MVA base greater than 100 MVA.
PLI will replace unsupported black-box wind farm models with generic renewable models.
PLI will tune up to 15 generic renewables models to improve benchmarking results, if benchmarking results are not acceptable to SPP.

Data Requirements:

The following data will be provided by SPP.

- Siemens PTI PSS/E power flow cases, and dynamics data files
- Test fault event file
- List of operations outages (generation, lines, transformers) added to the base MDWG model
- Any resource additions to obtain the desired wind penetration levels
- Resource dispatch modifications to obtain the desired wind penetration levels.
- Converter technology for wind farms: either doubly-fed induction machines or full-converter interface.
- Up to 20 contingencies per case for TSAT dynamic stability simulation purposes.
- PSS/E transient stability results output data.

Deliverables: (Task 2)

A report of the model development and benchmarking results.

- PLI TSAT, SSAT, and PSAT models
- Load and generation levels
- Benchmark results
- Wind penetration levels
- Outages
- Dynamic data
- Modifications to generic renewable models
- Users models replaced with generic renewable models

Task 3 proposal details.

Approach:

A transient stability analysis on the N-0 and N-X cases will be performed using DSATools TSAT for the identified FFS events in task 1b, with critical clearing times less than 9 cycles. During the stability simulations, monitored parameters will include rotor angle and speed, real and reactive power, bus voltages greater than 100kV in the disturbance area, transient voltage response, and machine rotor angle damping. The parameter values will be compared with the *SPP Disturbance Performance Requirements* criteria. DSA Tools TSAT results will be compared with PSS/E results in Task 1c for both N-0 and N-X cases.

Deliverables: (Task 3)

A report of the study will be produced containing the following information:

- TSAT results
- Security violations
- Recommended corrective action plans (No NTCs will be issued from this study)
- Transient stability comparison results

Task 4 proposal details.

Approach:

SPP Staff will perform a prony analysis to identify oscillatory modes for problematic events identified in transient stability results of task 3.

Deliverables: (Task 4)

A report of the study will be produced containing the following information:

- Oscillatory modes and damping ratios for each of the identified contingencies.

Task 5 proposal details.

Approach:

For the N-0 and N-X cases PLI and SPP Staff will perform a base case small signal study using DSATools SSAT to verify oscillatory frequencies and damping ratios identified in the prony analysis from task 4. Consultant and SPP Staff will determine machines and areas participating in identified inter-area oscillatory behavior of the SPP system. Consultant and SPP Staff will determine the impact severity and recommend necessary mitigations.

Deliverables: (Task 5)

A report of the study will be produced containing the following information:

- SSAT results
- Identified problematic machines in each identified severe oscillatory modes
- Oscillatory mode impacts
- Recommended mitigations

Task 6 proposal details.

Approach:

SPP staff will provide EPRI with all data and models required for a transient analysis to determine intra-area oscillatory behavior of the existing system due to interactions with inverter based generation near areas of concern. Multiple scenarios will be performed to capture possible topologies, and system stresses. EPRI will build the three-phase model from SPP provided data and perform the transient analysis using PSCAD or EMTP type program. EPRI will deliver the data and results in a final report as required.

Data Requirements:

The following data will be provided by SPP.

- Siemens PTI PSS/E power flow and short circuit models
- Dynamics data files, to include second generation wind models
- Relay fault clearing times
- Substation onelines
- Any applicable operating guides.

Deliverables: (Task 6)

A report of the model development and benchmarking results including the following:

- PSCAD or EMTP models
- Analysis results
- Load and generation levels
- Wind penetration levels
- Topologies studied
- Dynamic data
- Short circuit ratios
- Recommendations

Task 7 proposal details.

Approach:

Calculate the Short Circuit Ratio (SCR) at points of interconnection of existing inverter based generation within the SPP footprint. A combined SCR calculation method will be used where multiple inverter-based resource interconnections exist electrically close, according to the NERC "Integrating Inverter-Based Resources Into Weak Power Systems", Reliability Guide, June 2017. Results will be compared to existing industry standards.

Data Requirements:

The following data will be provided by SPP.

- Siemens PTI PSS/E power flow and short circuit models
- Dynamics data files, to include second generation wind models
- Substation onelines
- Any applicable operating guides.

Deliverables: (Task 7)

A report of the model development and benchmarking results including the following:

- PSCAD or EMTP models
- Analysis results
- Load and generation levels
- Wind penetration levels
- Topologies studied
- Dynamic data
- Short circuit ratios
- Recommendations