California Independent System Operator Renewable Integration Study

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California ISO
Your Link to Power

Proposed Transmission Plan for
Integration of Renewables

Transmission System Analysis - Overview

Joint Study between the CAISO and GE Consulting

- Study Objectives
- Assumptions
- Existing Wind Generation
- Additional Wind Generation
- Study Methodology
- Study Results
- Conclusion
- Recommendations

Transmission System Analysis

- Objectives
  - Evaluate transient stability and post transient voltage performance of the Grid with increased levels of wind generation in Tehachapi
  - Evaluate the post-transient voltage stability performance of the Grid with increased levels of wind generation in Tehachapi
  - Evaluate wind plant functional characteristics that are necessary to achieve acceptable static and dynamic performance of the CAISO Controlled Grid
  - Determine any needed improvements to the Grid to achieve acceptable performance with increased levels of wind generation

Voltage Stability (Q-V) Analysis

- Q-V analysis was performed for all critical twenty three contingencies to determine the following:
  - Whether the integration of 4,200 MW wind generation meet applicable WECC planning standards
  - Whether the proposed reactive support provide satisfactory voltage performance (i.e., nose point voltage) under critical contingencies
  - Whether additional analyses will be required to determine the optimal reactive support to meet the WECC voltage stability planning standards and to achieve better voltage performance (i.e., nose point) under Q-V analysis.

The transmission system analysis accounts for existing and new wind installations

The ISO study accounts for about 2,600 MW of existing wind generation

The ISO study assumes 500 MW of new generation is installed in Solano and 3,540 MW in Tehachapi wind areas

Choose to include these in the study because of transmission queue and approved transmission upgrades

Assumptions

- Existing Tehachapi wind generation: 722 MW (mostly connected to Tehachapi 66 kV system) modeled with the WECC Type 1 fixed speed conventional induction generator
- Total new generation for the Tehachapi Transmission Project is 4,372 MW, of which 3,540 MW is new wind generation and 832 MW is comprised of combine cycle and gas turbine
- No dynamic switching of any shunt capacitors was included in the transient stability analysis
- Reactive support modeled in the studies:
  - The Existing Tehachapi wind generation area was modeled with 317 MVAR voltage-controlled shunt capacitors and 500 MVAR fixed shunt capacitors
  - The proposed additional reactive supports 700 MVARs of voltage-controlled shunt capacitors; 917 MVAR of fixed shunt capacitors and two SVC totaling 800 MVAR (one at Antelope and the other at Vincent 500 kV Substations)
  - 1,300 MVAR fixed shunt capacitors were modeled at wind plants.

2010 Summer Peak Load Conditions

- 2010 Summer Peak Load with 1-in-10 year heat wave demand for Southern California and corresponding peak load in Northern California

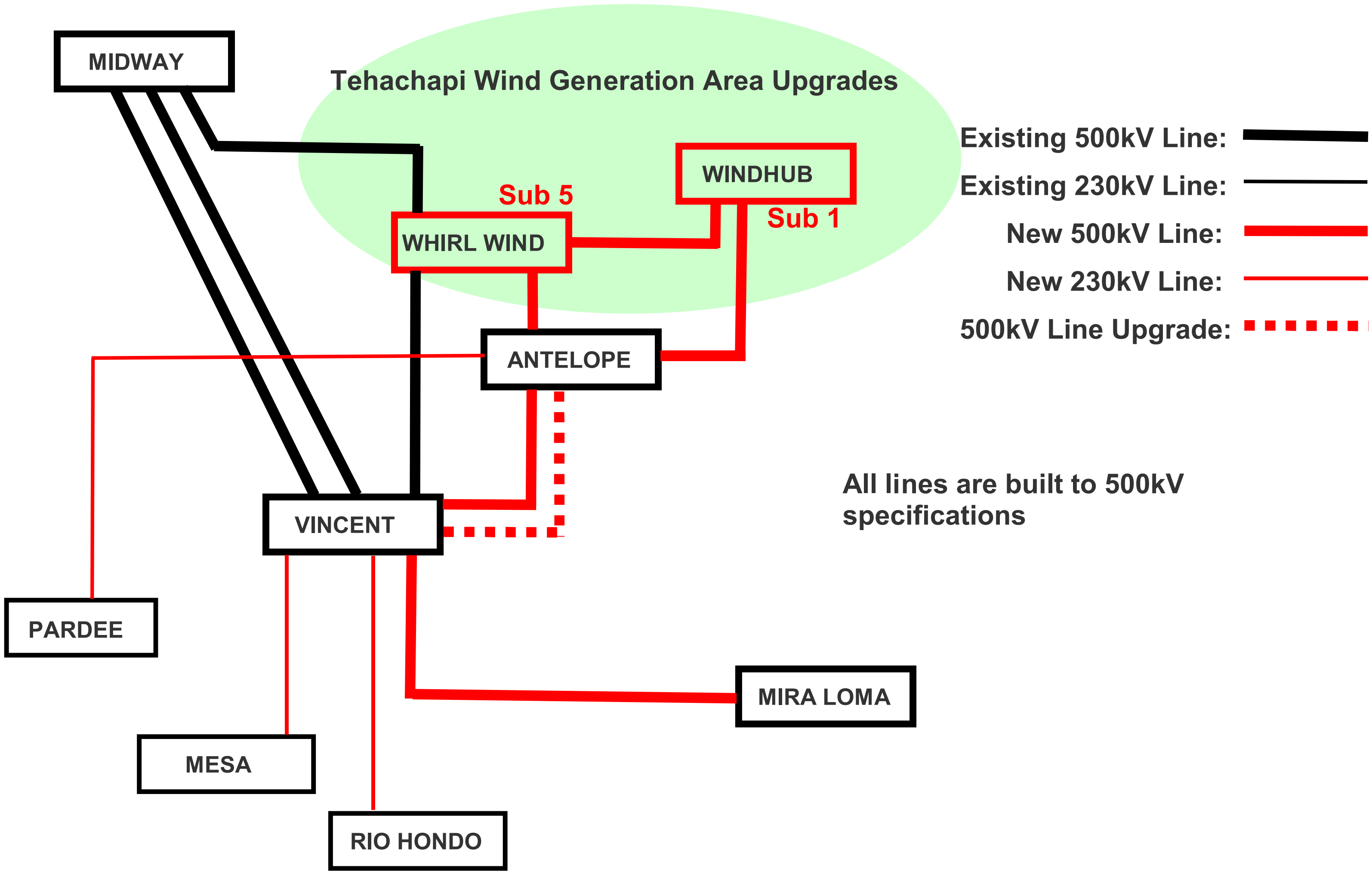
	Summer 2010 Peak Base case MW
COI (Path 66) (N to S)	4,284
Path 15 (N to S)	617
Path 26 (N to S)	4,000
PDCI (N to S)	2,000
West of Borah (E to W)	912
Bridger West (E to W)	1,951

2012 Light Spring Load Conditions

- Light Spring Load conditions with heavy South to North flows on Path 15

	Spring Off-Peak MW
COI (Path 66) S to N	3,542
Path 15 (S to N)	5,400
Path 26 (S to N)	1,583
PDCI (S to N)	2,200
West of Borah (E to W)	1,256
Bridger West (E to W)	2,000

Studies assume Tehachapi and Solano upgrades built on schedule.



All lines are built to 500kV specifications

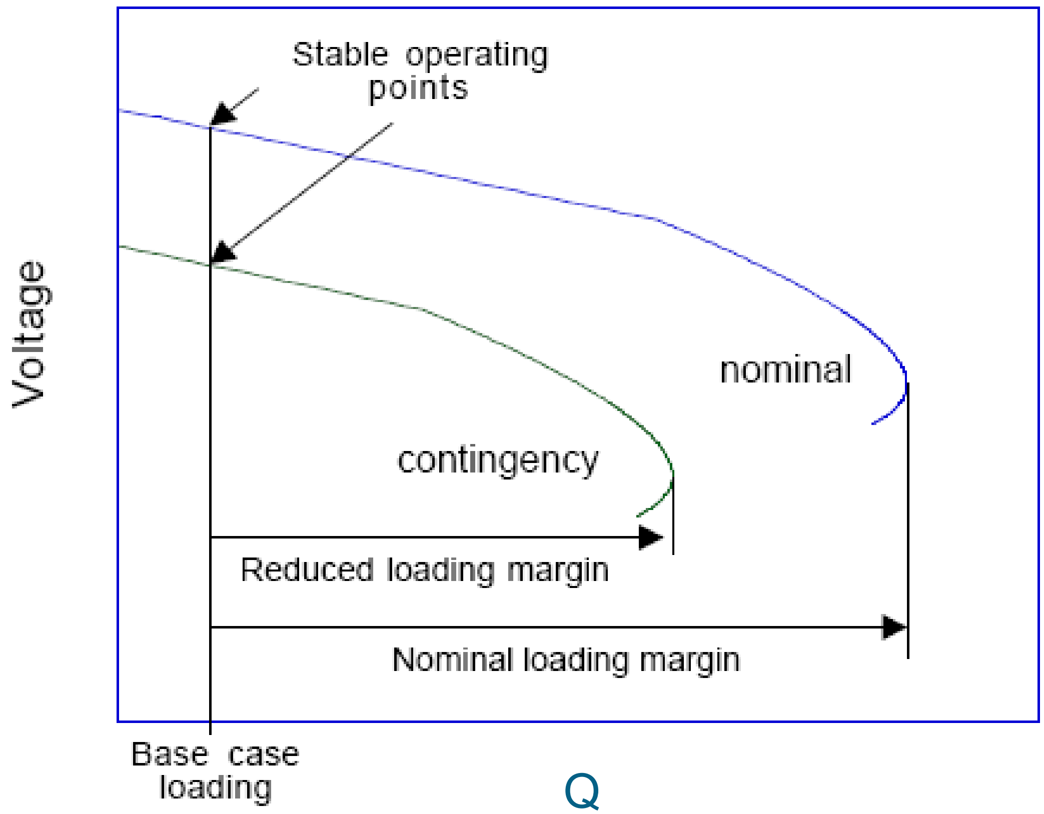
The analysis considered reactive power issues, as displayed in this typical Q-V “nose” curve.

Conclusions include:

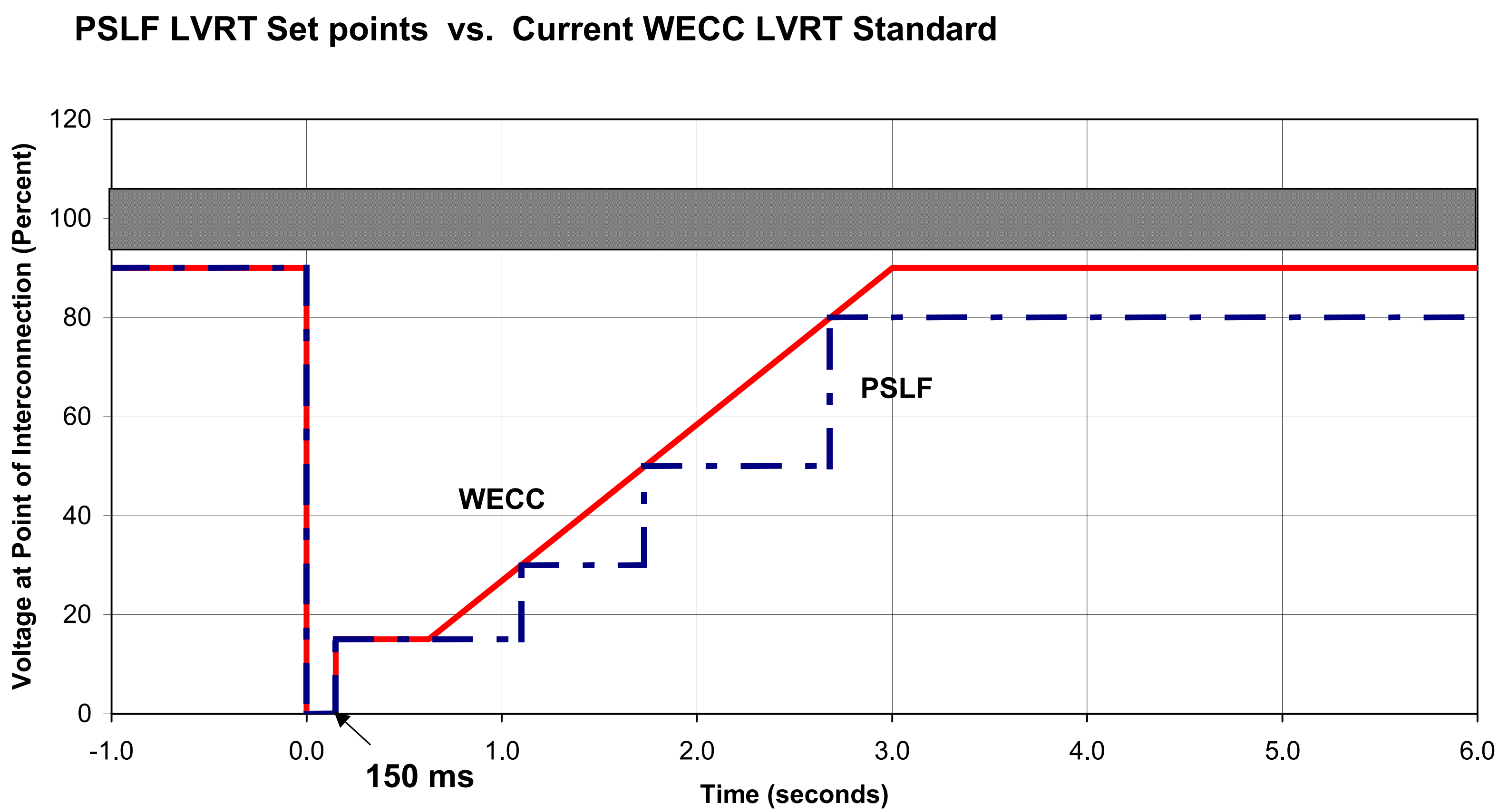
Existing & planned dynamic reactive infrastructure is adequate

Adequate reactive margins at 500 kV and 230 kV buses

New type 3 and 4 units meet WECC LVRT requirements and are essential to preventing post-contingency tripping



WECC Low Voltage Ride Through Model



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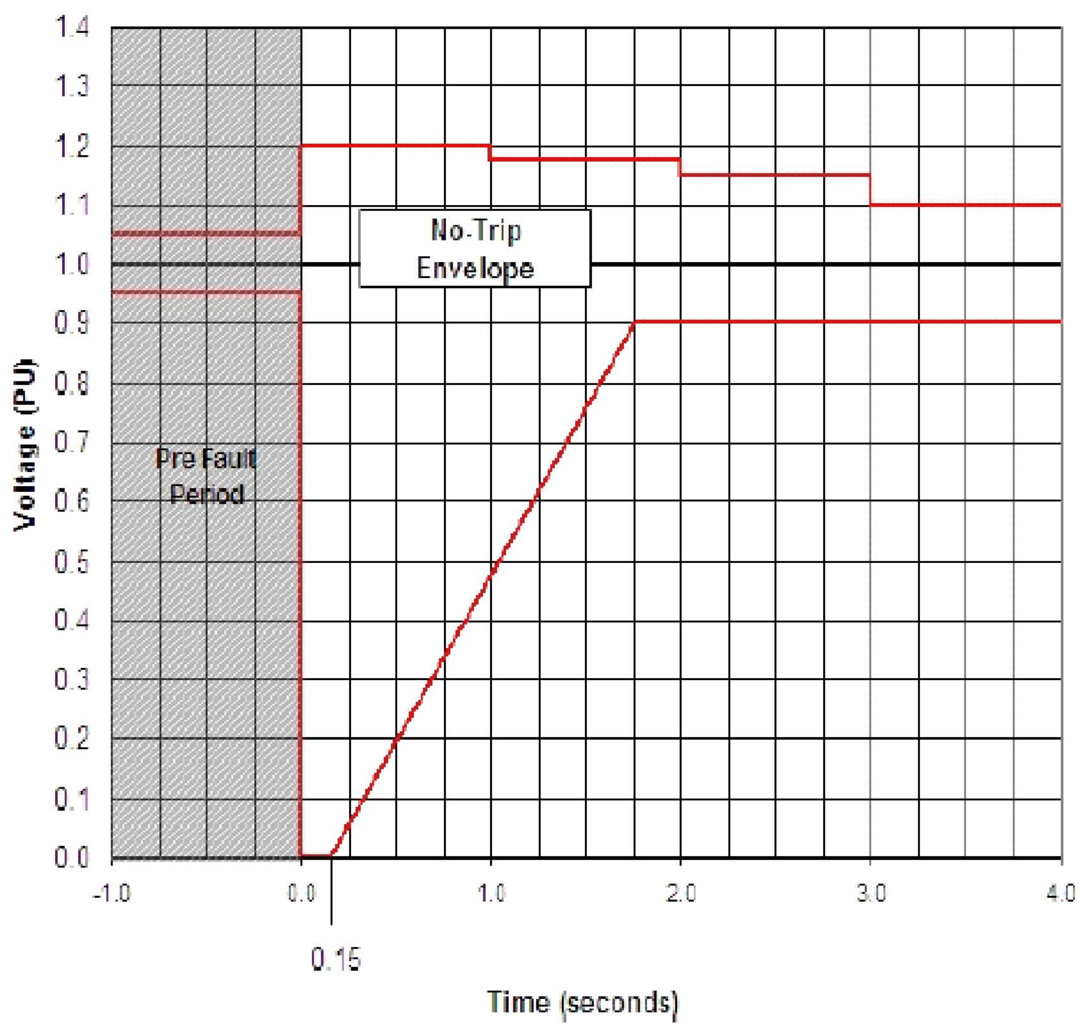

The transmission system analysis considers variety of scenarios and contingencies.

- **Study examines six scenarios**
  - Two base cases
    - Summer peak load conditions, heavy N-S flow on Path 15
    - Spring light load, heavy S-N flow on Path 15
  - Three wind output levels
    - Full wind: all Tehachapi operating at rated MW
    - Low wind: all Tehachapi operating at 25% rated MW
    - No wind: all Tehachapi wind off line
- **Simulated 23 contingencies for six scenarios to evaluate:**
  - Transient stability performance
  - Post transient performance
  - Other sensitivities, such as technology

New wind technologies will meet reliability requirements.

	Configuration	Tehachapi Installed and Planned Capacity	Meets WECC LVRT standards?
Type 1	Conventional induction generator	722 MW (existing)	No
Type 2	Wound rotor induction generator with variable rotor resistance	0 MW	No
Type 3	Doubly-fed induction generator	2,700 MW (forecasted)	Yes
Type 4	Full converter interface	840 MW (forecasted)	Yes

The transmission system analysis addresses transmission stability without accounting for operational issues.

- **Study focused on**
  - Transient Stability Performance
    - System Damping
    - Frequency Response
    - Power Swings
    - Voltage Dip and WTG Tripping
  - Dynamic Reactive Compensation Sensitivity
  - Post Transient Voltage Stability
    - Reactive Power Margin
    - QV Analysis
  - Wind Turbine Technology Sensitivity

Conclusions

- High wind generation at light load has little impact on frequency response due to loss of major generation units
- 4,200 MW of wind generation in the Tehachapi area can be integrated without causing any transient stability concerns providing the proposed Tehachapi Project is built
- Both transient stability and system damping are satisfactory
- Little impact on the frequency response following loss of major generation units (i.e., two Palo Verde nuclear generating units)
- Adherence to the present WECC LVRT requirements for new wind plants is essential for helping to maintain the wind generators on-line under severe fault conditions

Conclusions

- Dynamic reactive capability at wind plants is required to meet the WECC transient dip performance criteria
- The CAISO may consider requiring that a minimum portion of the required power factor range be dynamic for each new plant.
- Based on the transient stability and post-transient study results, the bulk system (500 and 230 kV) shunt capacitors and SVCs proposed in the Tehachapi Transmission Project appear to be conservative. *This will require further analysis to determine the optimal size and location for the dynamic reactive support*
- The sensitivity analysis shows that the proposed SVCs were not sufficient to achieve acceptable dynamic performance if all of the new wind plants were modeled with 100% Type 1

Conclusions

- The post-transient analysis indicated that the grid performance met applicable WECC planning standards, specifically the post-transient voltage deviation and voltage stability reactive margins
- Adequate reactive margins at critical 500 and 230 kV buses were observed for critical contingencies, varying between 950 MVAR and 3400 MVAR for 500 kV buses and between 600 MVAR and 1300 MVAR for 230 kV buses.
- The voltage nose point in the resulting Q-V curves for critical 500 kV buses under critical contingencies is high in the 0.95 – 1.0 p.u. voltage range

Recommendations

- The new wind plants need to comply with WECC LVRT requirements
- The majority of additional new wind plants need to be of the WECC Types 3 or 4
- The proposed reactive support that was proposed as part of the Tehachapi Transmission Project may need to be re-evaluated to determine the optimal location and size for the dynamic reactive support (i.e., SVCs)
- Additional analysis will be needed to determine potential solution for improving the nose point for critical 500 kV buses under critical contingency conditions

Overall, transmission system impacts are manageable.

- Transmission system impacts can be addressed
  - Transmission system impacts on system reliability, transient stability, system damping, and frequency response managed by future use type 3 or 4 wind technology
  - Transmission system upgrades in Solano and Tehachapi wind areas adequate to incorporate wind generation expected by CEC to meet 20% RPS
- 20% RPS target can be met, without adverse transmission system impacts