Impact of High Levels of distributed PV and Load Dynamics on Bulk Power Transient Stability

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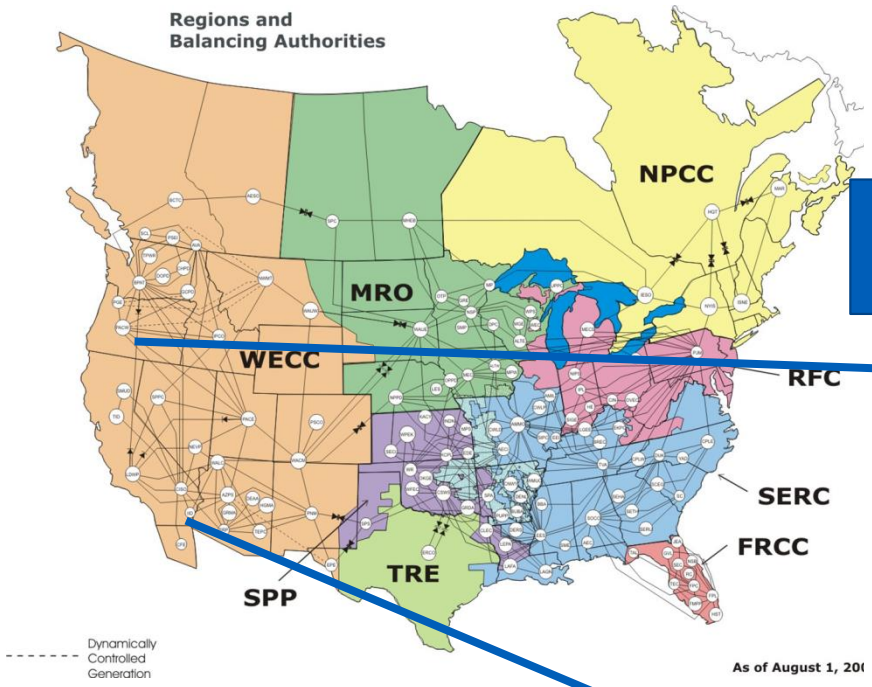
Where are we?



COI

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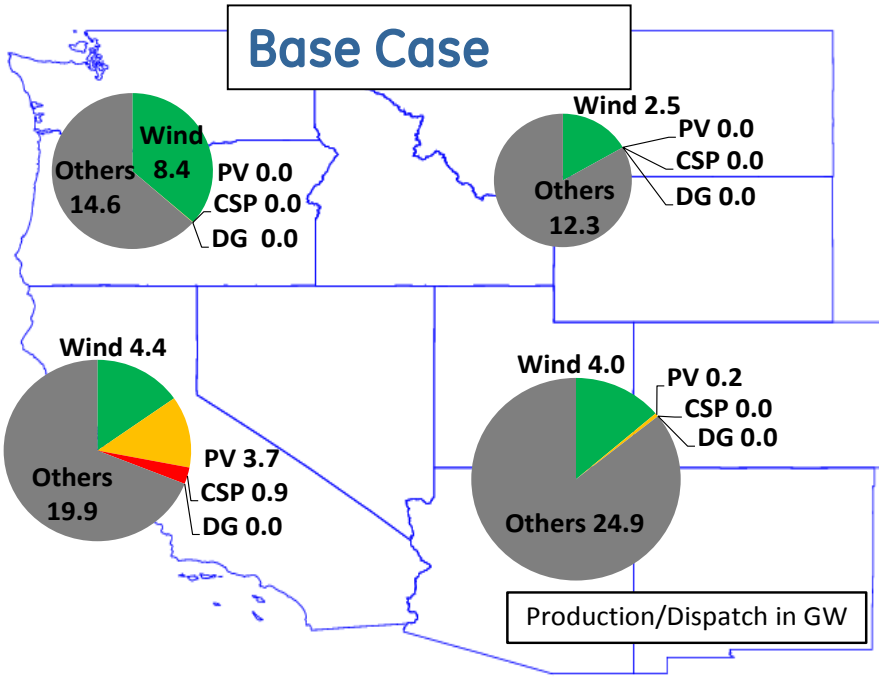
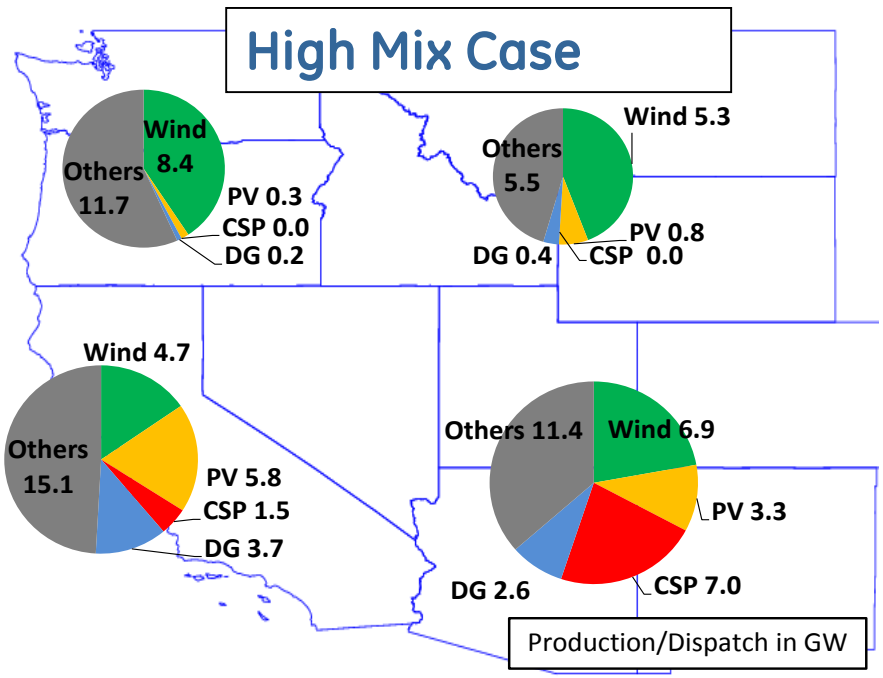
WWSIS-3: Light Spring Load Scenarios

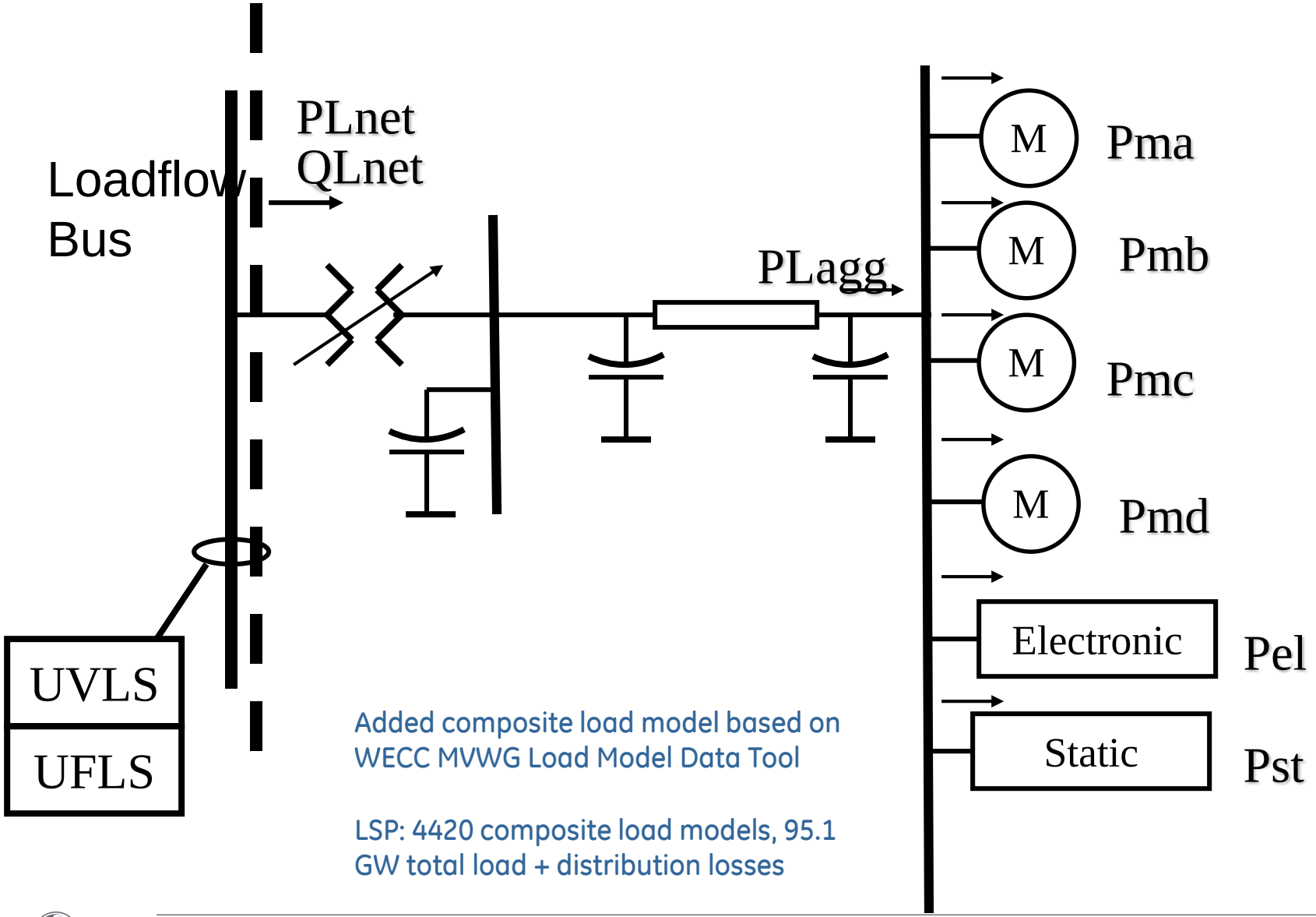




WECC-Wide Summary[1]	Light Spring Base[2]	Light Spring High Mix	Light Spring Extreme Sensitivity
Wind (GW)	20.9	27.2	32.6
Utility-Scale PV (GW)	3.9	10.2	13.5
CSP (GW)	0.9	8.4	8.3
Distributed PV (GW)	0	7.0	10.4
Total (GW) =	25.7	52.8	64.8
Penetration[3] (%) =	21%	44%	53%

(1) Western Electricity Coordinating Council includes parts of Canada and Mexico, (2) Provided by WECC, (3) Penetration is % of total generation for this snapshot.

Composite Load Model Structure



Added composite load model based on WECC MVWG Load Model Data Tool

LSP: 4420 composite load models, 95.1 GW total load + distribution losses

Load-induced voltage collapse

- 500kV bus fault, in high density load region
- Standard load model shows N problem
- Composite loac caused comple system failure
- No load “self-shedding”… important

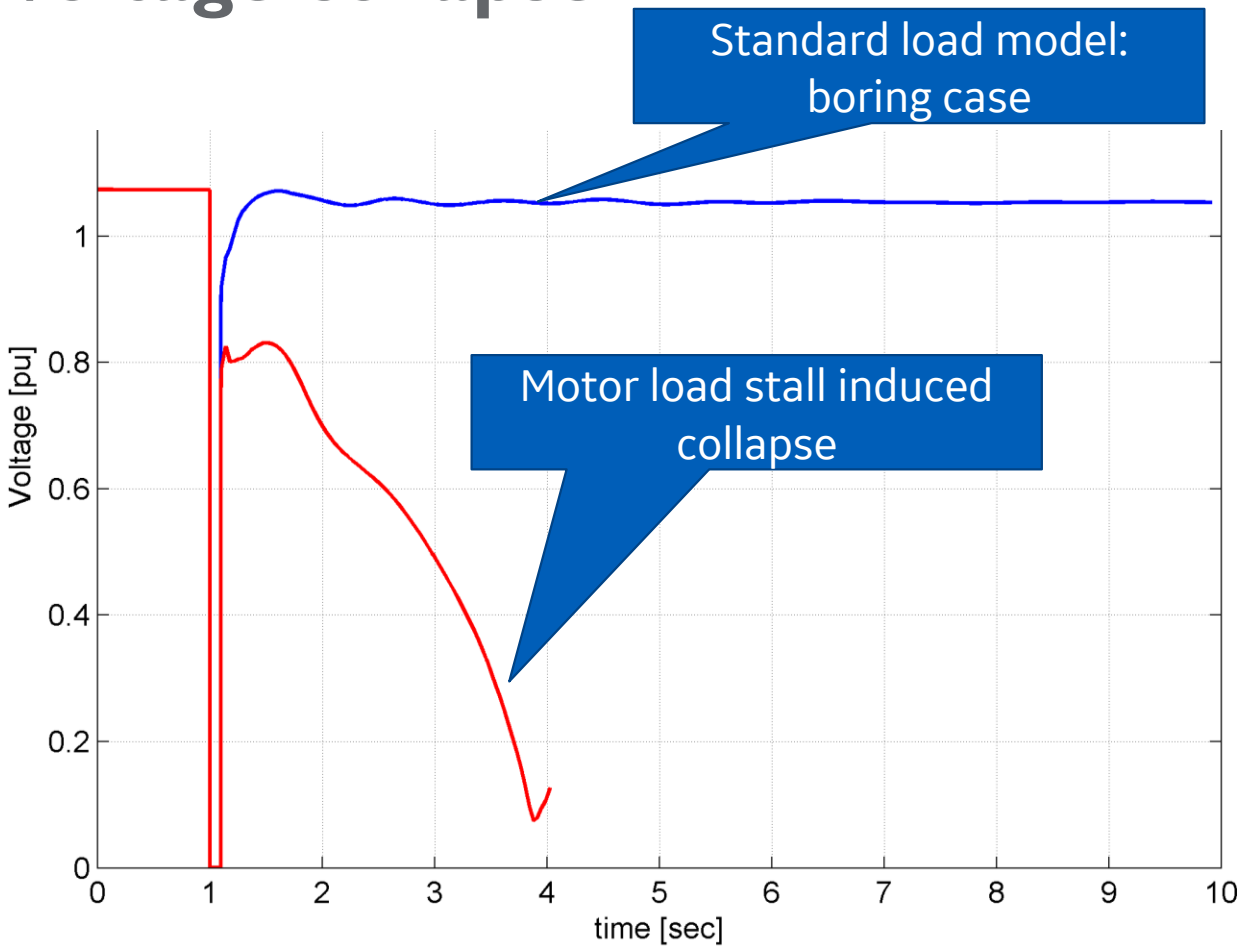
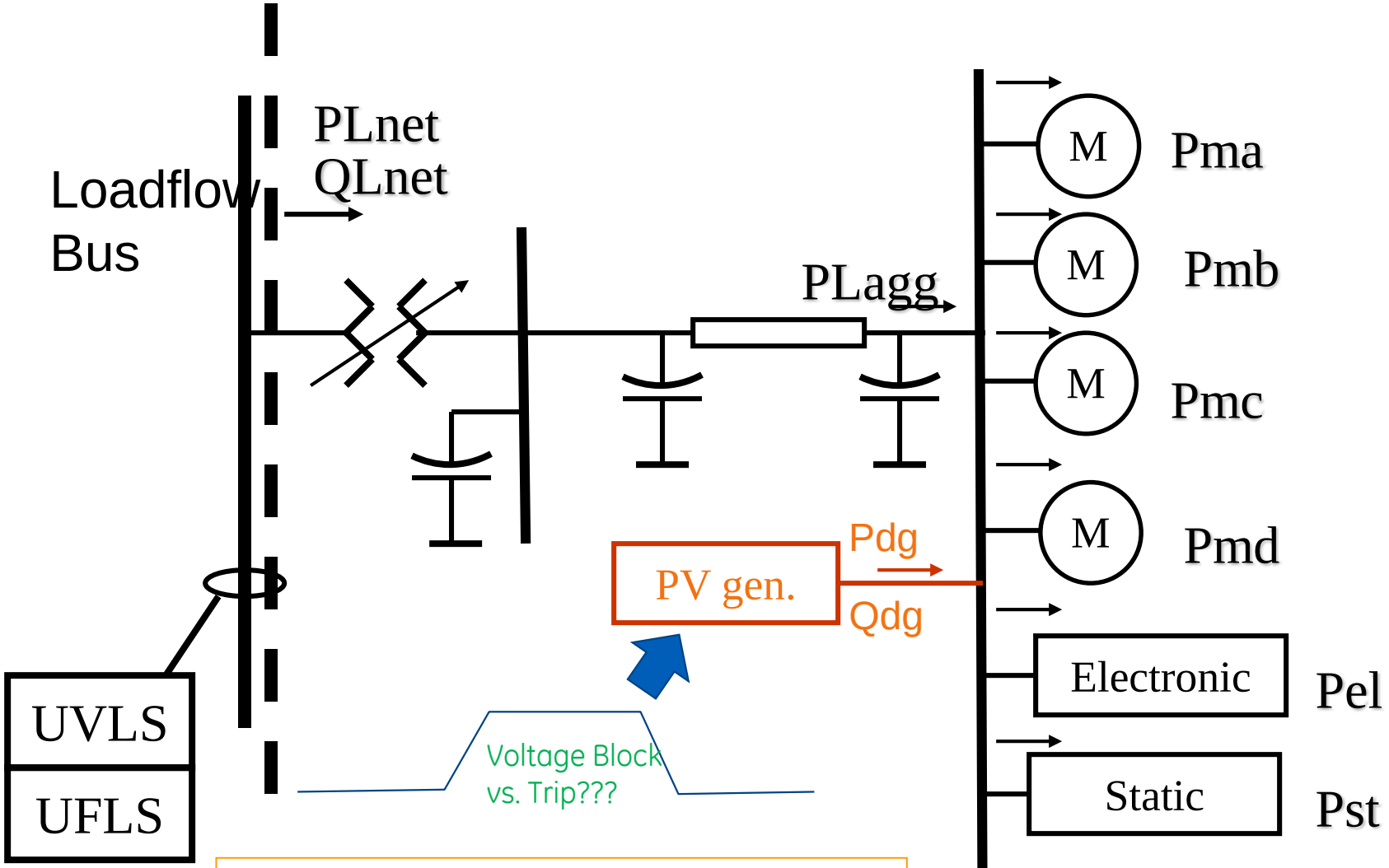


Figure 1. Load-induced voltage collapse

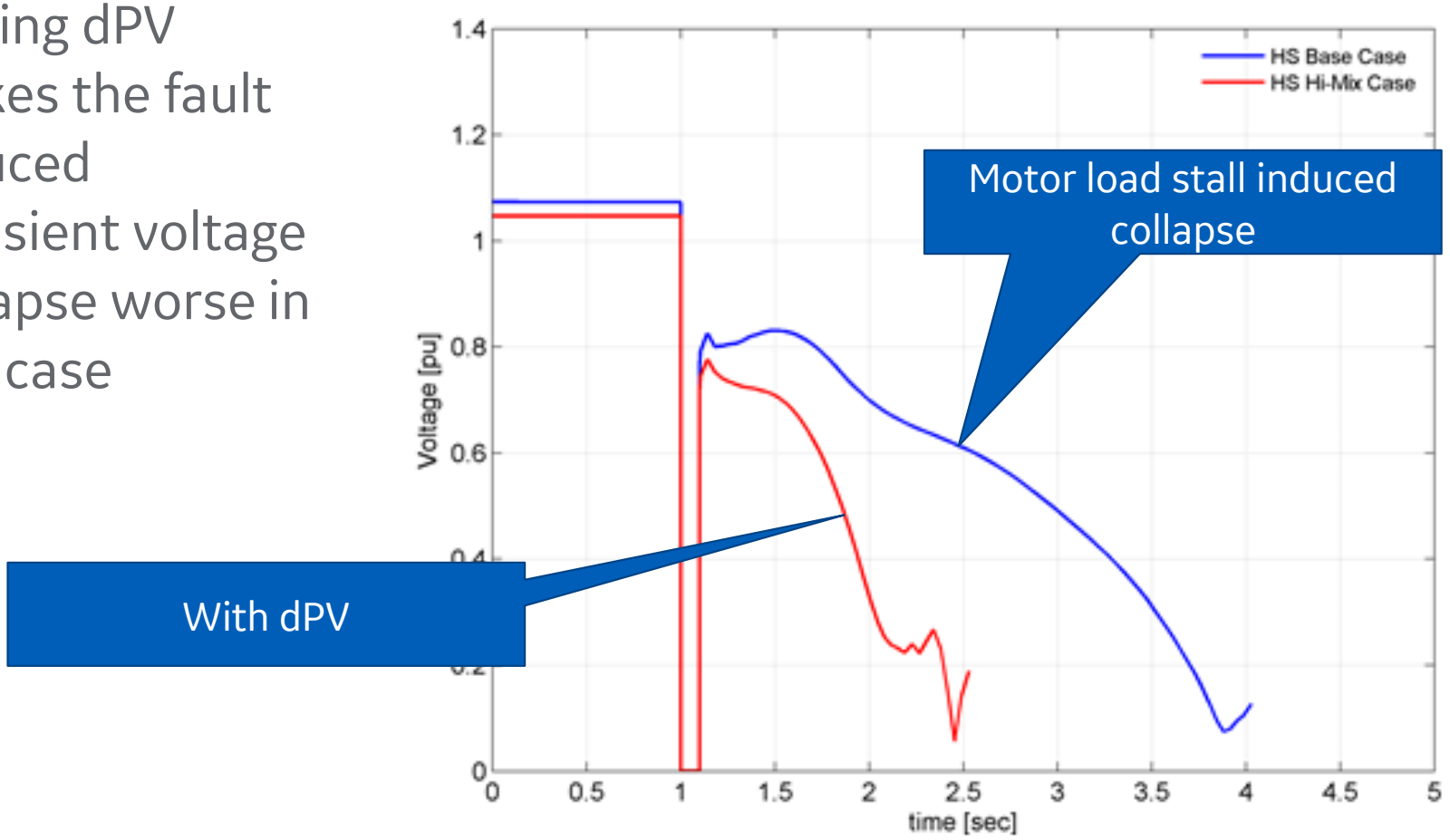
Composite Load Model Structure with Distributed Generation



dPV resides with the load…if you want insight into impact on the BPS, you need a good load model!!

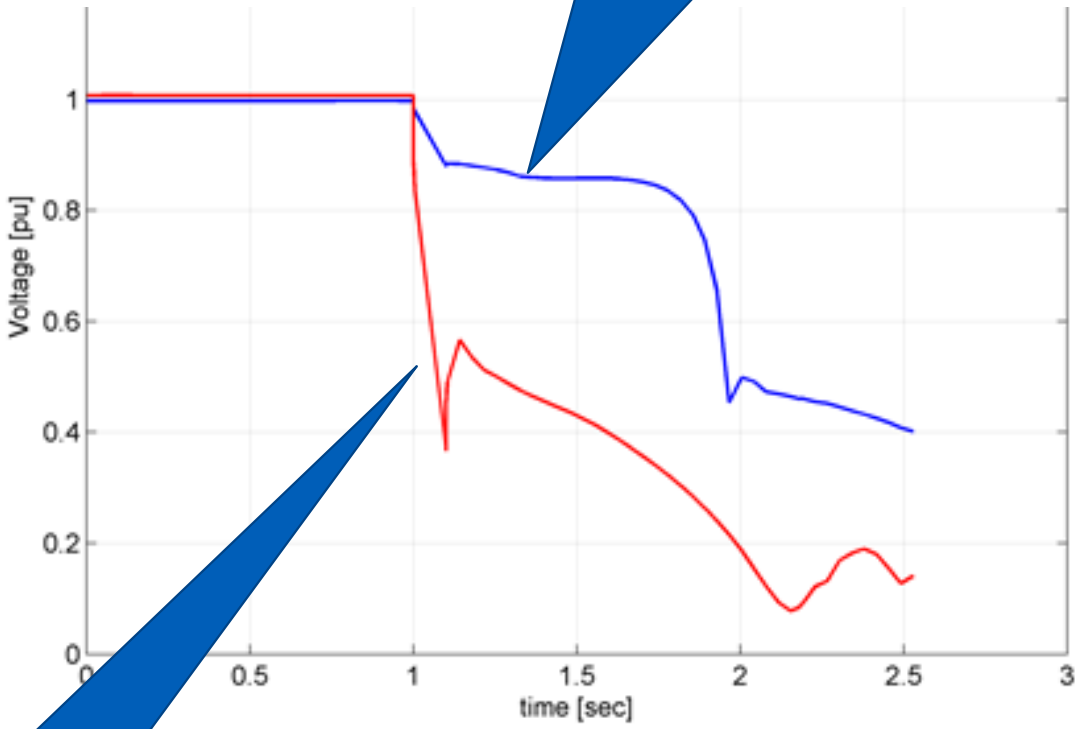
Impact of Distributed PV on Motor Load Stall induced Voltage Collapse

Adding dPV makes the fault induced transient voltage collapse worse in this case



Details of Composite Load Model Behavior

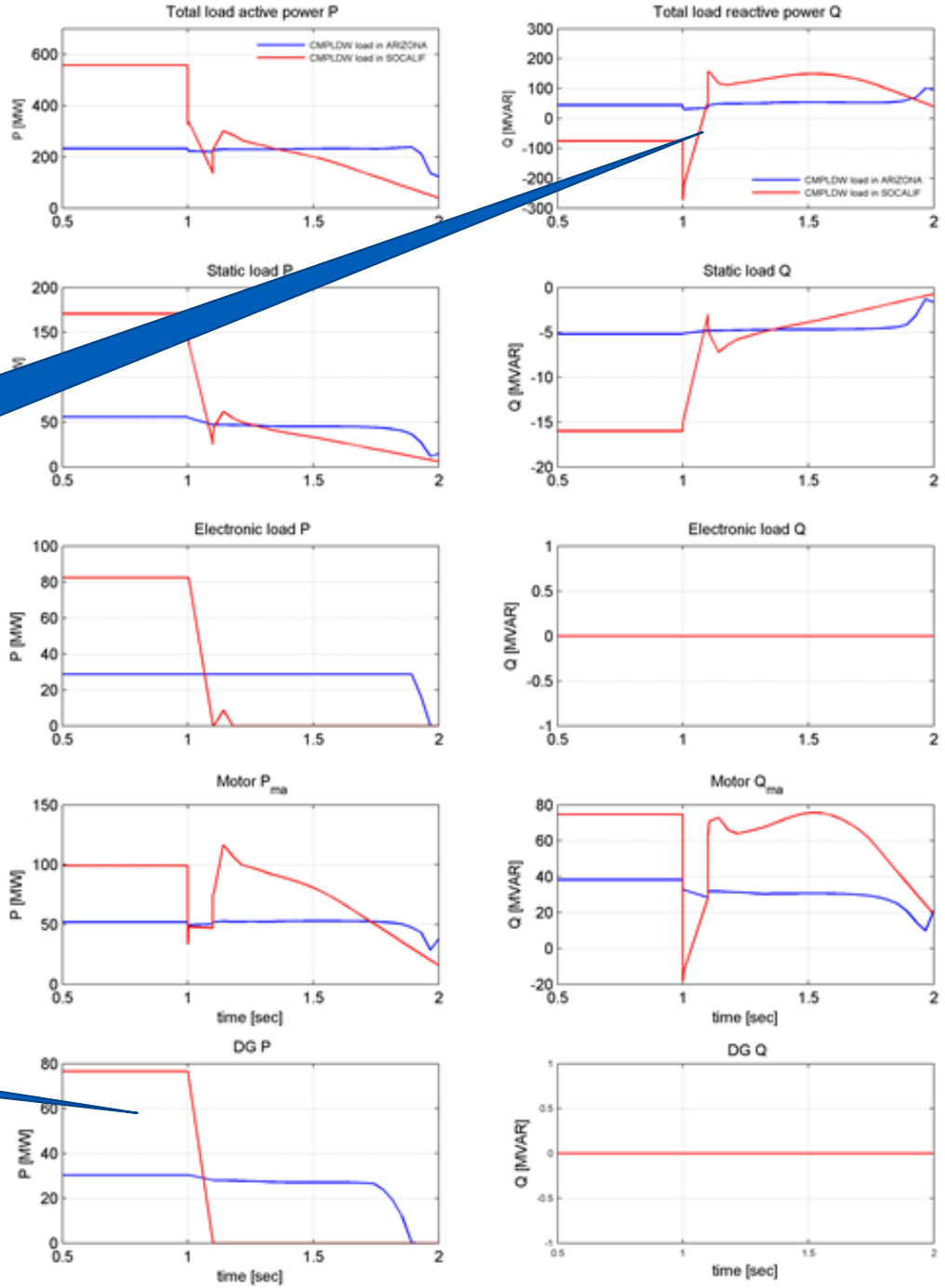
- Load bus voltages at different distances from fault location



Details of load behavior relative to fault proximity

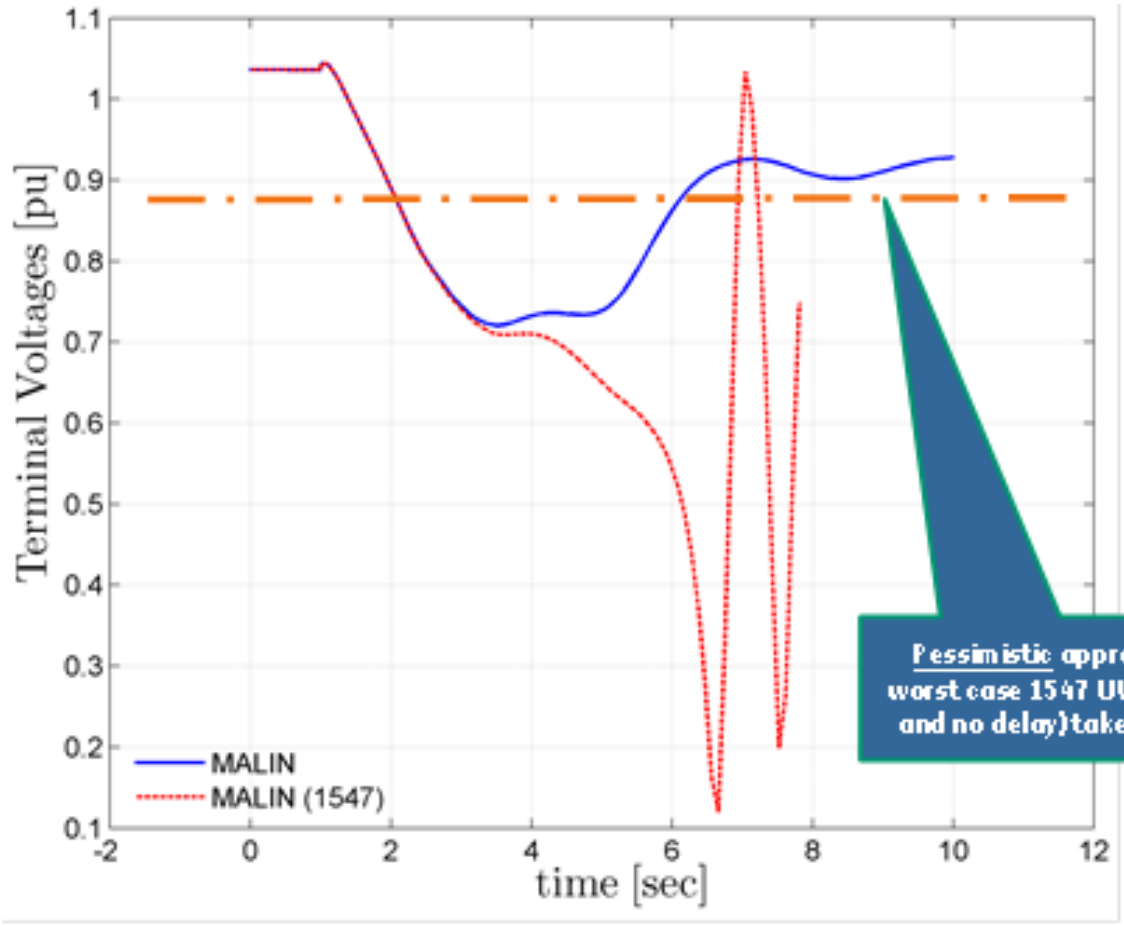
Nearby Q jumps up

Nearby dPV blocks



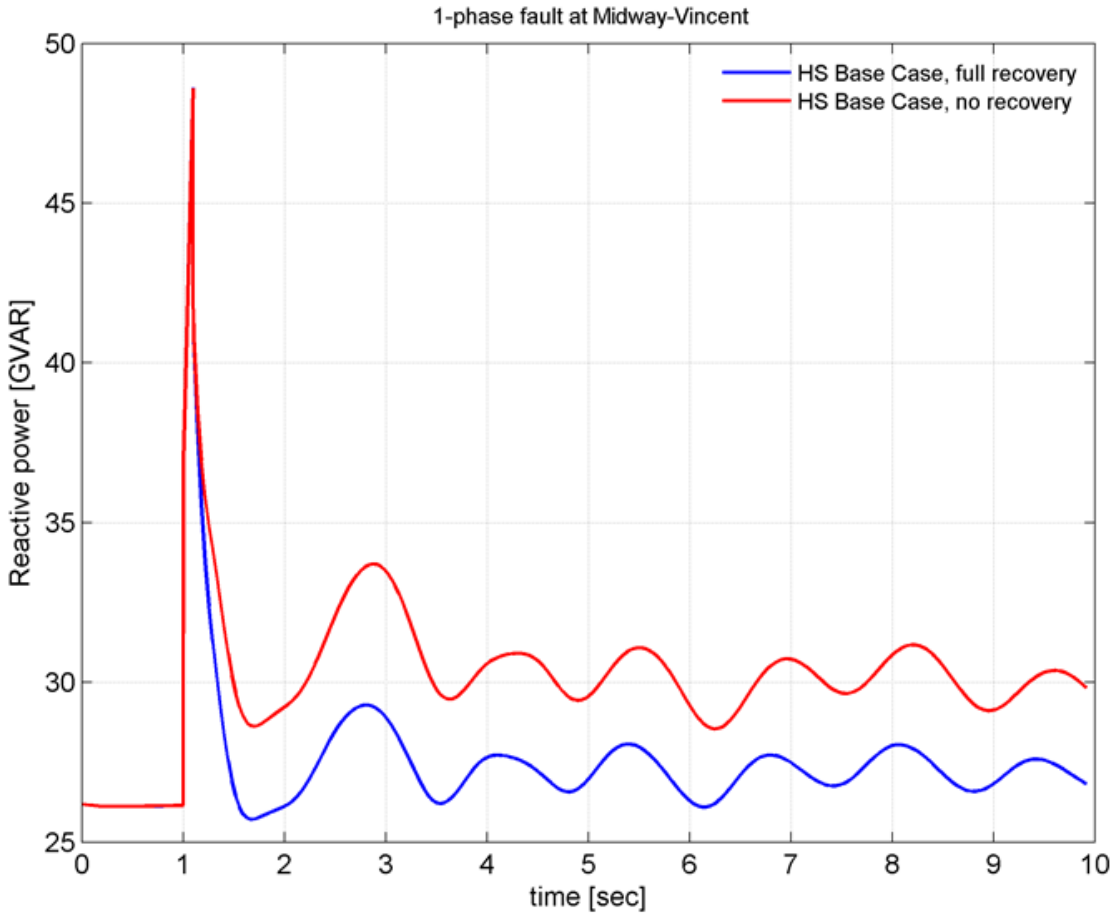
IMPACT OF SOLAR PV RIDE-THRU BEHAVIOR

- dPV assumed to have pessimistic old IEEE 1547 tripping
- Destabilization of entire WECC grid due to DG tripping on voltage dip



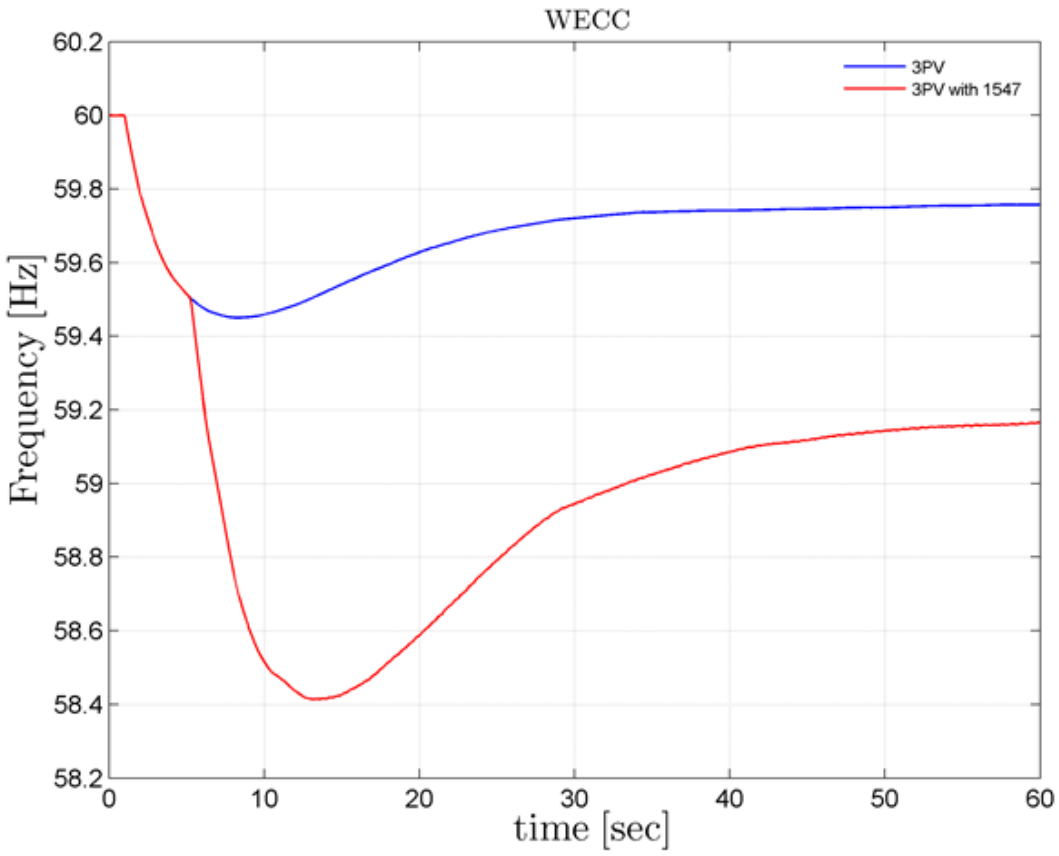
IMPACT OF DISTRIBUTED PV RECOVERY

- Even with transient stability fail; blocking can be a problem
- Reactive power depletion due to DG tripping on voltage dip



Impact of DG Tripping during severe frequency events

- Frequency response to trip of 3 Palo Verde units
- DG trip vs. no DG trip on low frequency can exacerbate system problems



Conclusions

- Dynamic behavior of distributed PV generation has the potential to substantially impact the bulk power system
- Distribution is not decoupled from transmission, and will impact bulk power system operation.
- For transient stability, the system appears to tolerate substantial displacement of thermal generation.
- Poor dynamic behavior of loads can create problems
- Failure of embedded photovoltaics (or other distributed generation) to operate through and, especially immediately after, system faults can greatly exacerbate poor load dynamic behavior.

Conclusions, continued

- In the extreme, such poor behavior can cause system-wide cascading failures.
- Failure of DG to ride-through disturbances can also cause acute shortages of reactive power and voltage stability problems.
- Conversely, as long as the distributed PV does not trip, it is beneficial to stability of the loads.
- Sensitivity of load active power to voltage changes may effect of bulk system frequency response more than load frequency sensitivity.
- Details vary, basic physics doesn't: These conclusions apply broadly to other grids.

Acknowledgements

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Thanks

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