Examining Reliability with High Renewables and Coal Retirements

Experiences from Recent Studies

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Joint CREPC-SPSC-WIRAB Meeting, October 29, 2015

Imagination at work

Changing Generation Mix….. Is the future here?

Trends in generation: more renewables, less coal, cheap gas and more distributed energy resources

Renewable integration/production simulation studies:

- The industry has done many of these to address operational issues (efficiencies, emission reduction, curtailment, ramp rates, duck curves…)
- High level conclusion – we can make it work

Recent activity has moved towards reliability studies

- Frequency response
- Transient Stability & Weak grid issues

Large Eastern Utility Generation Retirement Study

System with high concentration of load & coal generation, strong transmission infeeds

- Generation provides MWs + needed reactive power/voltage control and short circuit strength
- Transmission system capable of supplying substantial MW's but not MVAR's

Uncertain future generation scenarios

- **Generation owners required to give < 1 year notice for retirements**
- **New transmission projects… >5 years**
- Transmission Owner had little to no influence on generation project, including retirements

Work Began in Early 2010....

Probabilistic Planning Study

- Considered 4 levels of generation retirement based on TOs “best guess”
- Base, reasonable, high retirement, extreme retirement
- Considered ~8 transmission projects
- All but extreme retirement scenario could be addressed new transmission

Towards the end of project in late 2010 (8 month after study started), generation owners announced retirements.....

Extreme Scenario Became Reality

Utility had a year to address the problem

Grid Reliability with High Renewables and Coal Retirements

We'll discuss some lessens from recent studies

- WWSIS-3, MRITS and other studies
- Study findings and applications to other regions

High level conclusions – we can make it work but…..

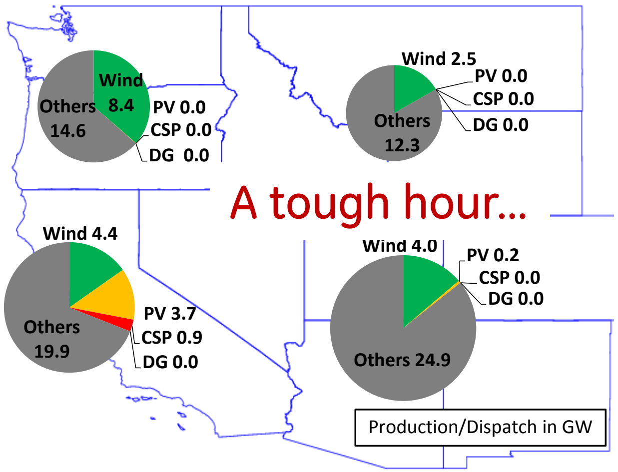
We need to have plans ready before it's too late

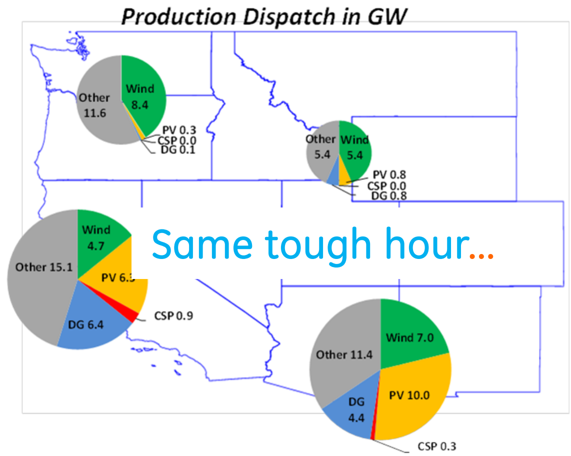
Don't Panic!

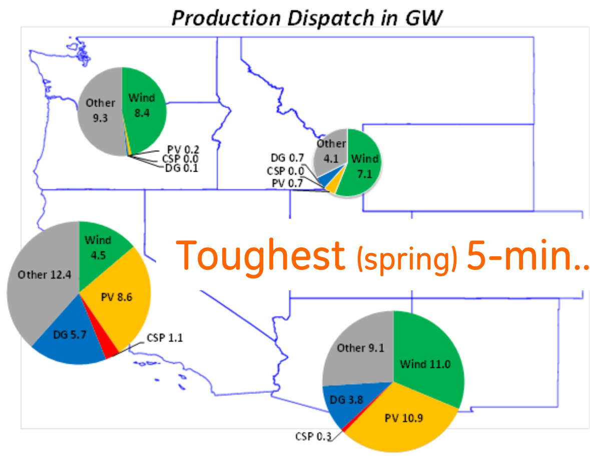
WECC WWSIS3 Example

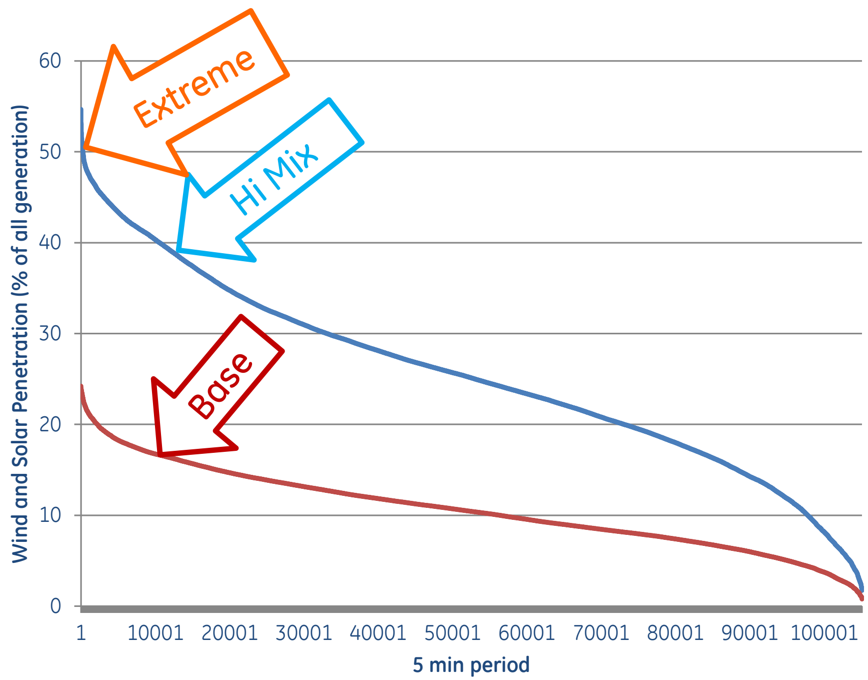
33%High Mix Case

"Base": ~15 % energy…









Synchronous Generation

Post-fault & system event: 0 to 5 sec

- Primarily based on physics (inertia, flux), starts to be influenced controls (excitation system), governor begins to respond
- High short-term overload capabilities

5 sec to 1 minute response

- Frequency response based on autonomous governor control and unit operating point (i.e. open or close valves if unit has capability)
- Many plants don’t respond

Longer-term response (i.e. minutes to hours)

- Local controls give way to centralized controls
- Units controlled by AGC, SCED & operator action (i.e. burn more or less fuel)

Wind and Solar

Post-fault & system event: 0 to 5 sec

- Primarily based on controls, limited by physics, influenced by standards and rules
- Devices do what we tell them to do, no more and sometimes less

0.5 sec to 1 minute response

- Frequency response based on controls if equipped and enabled
- Currently not widely used

Longer-term response (i.e. minutes to hours)

- Dominated by the weather
- Units can always be dispatched down

We can do almost anything with controls

- Active and reactive power controls
- Can be very fast & very grid-friendly

ERCOT completely revamping their frequency ancillary services to better align with physical reality

We can't change physics

What issues can these trends present to operational reliability in this future scenario?

Frequency response

- Response to loss of a large thermal unit (or two) is still most critical event
- Is frequency response acceptable, can you avoid shedding load for critical outages?

Stability issues

- Do flow pattern & generation changes cause new path limits?

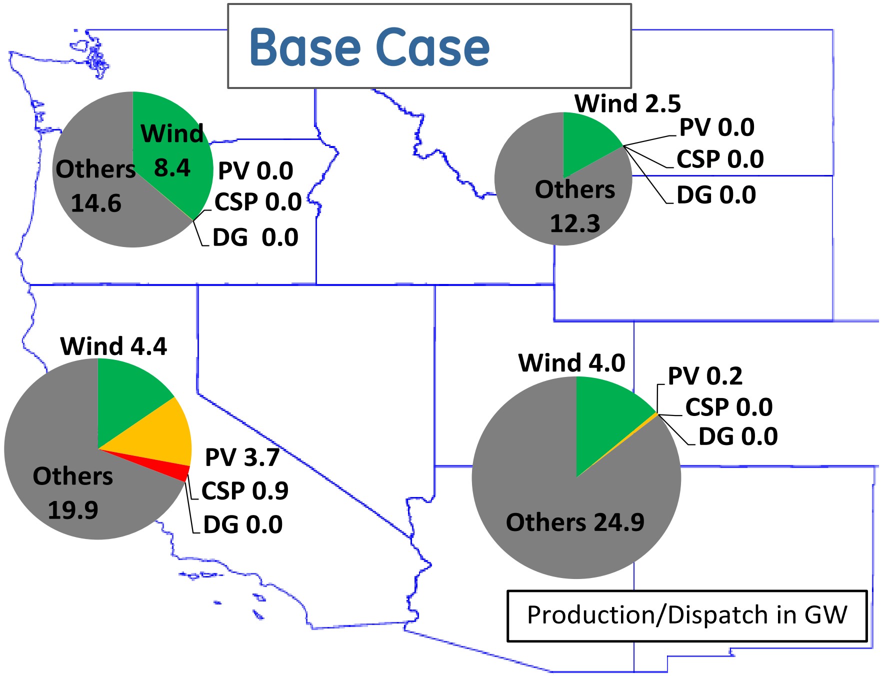
Weak grid issues

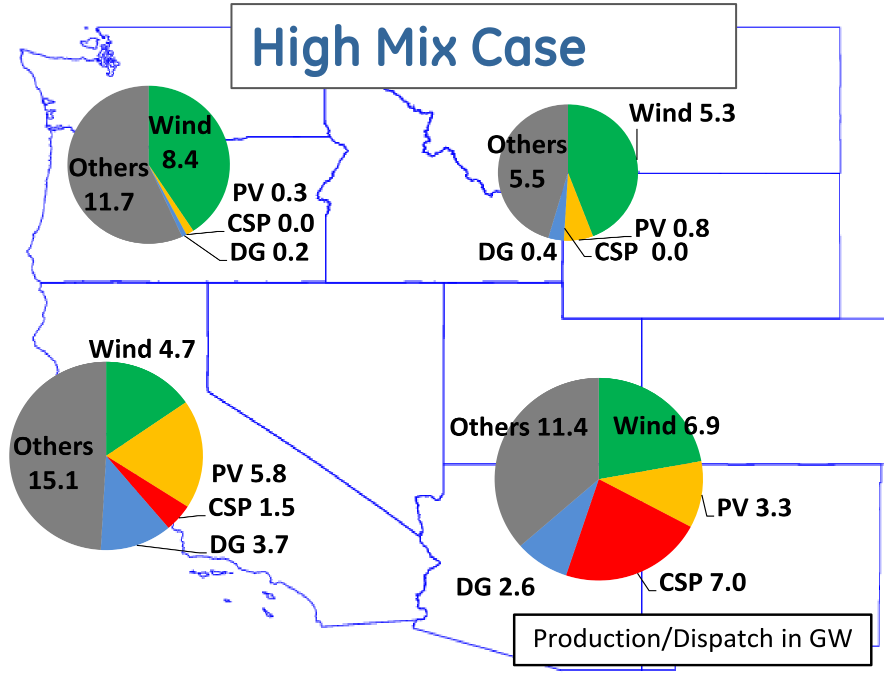
- Short circuit strength can degrade with lower synchronous levels of generation
- Is post-fault voltage recovery acceptable? Does grid strength present control instabilities for renewables (i.e. low short circuit ratio)?

Frequency Response Analysis from WWSIS-3

Western Frequency Response and Stability Study

Light Spring Load Study Scenarios



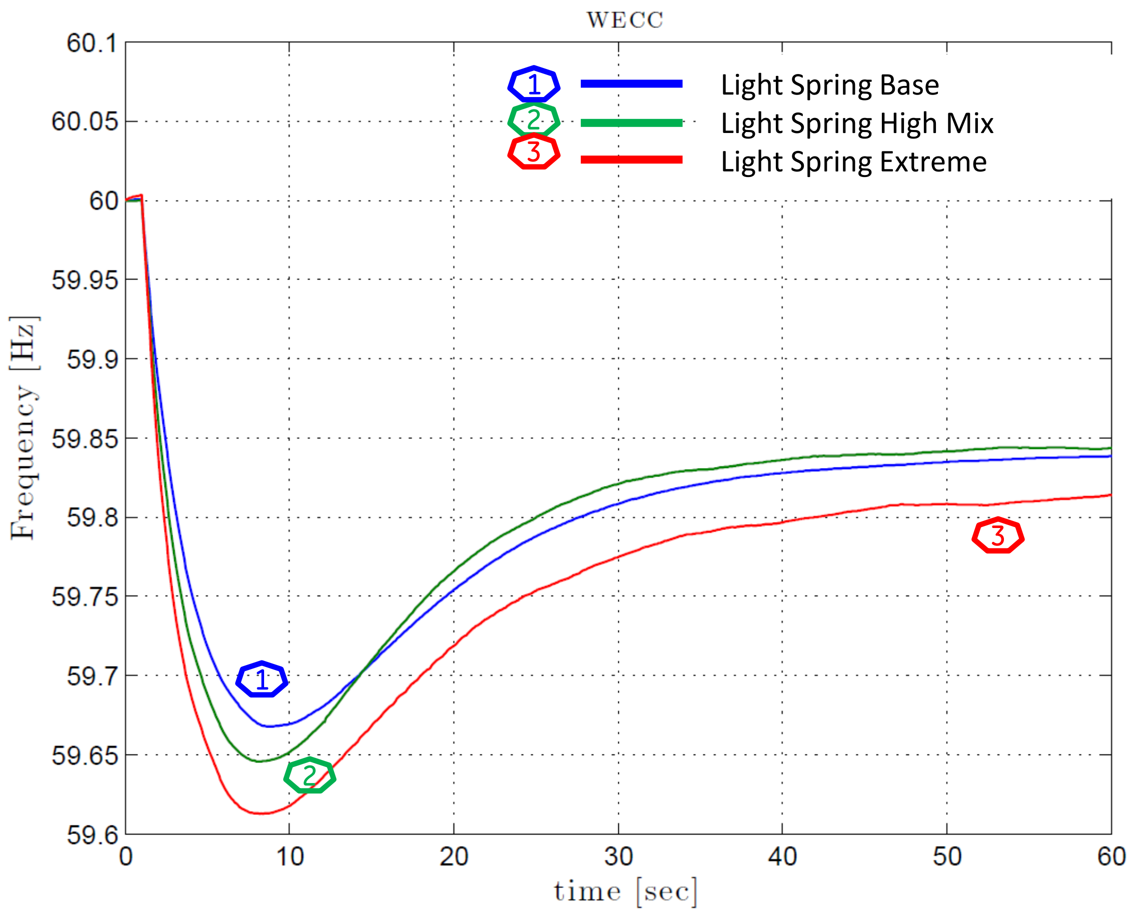


WECC-Wide Summary[1]	Light Spring Base[2]	Light Spring High Mix	Light Spring Extreme Sensitivity
Wind (GW)	20.9	27.2	32.6
Utility-Scale PV (GW)	3.9	10.2	13.5
CSP (GW)	0.9	8.4	8.3
Distributed PV (GW)	0	7.0	10.4
Total (GW) =	25.7	52.8	64.8
Penetration[3] (%) =	21%	44%	53%

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

Frequency Response with High Renewables

Loss of 2 of 3 Palo Verde Nuclear units (~2,750 MW)



~40GW increase in wind and solar, from ~21% to ~53%, caused initial ROCOF to increase ~18%.

Nadir occurs ~20% sooner.

Disturbance: Trip 2 Palo Verde units (~2,750MW)

Interconnection frequency response > 840 MW/0.1Hz (interconnection FRO) threshold in all cases.
No under-frequency load shedding (UFLS).

Wind Plant Frequency Responsive Controls

Inertial control responds

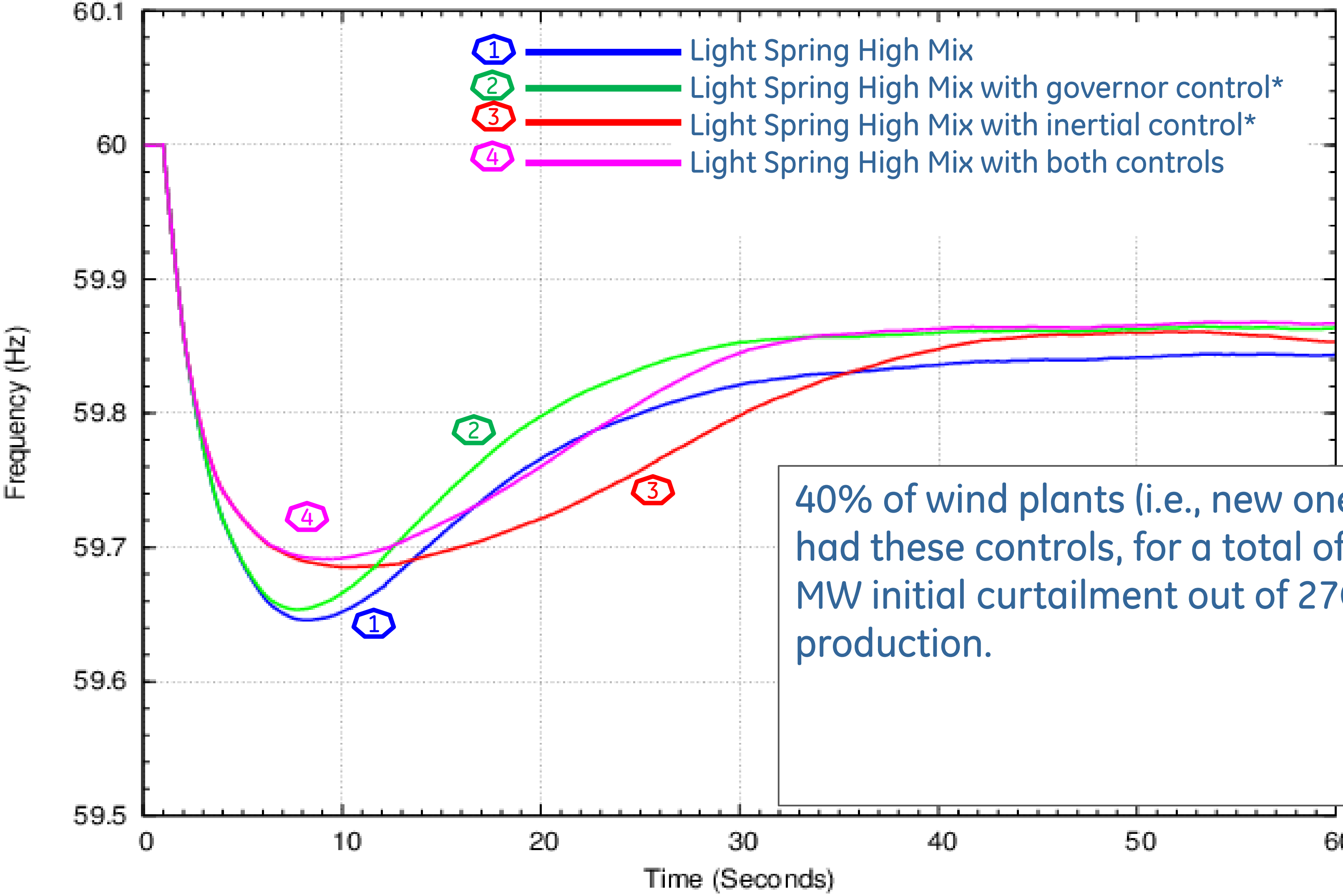
- to frequency drops only
- in 0.5-10 second time frame
- uses inertial energy from rotating wind turbine to supply power to system
- requires energy recovery from system to return wind turbines to nominal speed
- more responsive at higher wind speeds

Governor control responds

- to both frequency drops and increases
- in 5-60 second time frame
- requires curtailment to be able to increase power

Frequency Control on Wind Plants

Disturbance: Trip 2 Palo Verde units (~2,750MW)



40% of wind plants (i.e., new ones) had these controls, for a total of 300 MW initial curtailment out of 27GW production.

Frequency Response Observations

Traditional approaches to meeting frequency response obligations are to commit synchronous generators with governors are still effective

Non-traditional approaches are also effective at improving frequency response including:

- Sharing frequency response resources
- Frequency-responsive controls on inverter-based resources
  - Wind
  - Utility-scale PV
  - Energy storage
  - Demand response

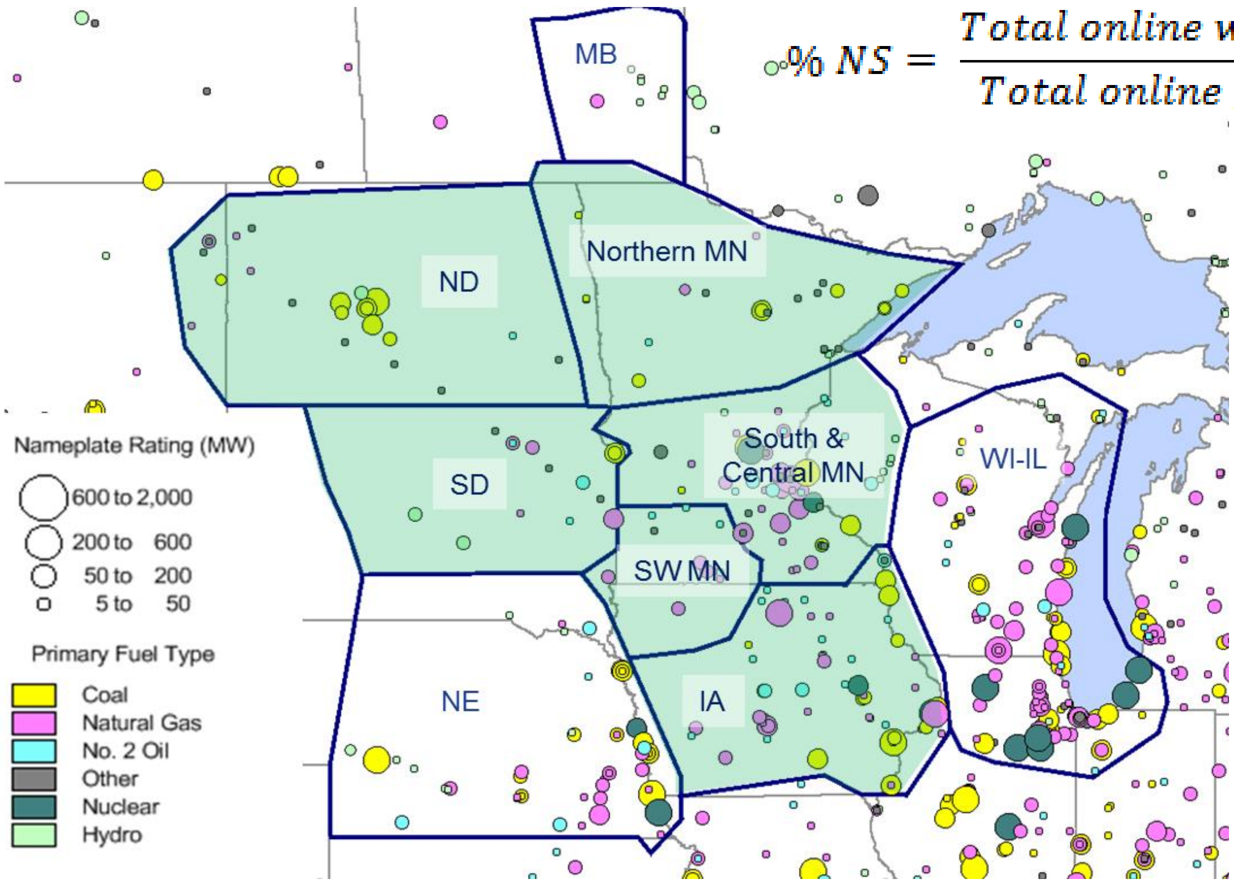
Stability Analysis & Weak Grid Issues

From MRITS, WWSIS-3 & Other Studies

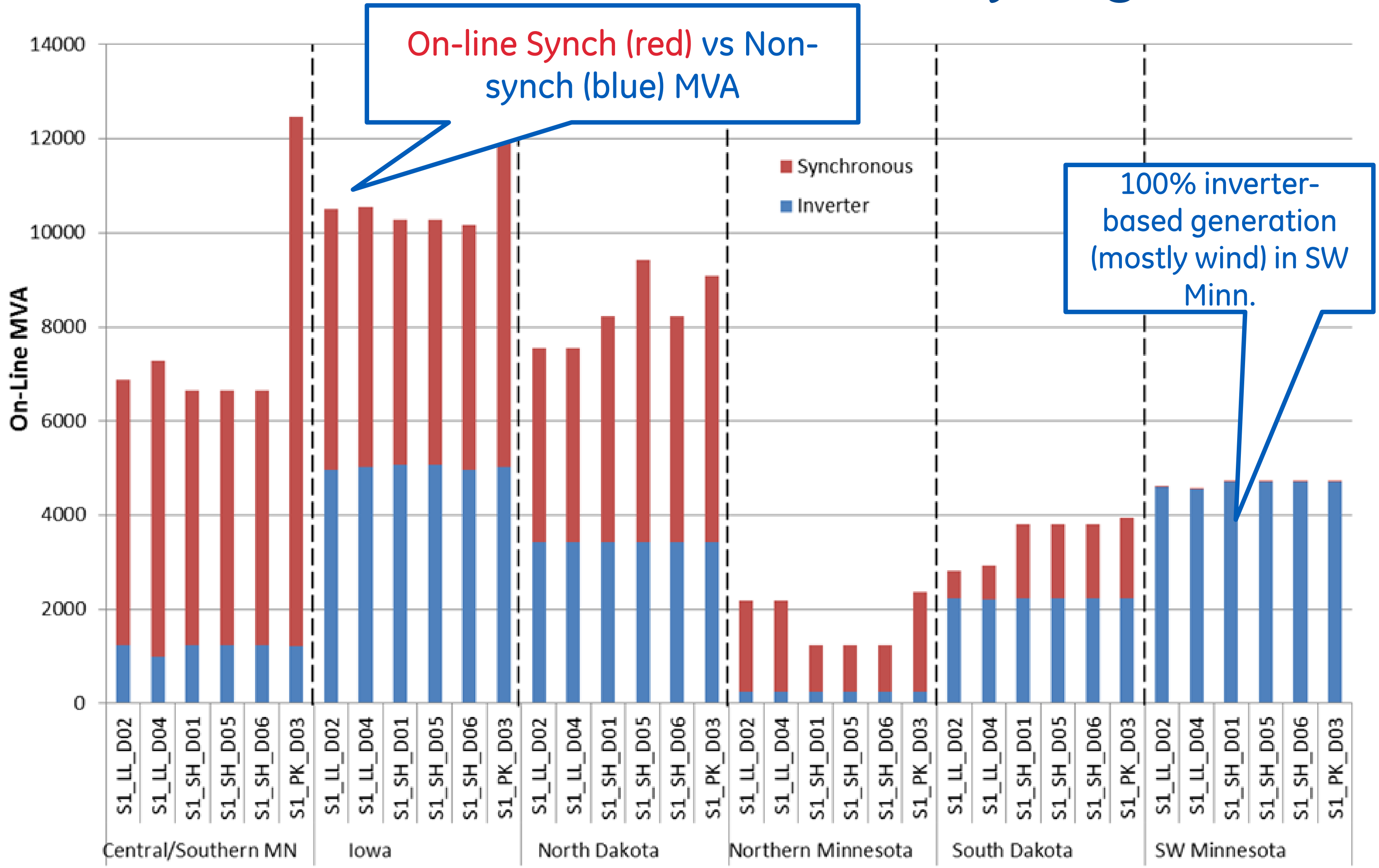
Performance with High Renewable Penetration

Geographic Footprint of Minn-Centric Region for % Non-Synchronous Generation Metric (% NS)

$$\% NS = \frac{Total\ online\ wind + solar\ MW\ rating}{Total\ online\ generation\ MW\ rating}$$



Instantaneous SNSP (Simultaneous Non-Synchronous Penetration) levels buy region



Six different load/dispatch scenarios developed production simulation

Transient Stability Observations from MRITS

No system-wide stability issues found

Wind and solar:

- Oscillate less than synchronous generation
- Have reactive capability and fast voltage regulators

Weak grid/low short circuit strength could be an issue with decommitment* of synchronous generation

- Stability of renewable generation in high penetration areas
- Local area load serving capability

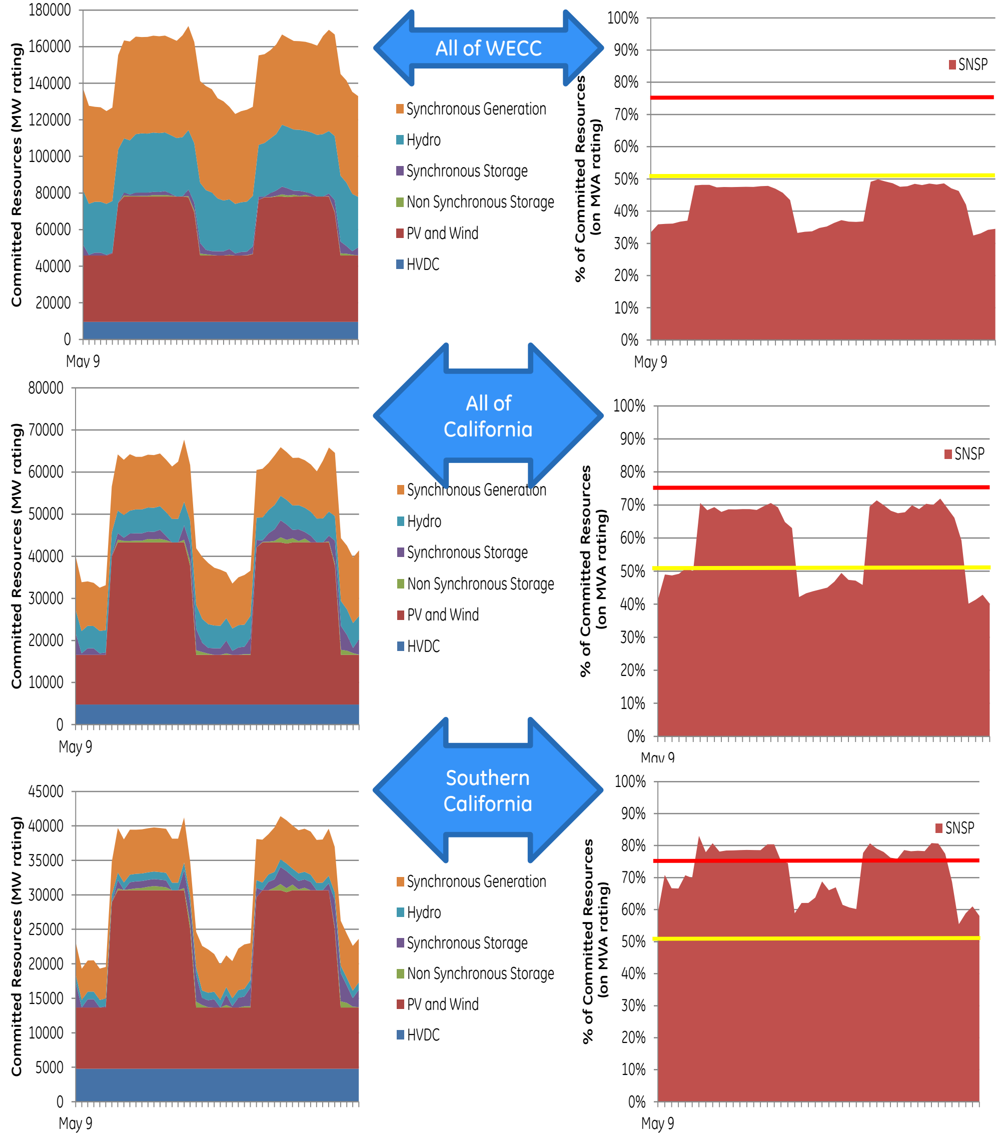
Local areas will require attention

* In this world, decommitment and retirement are the same

SNSP for California Low Carbon Grid Study

Southern California for 2 example days:
100% of time over 50% "warning track"

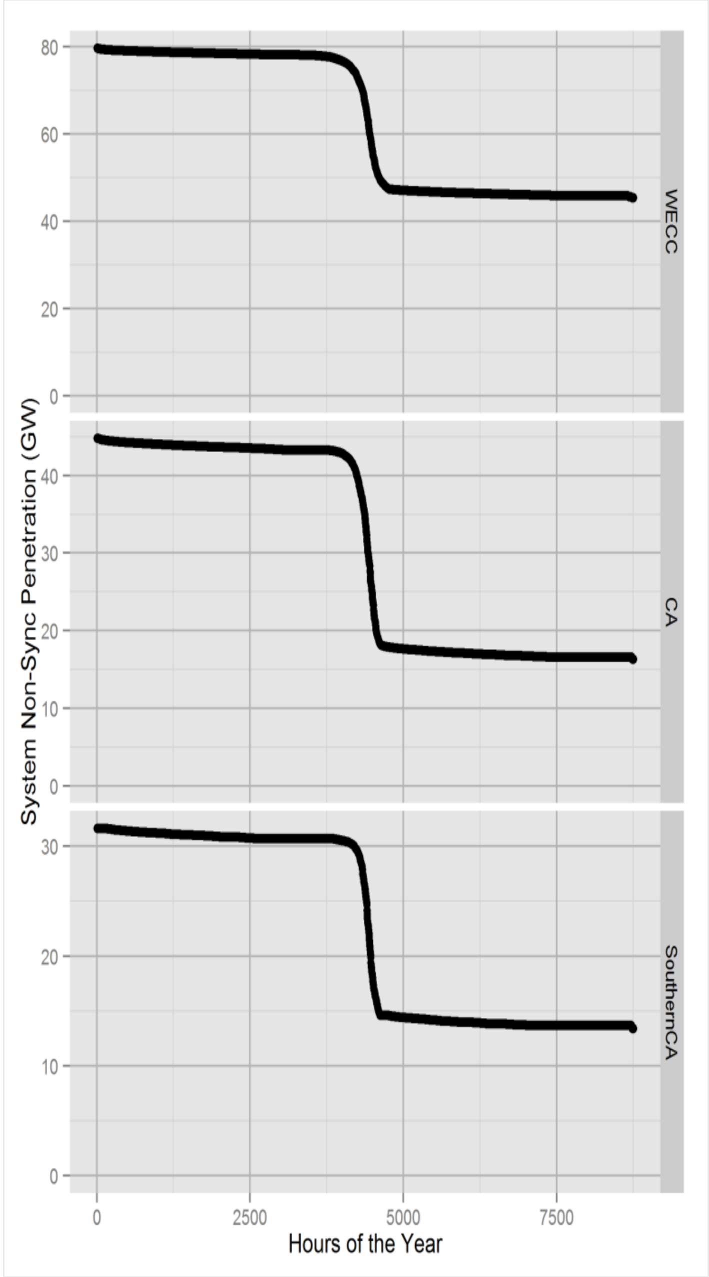
50% of time over 75% "red line"

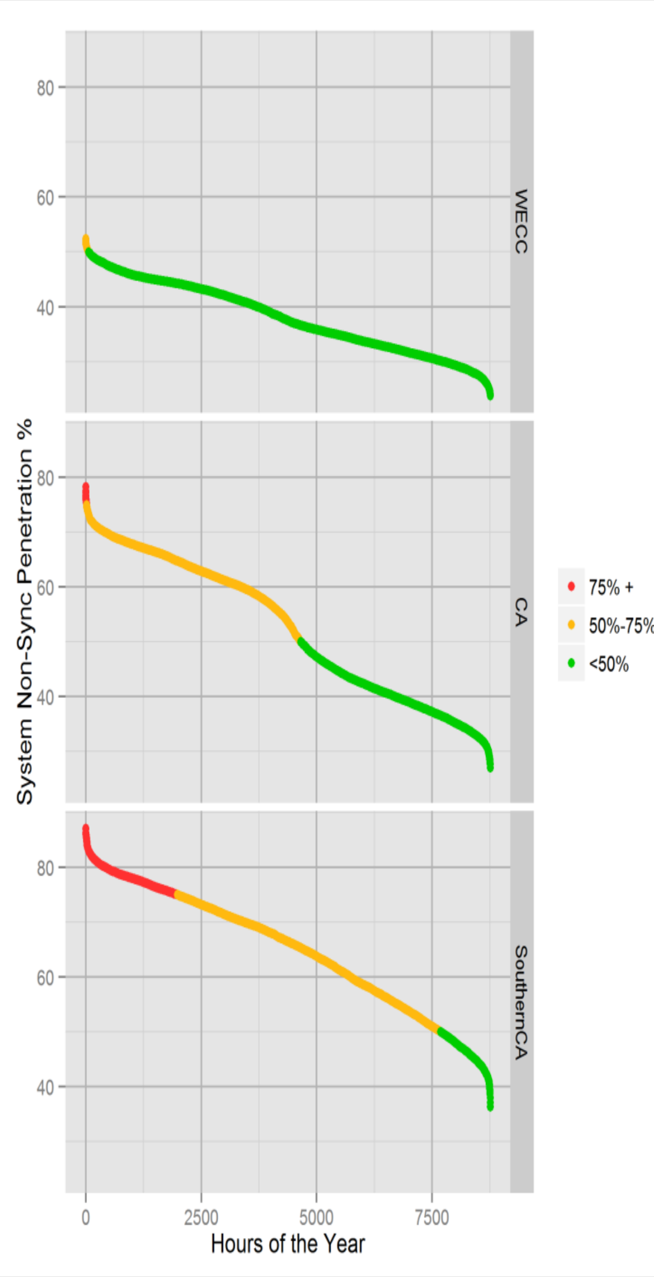


SNSP for California Low Carbon Grid Study

We believe that No major power system has ever run for extended periods at these levels of SNSP.

Prudence indicates analysis is required





Observations from Other Studies

Remember that Retirement Study.....

Towards the end of project in late 2010 (8 month after study started), generation owners announced retirements.....

Extreme Scenario Became Reality

Utility had a year to address the problem

TO "found a way" to purchased > 1000 MVA of retired generation

Converted to synchronous and largely eliminated the need for <u>major</u> transmission projects

- ~12 to 14 months to convert
- **Very economical, $ less than large SVC**

Ongoing Coal Retirement Study

Eastern Utility dealing with uncertain coal retirement + very high renewable penetration + increased RPS

Study is considering

- Energy/Production/Operation issues
- Thermal and voltage
- Grid stability, weak grid, voltage recovery issues

Stability analysis performed under worst-case conditions

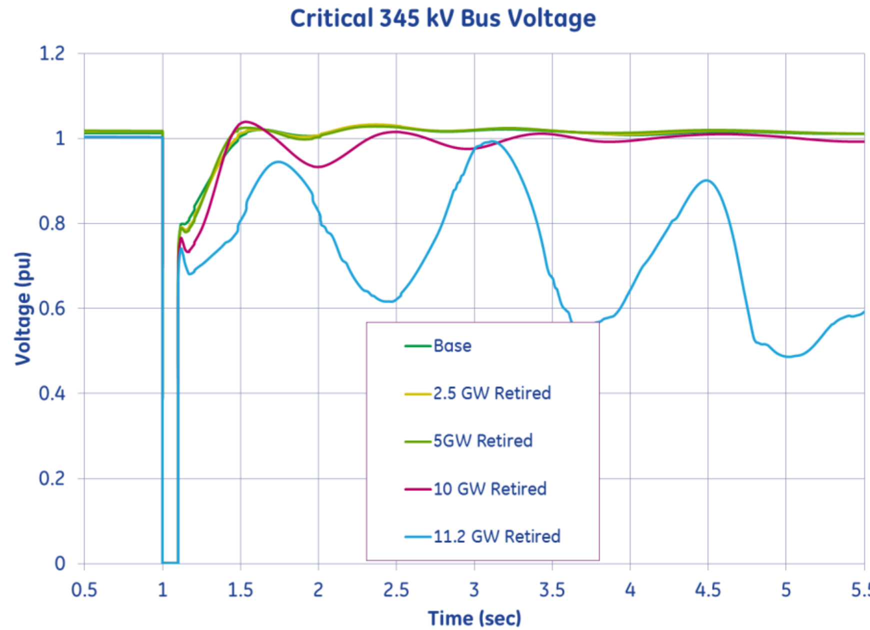
Initial system 30 GW of generation, 50% renewable

Retire ~11.2 GW of coal, increase imports (no new generation)

Observations

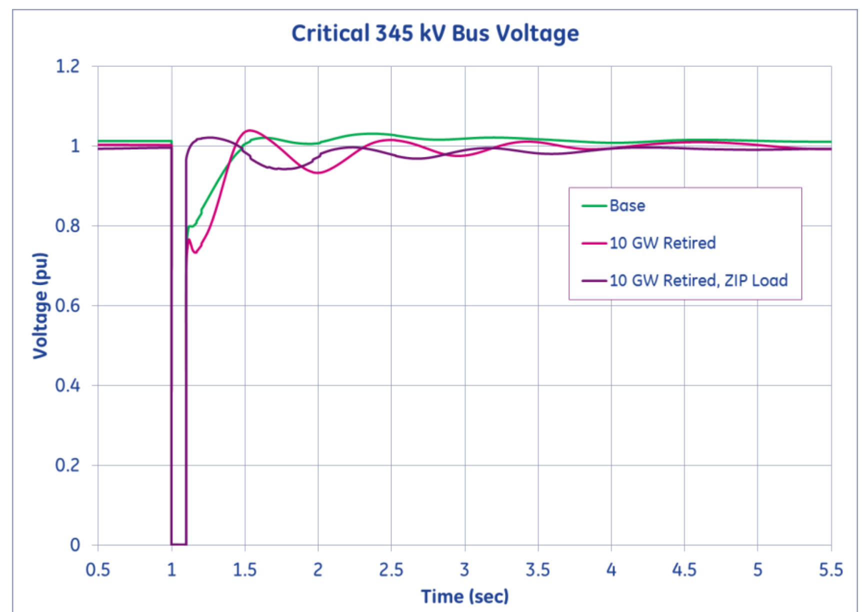
Voltage recovery with up to 10GW of coal retirement degrading but still acceptable.

Retirement of additional 1200 MW causes system collapse.



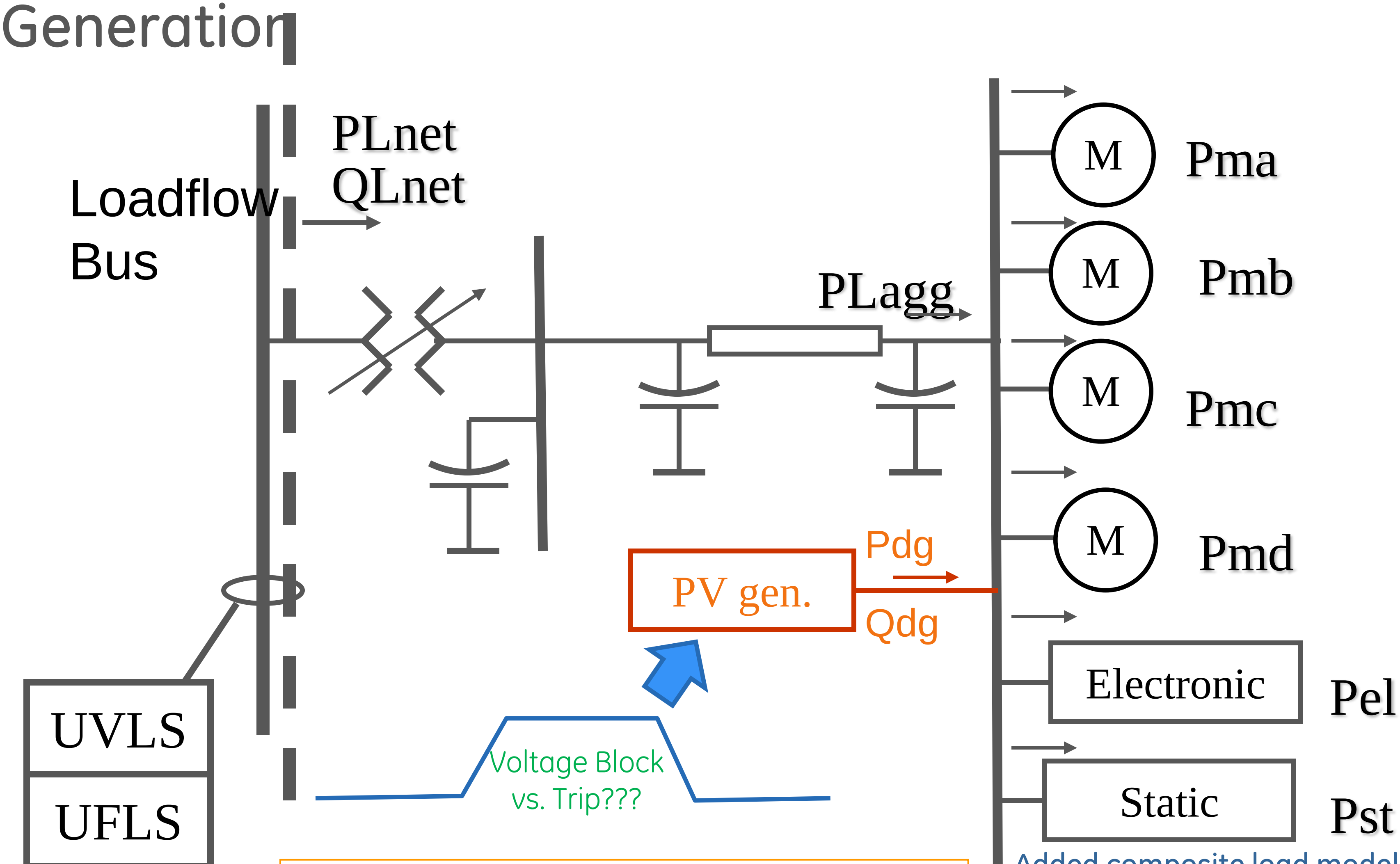
Perspective

Dynamic behavior of load impacts system stability more than retiring 30% of synchronous generation



What about distributed PV response?

Composite Load Model Structure with Distributed Generation



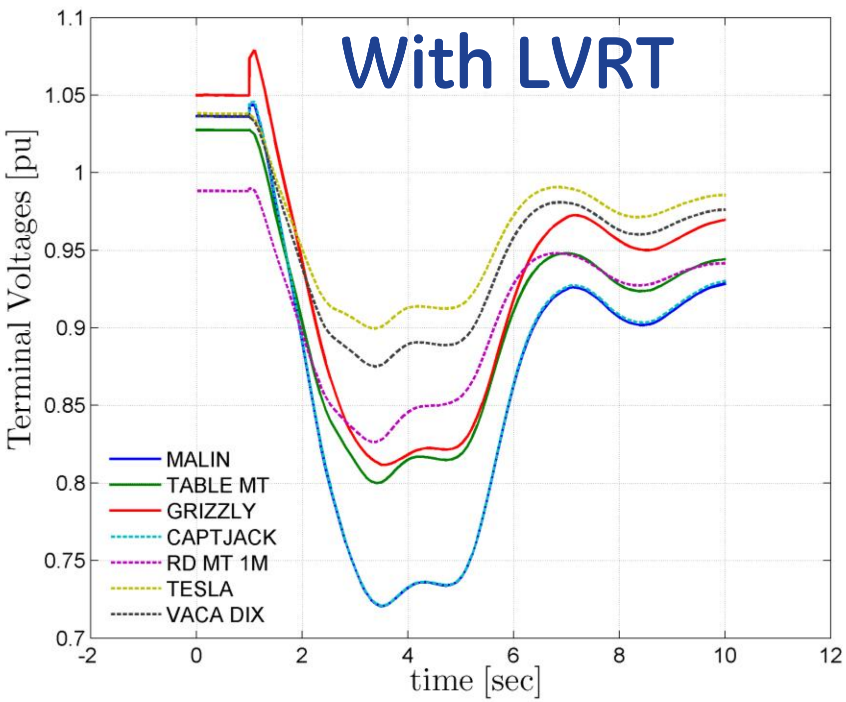
dPV resides with the load…if you want insight into impact on the BPS, you need a good load model!!

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

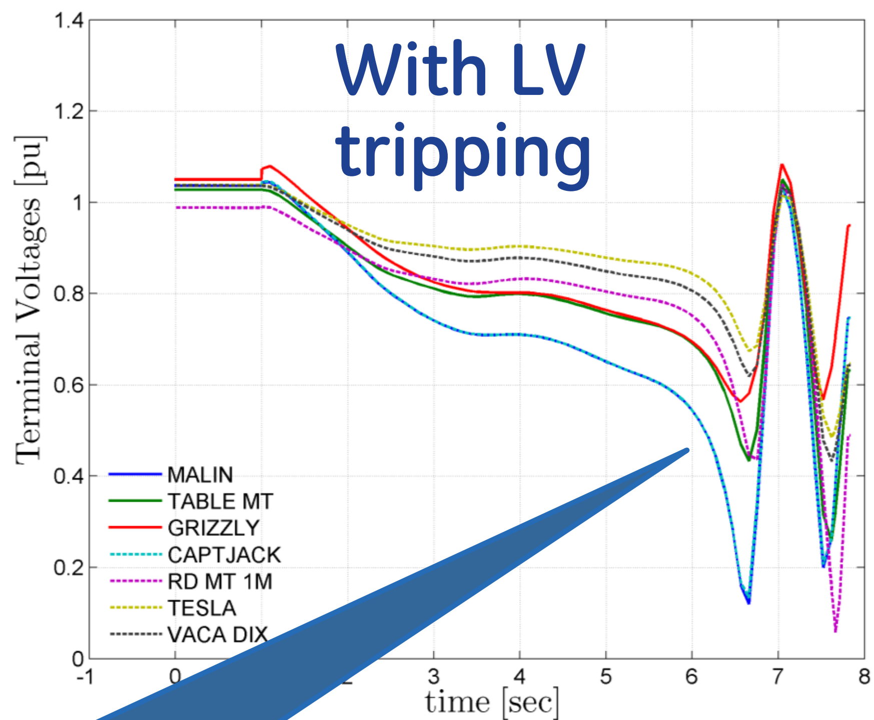
LSP: 4420 composite load models, 95.1 GW total load + distribution losses

PDCI (Pacific DC Intertie) Trip: A big nasty BPS event

DPV voltage tripping response:
Full output between 0.8 and 1.1 pu
DG Trip below 0.7 pu, above 1.2 pu
Full output upon voltage recovery



DPV voltage tripping approximates IEEE 1547:
Full output between 0.88 and 1.1 pu
DG Trip below 0.83 pu, above 1.2 pu (no time delay)
Tripping is latched



<u>Pessimistic</u> approximation to worst case 1547 UV tripping (88% and no delay) takes down WECC

Nuggets of insight/Common themes

No miracles or new inventions needed:

- Stable, reliable performance well within reach.

Use every tool at your disposal:

- For systems with high stress, new, available functions on wind (and solar) plants can be a big help.

Pay attention to details:

- localized problems must be addressed. Some details you used to be able to ignore become important

Massive new transmission not *always* needed:

- these studies were done with a minimalist approach to adding wires

All other things being equal (which they never are), wind & solar tend to be *more* stable than synchronous thermal:

- For stability questions, decommitted and retired are the same thing

Closing thoughts:

A low coal, high VER grid will be very different from today's grid. It is important to be proactive in studying potential future scenarios

- More time to implement solutions means the solution space is much bigger and can include more complex, inexpensive solutions such as demand-side solutions, new grid technologies, contractual solutions
- Saving money on potential retrofits/retroactive requirements
- Using the grid to experiment is expensive, compared to simulation
- Extremely high SNSP conditions are new ground for the industry

Many lessons learned from completed analyses

- New tools and techniques for planning are here…use them!

Many mitigation options for a low coal, high VER future including:

- *Available* advanced power controls on *Wind and Solar*
  - *They can do more than you think!*
- Synchronous condensers/conversions/clutches
- Traditional reinforcements

Time is of the essence!

Thanks!

Western Wind and Solar Integration Study, Phase III (WWSIS3)
http://www.nrel.gov/electricity/transmission/western-wind-3.html
http://www.nrel.gov/docs/fy15osti/62906.pdf

Minnesota Renewables Integration and Transmission Study (MRITS)
http://www.minnelectrans.com/documents/MRITS-report.pdf

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