Use of renewable generation for frequency control in the normal operating frequency band – international experience

Workshop

Venue: Sydney, Brisbane

Presented by: Jennifer Crisp

Date: November 2017

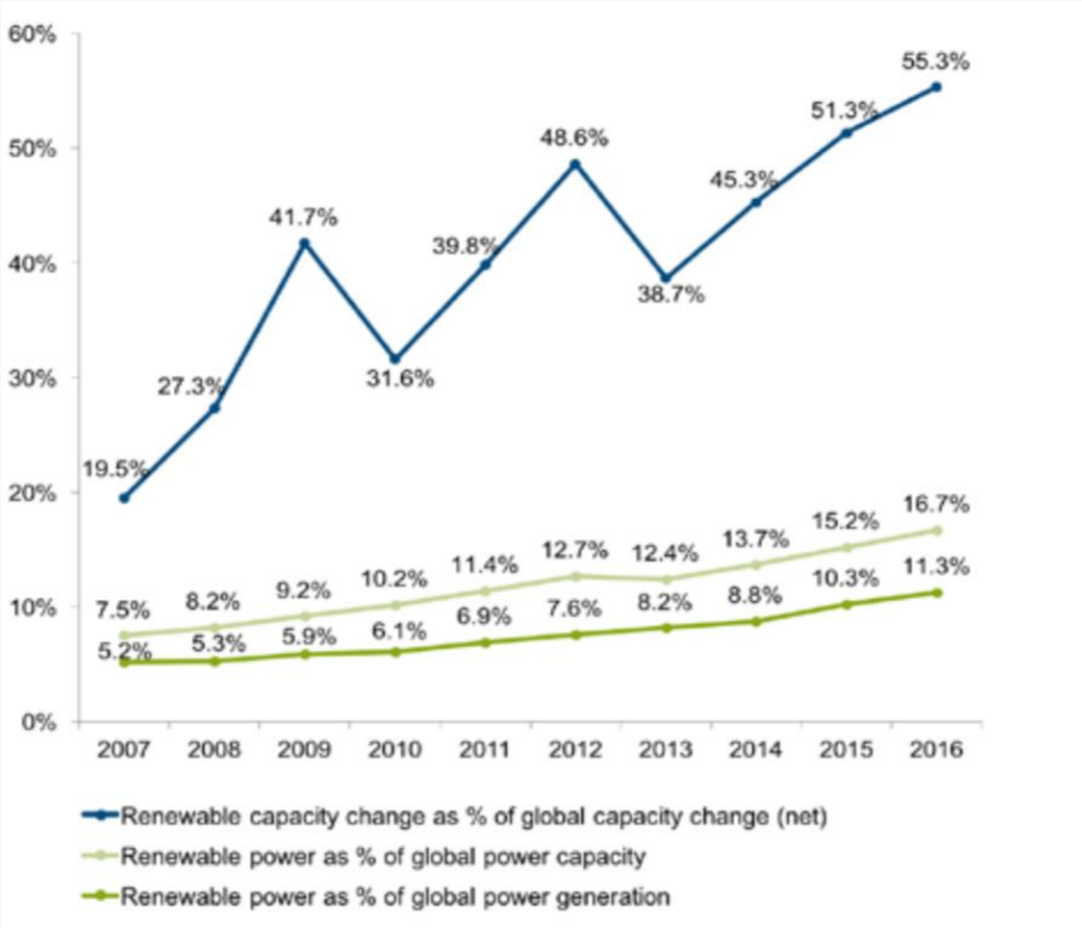
Frequency control in the normal operating frequency band

- 2 Types of frequency control in this band
  - ***Primary frequency control*** – direct response of generating system to frequency measured at the terminals of the generating unit
  - ***Secondary frequency control*** – central dispatch sends out signals via automatic generation control to a subset of generators to raise or lower active power in response to a calculated value (related to frequency, tie line control and time error)
- Both traditionally provided by synchronous generators

Key changes in the power system since 2007

- Increase in renewable generation – wind and solar
  - Rapid increase in wind and
  - In last couple of years – increase in solar generation
  - Cost of renewable generation reduced 30% in past year
- Increase in size of renewable power stations
- Retirement of aged thermal plant
  - Unless driven by government policy/subsidy, unlikely to be replaced
  - If coal fired generation is replaced, it is likely to be with ultra-super critical (high efficiency) coal fired generation
    - Less likely than older technologies to participate in frequency control
- Renewed interest in storage solutions
  - Increased interest in pumped storage
  - Batteries – costs trending down; starting to see some connections, but mainly with subsidies, often with research and development components

Renewable power - globally



Source: Frankfurt School-UNEP Centre/BNEF. 2017.[1]

USA VRE additions and Synchronous retirements

- Added:
  - 13 GW of wind,
  - 6.2 GW of utility scale solar photovoltaic (PV), and
  - 3.6 GW of distributed solar PV generating facilities in 2014 and 2015.

- Subtracted
  - 42 GW of synchronous generating facilities (e.g., coal, nuclear, and natural gas) retired between 2011 and 2014
  - nearly 14 GW of coal and 3 GW of natural gas generating facilities retired in 2015

Source: EIA[2]
Source: NERC[3]
Source: EIA[4]

It's happening here too

'…based on AGL's latest analysis, the levelised cost of wind generation is currently at about $A65/MWh and the equivalent cost of solar is about is around $75/MWh.

And while that cost increases to about $100/MWh for wind and $125/MWh for solar when you add gas peaking to balance the renewables output, it still beats the cost of using gas outright, for baseload generation.

Indeed, according to AGL, the price of new baseload gas sits at between $100-$130/MWh – and "that's not including a carbon cost," Redman adds. And wind and solar costs, along with battery storage, continue to fall dramatically …'

Reach [Solar] received estimates in late December 2016 for solar PV and energy storage (40MWh to 100MWh) which translated into a tariff between $110/MWh to $130/MWh

Source: Renew Economy May 2017[5]

Trends in frequency regulation

- Reduction in synchronous generation providing primary control
  - Minimising operating and maintenance costs
  - Market related – absence of payment for service
  - Not mandated

- Many developed countries have experienced a reduction in the quality of frequency regulation in the normal operating band.

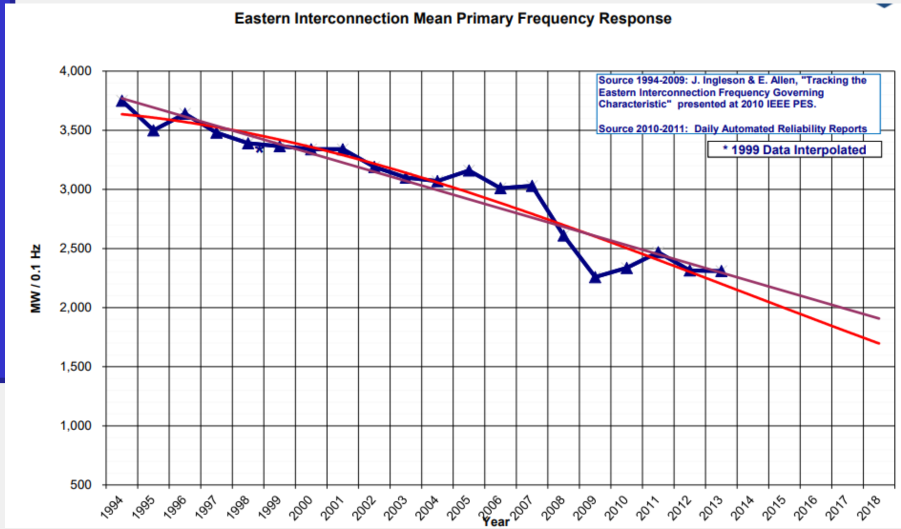
- Changes to the generation mix will make it necessary for wind and solar to participate actively in frequency control.

- Scarcity of primary frequency control is likely to increase its perceived value.

US Experience

In 2010, NERC conducted a survey of generator owners and operators and found that only approximately 30 percent of generators in the Eastern Interconnection provide primary frequency response, and that only approximately 10 percent of generators provide sustained primary frequency response.

Source NERC [6]



Source NERC [7]

Similar to the Australian experience …see our report https://www.aemo.com.au/Stakeholder-Consultation/Industry-forums-and-working-groups/Other-meetings/Ancillary-Services-Technical-Advisory-Group

International approaches to integrating high VRE

- Increase flexibility of power system operation to integrate more VRE:
  - Improved forecasting
  - Electricity storage
  - Demand response
  - Coordination of trade of electricity across larger balancing areas
  - Increased use of flexible generation
  - Flexibility through additional transmission capacity
  - Hybrid generation (eg wind/solar solar/battery) (less variability)

- Mostly VRE is still treated as non-dispatched
  - Low operating cost
  - Variable energy source

NERC Primary Frequency Control Guideline (2015)

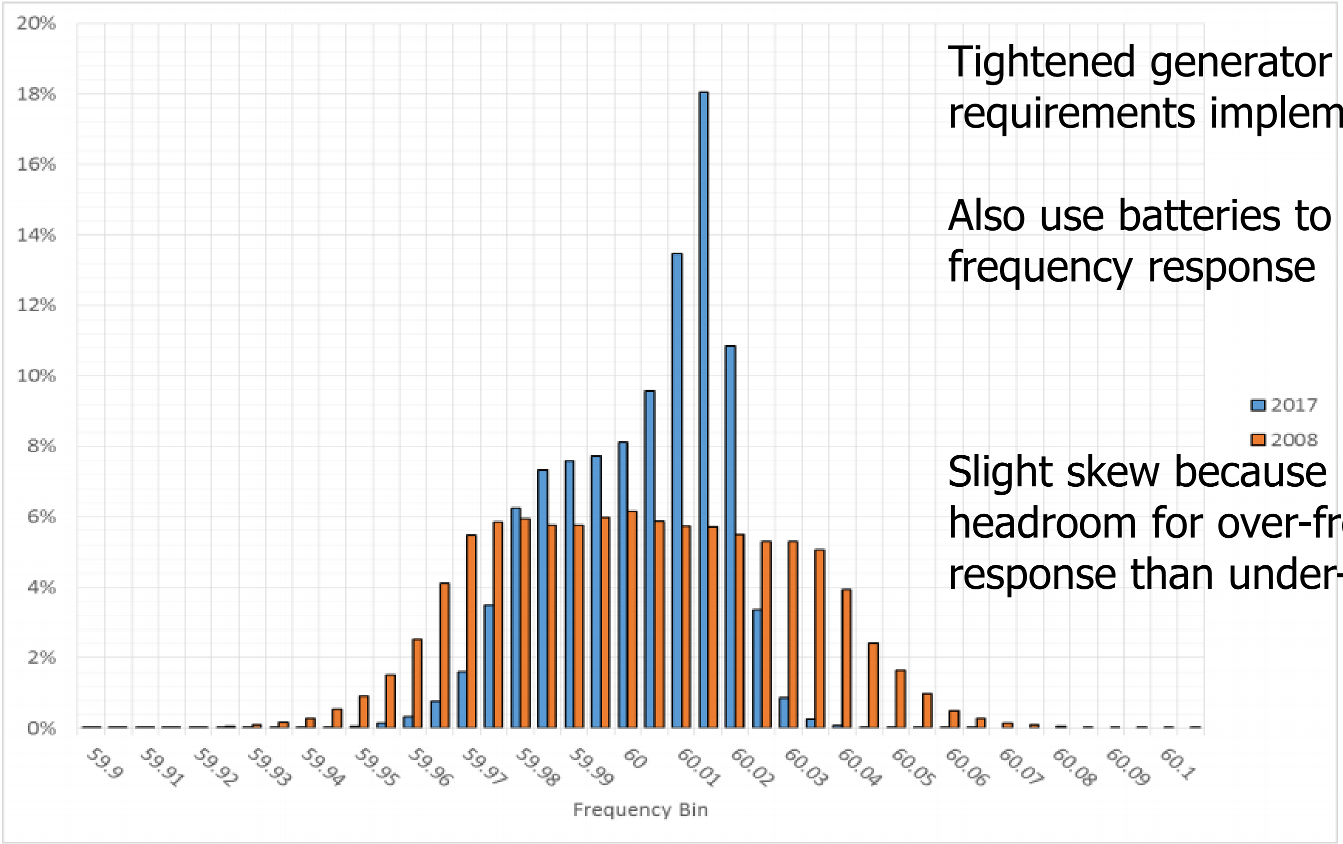
- Recommends maximum 5 percent droop and ±0.036 Hz deadband settings for most generating facilities
- Voluntary
- Encourages generators to provided sustained effective primary frequency response.

Source NERC [7]

US Transmission operators

Operator	Requirements	Applies to?
ISO New England Inc.	Functioning governor with maximum 5 percent droop and ±0.036 Hz deadband Outer loop control not to inhibit primary control	Gens>10 MW
PJM (draft 2017)	maximum 5 percent droop and ±0.036 Hz deadband	Gens > 75 MW, excluding nuclear
MISO	Governor required (settings unspecified)	Gens providing regulating service
CAISO	Functioning governor with maximum 5 percent droop, deadband +/-0.036Hz * *Recent change to +/-0.017Hz	Only on plant with traditional governors
ERCOT	Deadband Steam & hydro +/-0.034 Hz Other generating units +/- 0.017Hz Droop 5% (CCGT 4%) max	All gens

ERCOT Frequency response 2008 to 2017



Tightened generator frequency requirements implemented 2015

Also use batteries to provide fast frequency response

Slight skew because more headroom for over-frequency response than under-frequency

Source: ERCOT [9]

FERC primary frequency response November 2016

- Proposed amendments to Large Generator Interconnection Agreement and Small Generator Interconnection Agreement templates
- All new generators to have primary frequency response (except nuclear)
  - applies to synchronous and asynchronous
  - Requirement to install, maintain and operate equipment capable of providing primary frequency response as a condition of interconnection
  - operating requirements, including maximum droop and deadband parameters

- In August 2017 FERC requested additional comments on how storage should be treated for the purpose of these frequency response requirements
- … watch this space

Source: FERC [8,10]

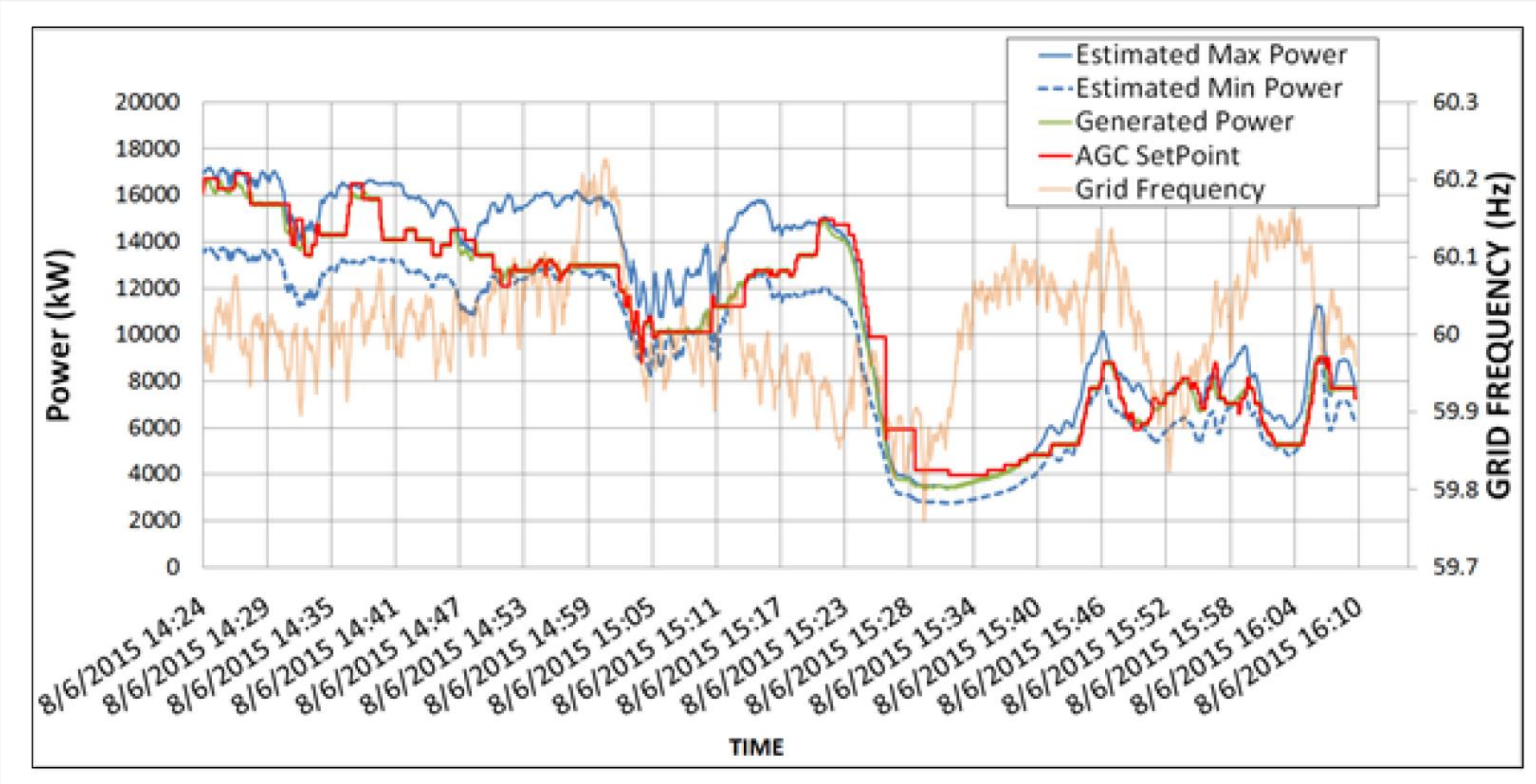
Case Study: Use of VRE for frequency control Puerto Rico 2015

- Peak load 2.7 GW
- 173 MW wind and solar PV
- Bulk of generation petroleum and coal, some gas
- Test system: Ilumina PV Plant – 20 MW
- P estimated by irradiance

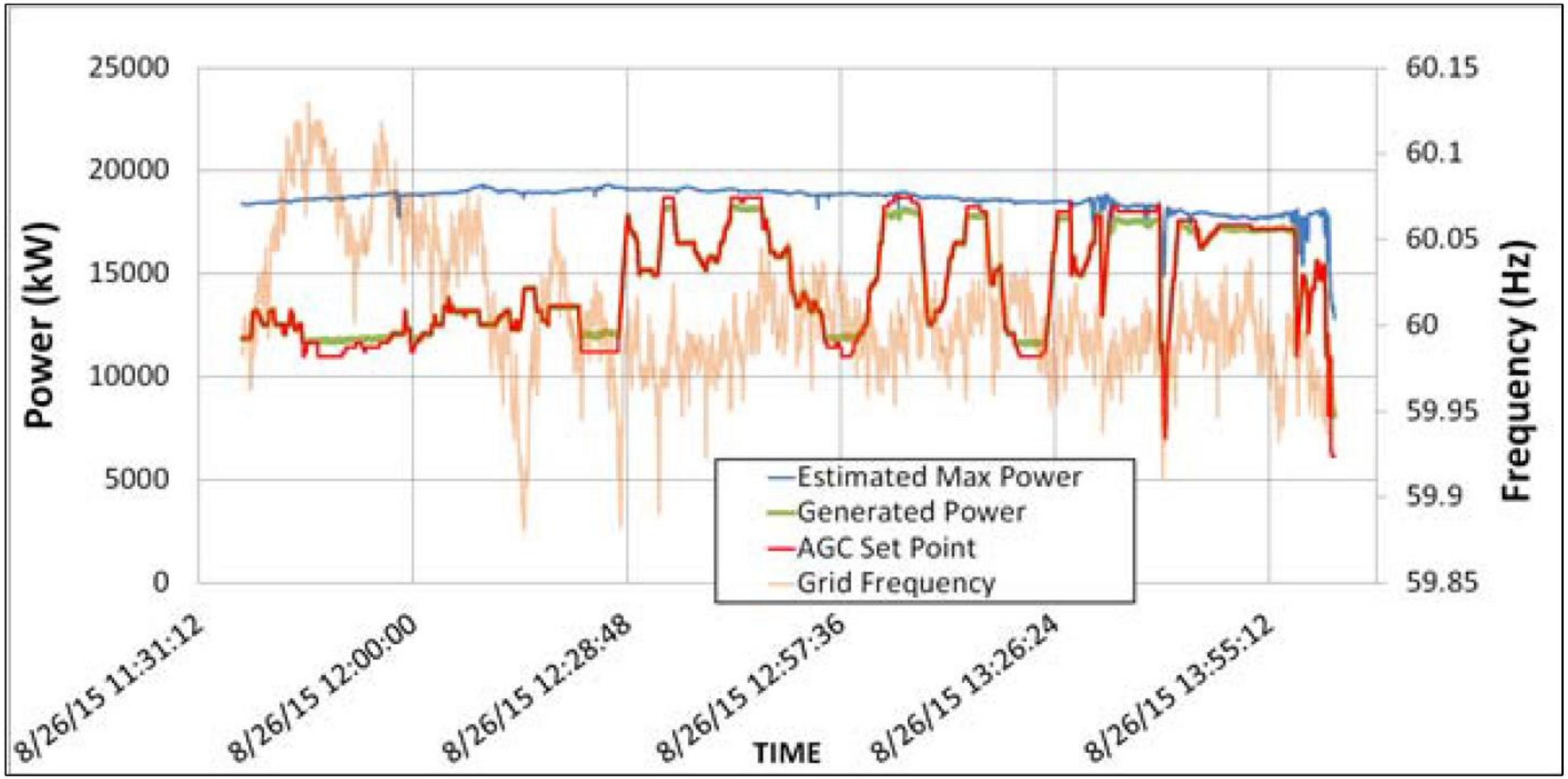
- AGC raise and lower
- Primary frequency response
- Fast frequency response

Source: Gevorgian, O'Neill[11]

Test results with 20% curtailment



Test results with 40% curtailment



Sources of error

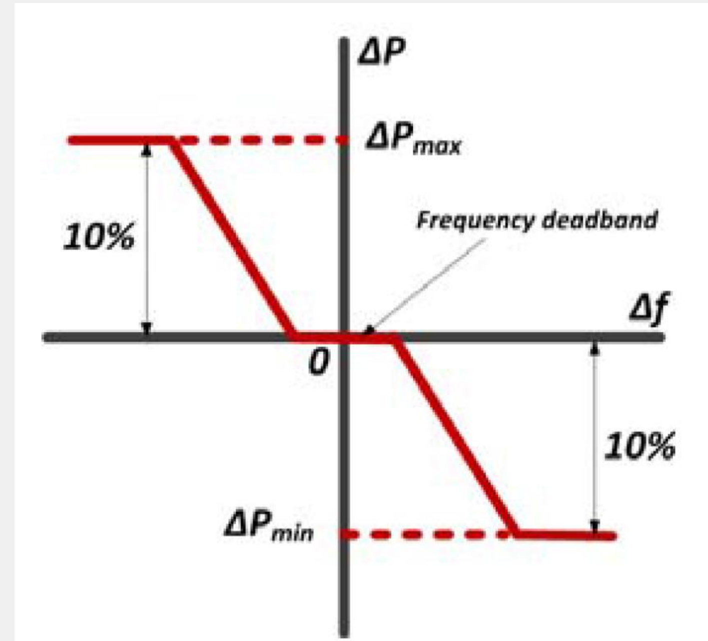
- During periods of rapid cloud movement – not able to follow target precisely (more the case with low level of initial curtailment)
- Optimistic forecasting
- Requested power lower than an artificial 40% limit (wouldn’t occur in real conditions)

On the plus side …

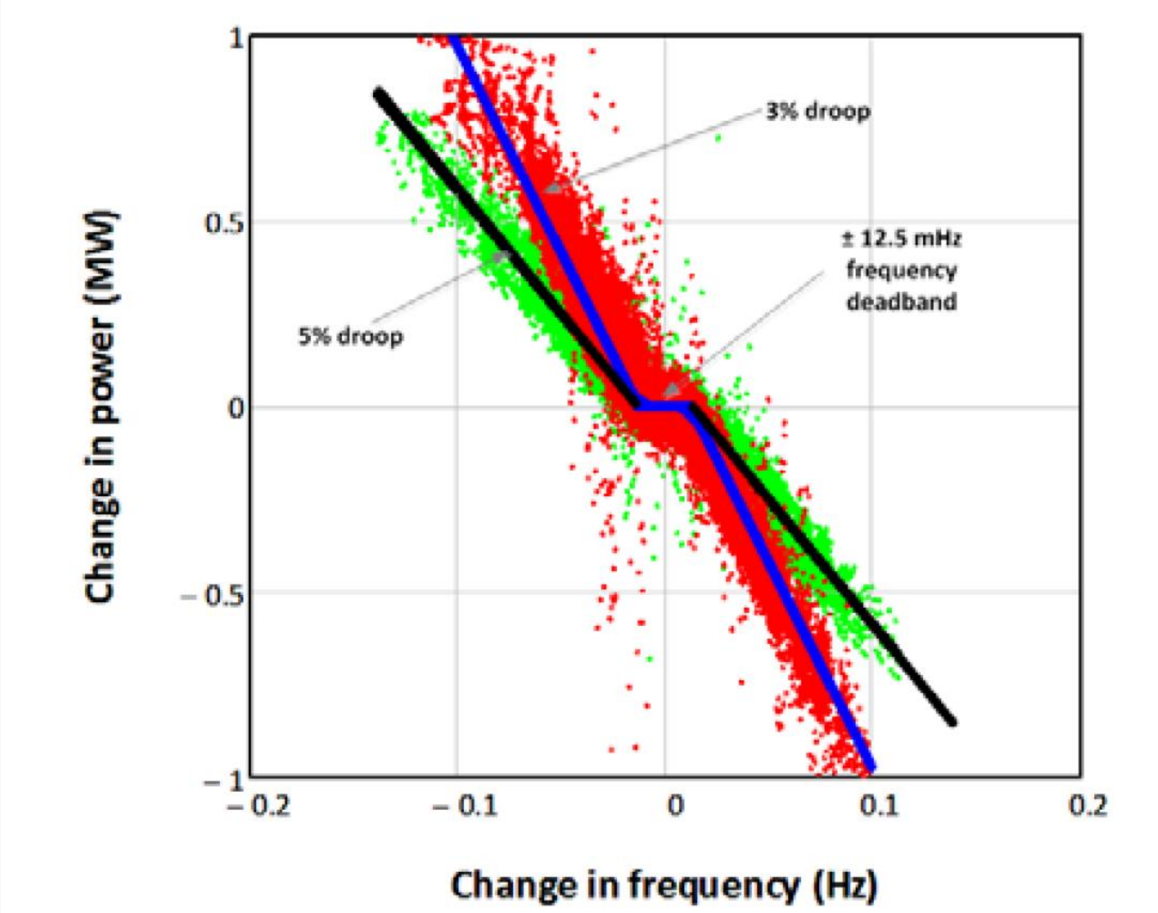
At times of low ramp the power system was able to be operated with only this solar farm participating in AGC.

Tests of primary frequency control

- Max P - maximum available P of Solar farm
- Min P – 20 % less than maximum available P
- Droop 3%, 5%
- +/- 12 mHz deadband
- Set point 10% below available P

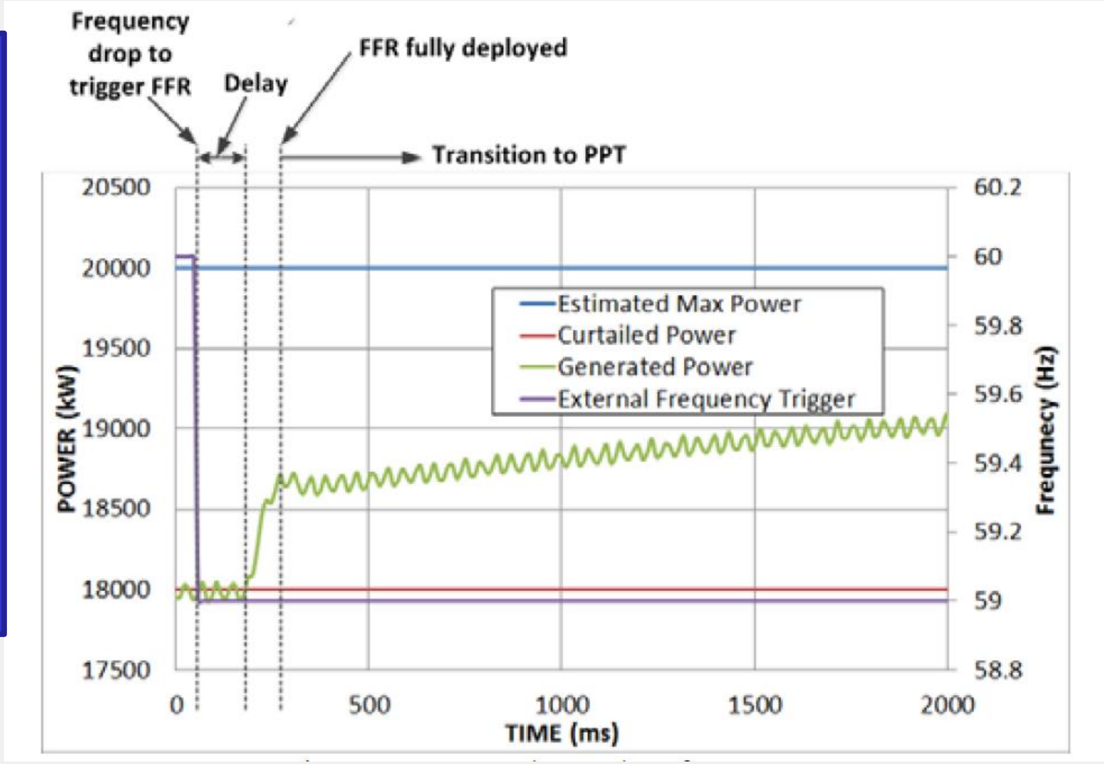


Frequency response results



Fast Frequency Response

Simulated frequency drop
Plant control set to deliver response as fast as possible
Initial curtailment 10%
Tested at different initial conditions



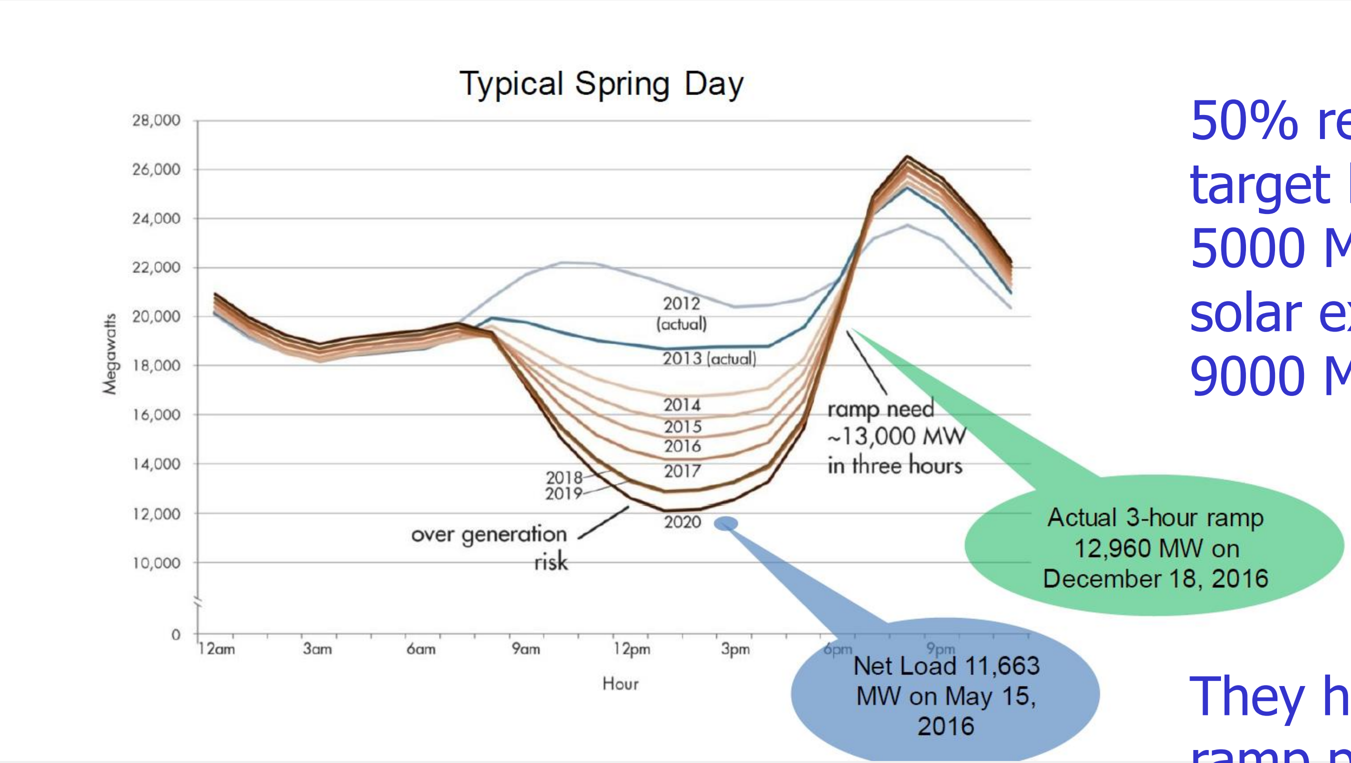
Response in <500 ms

Wind generation for secondary frequency control

- Public Service Company of Colorado (PSCO):
  - Has a means to control its wind generation to provide both up and down regulation reserves
  - has had periods of 60-percent wind power generation in its ~5000 MW system.
  - Uses wind reserves as an ancillary service for frequency regulation by integrating the wind power plants in their footprint to AGC.
- PSCO supplemental category of reserves to address large reductions in on-line wind generation due to reduction in wind speed
- Approx 18%/MW of installed wind generation
- Any transmission customer or ancillary service customer using wind generation to serve load in the PSCO balancing must purchase or self-supply

Source: CAISO [12] Xcelenergy [13]

Case Study: CAISO

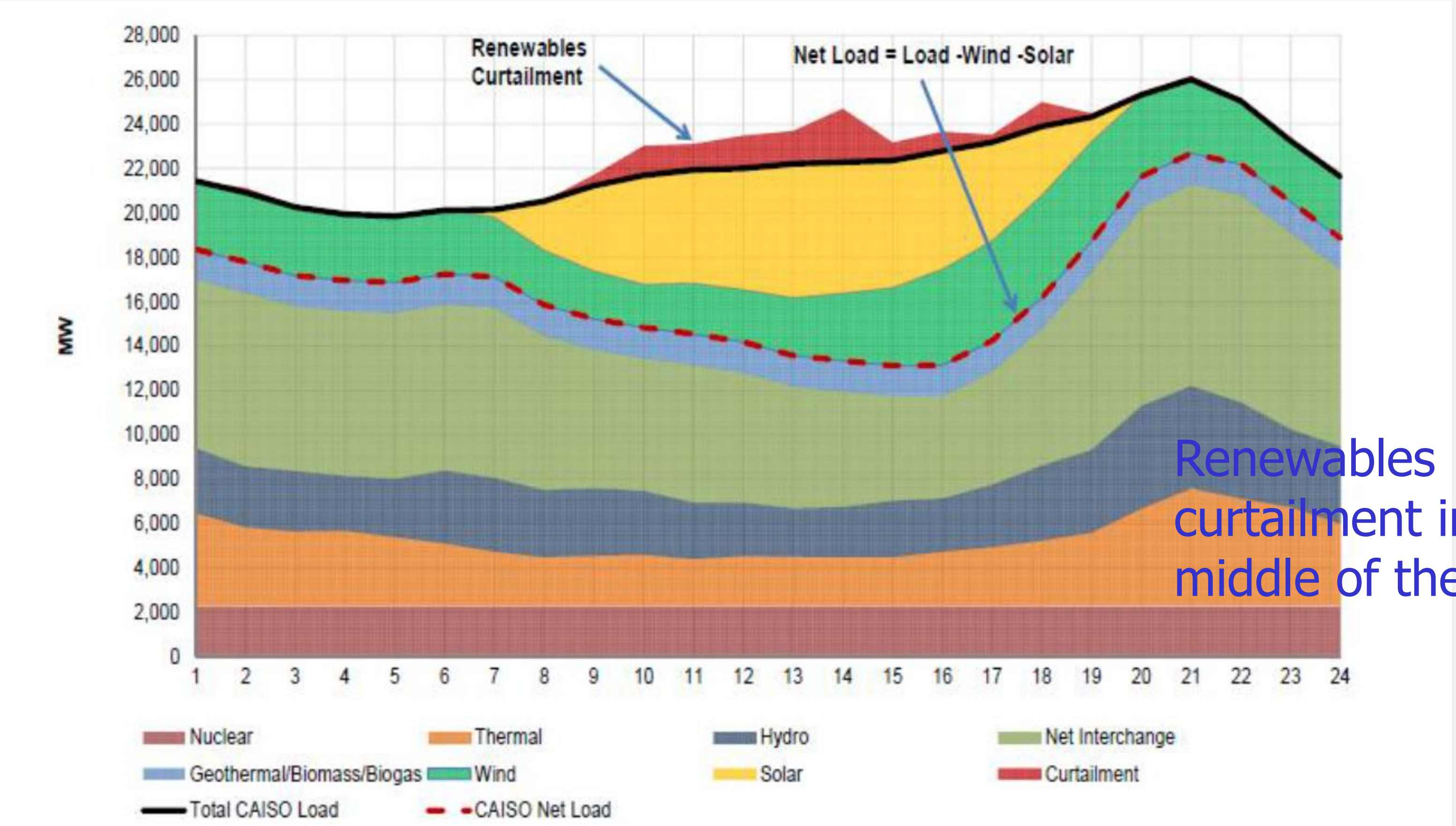


50% renewable target by 2030
5000 MW of rooftop solar existing
9000 MW by 2020

They have a bit of a ramp problem

Source: CAISO [12]

Load curve

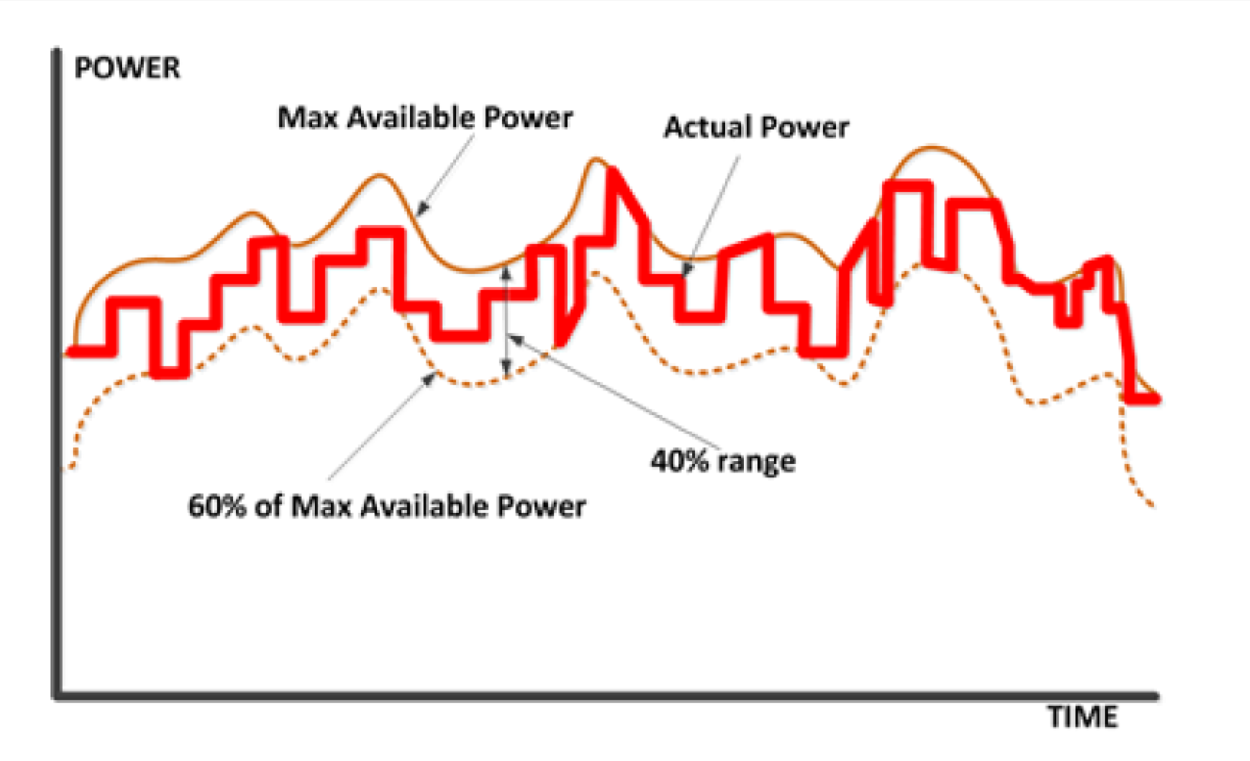


Renewables curtailment in the middle of the day

The tests

- Test system: 300 MW solar plant
  - Regulation up and down, (AGC) tests during sunrise, middle of the day, and sunset
  - Frequency response tests with 3% and 5% droop setting for over and under-frequency conditions
  - Power curtailment and ramp rate tests

Concept of AGC setpoints for solar



Results – AGC test

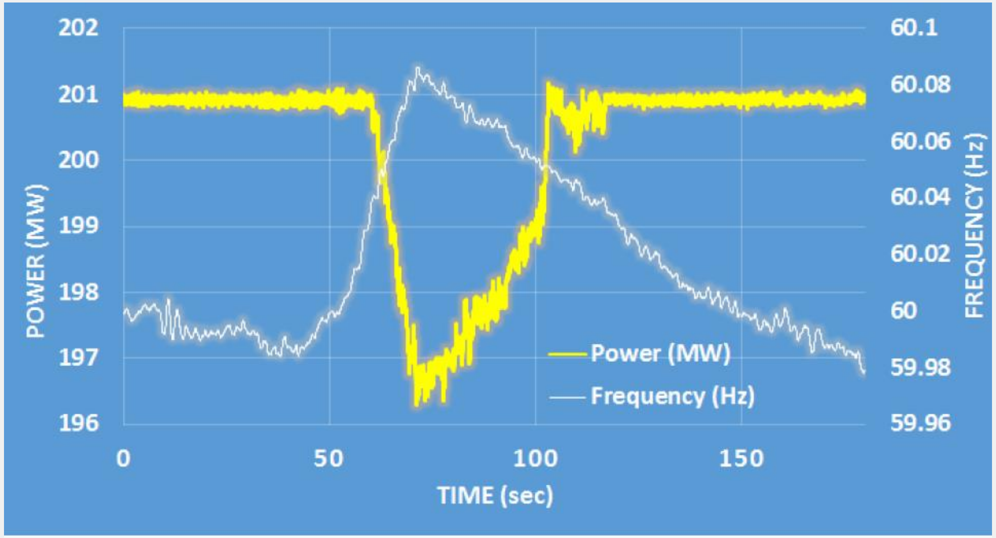
Table 2. Measured regulation accuracy by 300 MW PV plant

Timeframe	Solar PV Plant Test Results
Sunrise	93.7%
Middle of the Day	87.1%
Sunset	87.4%

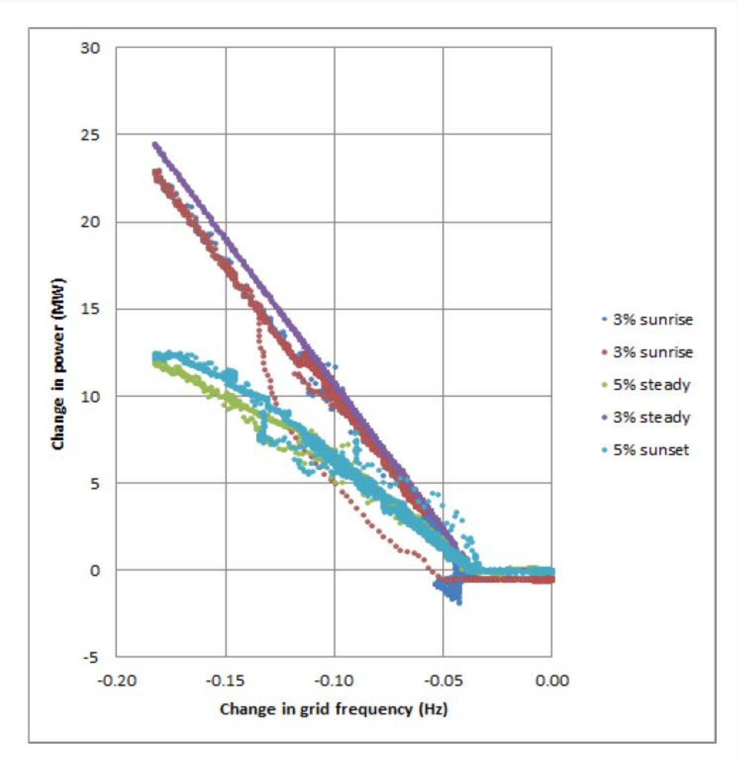
Table 3. Typical regulation up accuracy of CAISO conventional generation

	Combined Cycle	Gas Turbine	Hydro	Limited Energy Battery Resource	Pump Storage Turbine	Steam Turbine
Regulation-Up Accuracy	46.88%	63.08%	46.67%	61.35%	45.31%	40%

Frequency droop

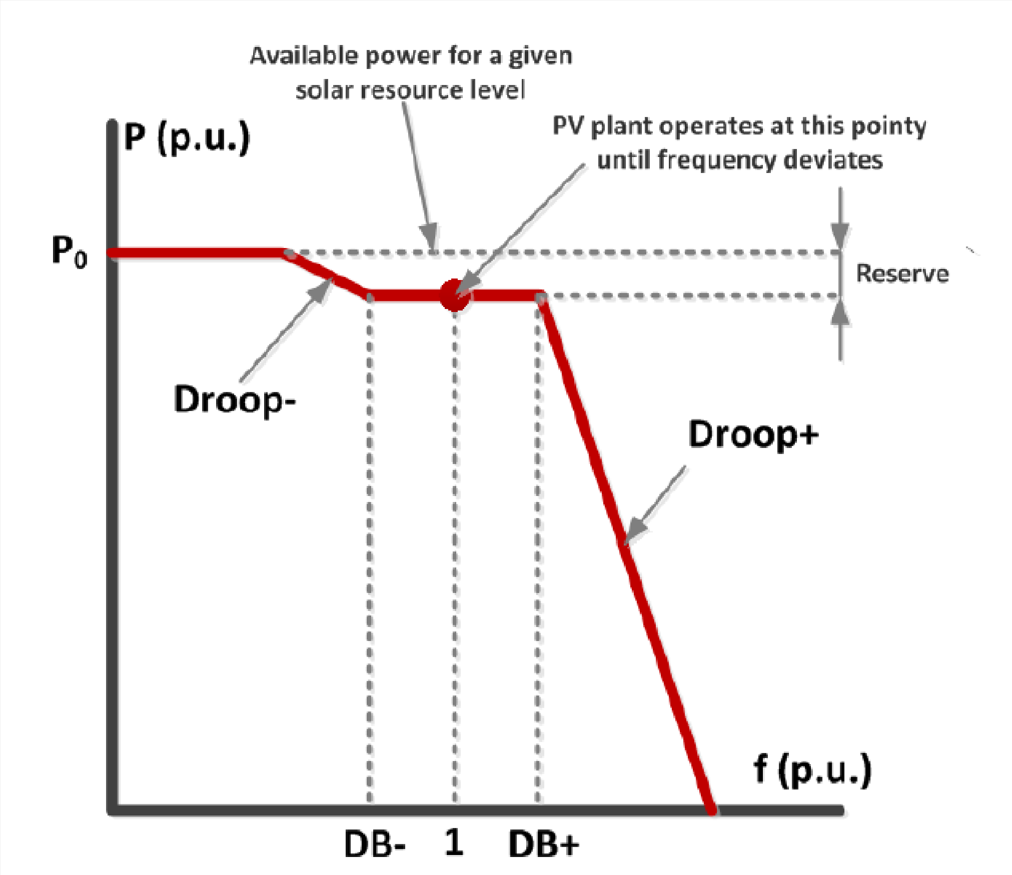


Over - frequency response
this one at 5% droop at sunrise



Under-frequency responses

Suggestion to use non-symmetric droop for PV plants



Summary

- Changing generation mix makes it valuable for variable renewable generation to provide frequency control services
- AGC response has been tested but not as we know it
- Frequency droop control requirements becoming a reality in some places (especially in the US)
  - Mandatory droop and deadband requirements
  - Headroom requirements not generally specified

References

1. Frankfurt School FS-UNEP Collaborating Centre for Climate and Sustainable Energy Finance. (2017). Global Trends In Renewable Energy Investment 2017.
2. EIA. (2016, March 23). U.S. electric generation capacity additions, 2015 vs. 2014. Retrieved from U.S. Energy Information Administration: https://www.eia.gov/todayinenergy/detail.php?id=25492
3. NERC. (2015). 2015 Long-Term Reliability. Retrieved from http://www.nerc.com/pa/RAPA/ra/Reliability%20Assessments%20DL/2015LTRA%20-%20Final%20Report.pdf
4. EIA. (2016, March 8). Electricity generating capacity retired in 2015 by fuel and technology. Retrieved from U.S Energy Information Administration: https://www.eia.gov/todayinenergy/detail.php?id=25272
5. Renew Economy May 2017 http://reneweconomy.com.au/agl-kills-idea-of-gas-as-transition-fuel-wind-solar-storage-cheaper-63013/
6. NERC Frequency Response Initiative Report: The Reliability Role of Frequency Response (Oct. 2012), http://www.nerc.com/docs/pc/FRI_Report_10-30-12_Master_w-appendices.pdf (NERC Frequency Response Initiative Report)
7. Referenced in NERC Frequency Response Initiative: Industry Advisory – Generator Governor Frequency Response (webinar) April 2015 http://www.nerc.com/pa/rrm/Webinars%20DL/Generator_Governor_Frequency_Response_Webinar_April_2015.pdf
8. FERC 157 18 CFR Part 35 [Docket No. RM16-6-000] Essential reliability services and the evolving bulk power system – Primary Frequency Response, 17 November 2016 https://www.ferc.gov/whats-new/comm-meet/2016/111716/E-3.pdf
9. ERCOT Demonstration of PFR Improvement September 2017 http://www.pjm.com/-/media/committees-groups/task-forces/pfrstf/20171009/20171009-item-04-ercot-frequency-response-improvements.ashx

References

10. FERC Essential Reliability Services and the Evolving Bulk-Power System-Primary Frequency Response: Notice of Request for Supplemental Comments https://www.federalregister.gov/documents/2017/08/24/2017-17952/essential-reliability-services-and-the-evolving-bulk-power-system-primary-frequency-response-notice
11. Gevorgian, Vahan, O'Neill Barbara Demonstration of active power controls by utility scale PV power plant in an Island Grid 2015 Presented at 15th International Workshop on Large-Scale Integration of Wind Power inot Power Systems https://www.nrel.gov/docs/fy17osti/67255.pdf
12. CAISO Using Renewables to operate a low-carbon grid: Demonstration of advanced reliability services from a utility-scale solar PV Plant 2017 https://www.caiso.com/Documents/UsingRenewablesToOperateLow-CarbonGrid.pdf
13. Excel Energy 30 Minute Flex Reserve on the Public Service Company of Colorado System 13 May 2016 https://www.xcelenergy.com/staticfiles/xe-responsive/Company/Rates%20&%20Regulations/CO-Rush-Creek-Attachment-JTW-2.pdf

Thank you!