FREQUENCY CONTROL AND MODELING OF INVERTER-BASED RENEWABLES FOR GRID STUDY: AN INDUSTRY PERSPECTIVE

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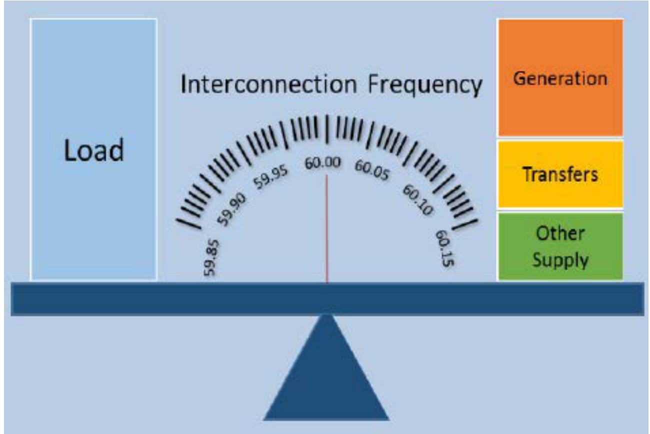

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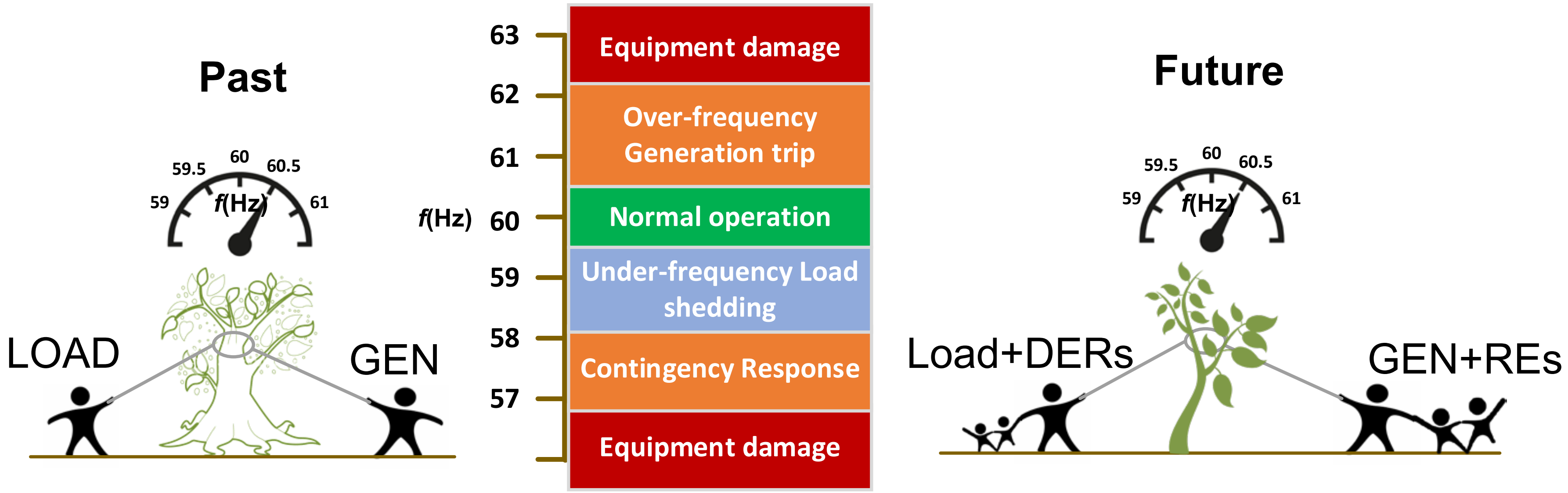
Content

- Introduction
- Impact of IBR(Inverter-based Resource) on frequency response of Interconnections
- Industry Actions
  – IBR provides frequency controls
  – Improve situational awareness of inertia
  – Develop new ancillary services product

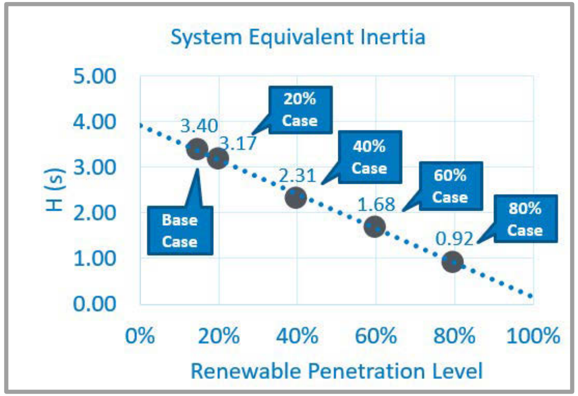
Introduction

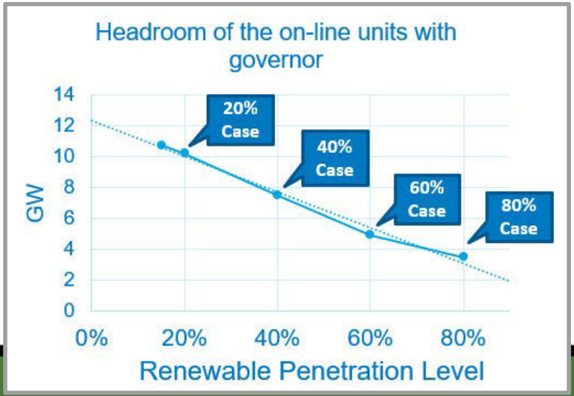
- System frequency and inertia

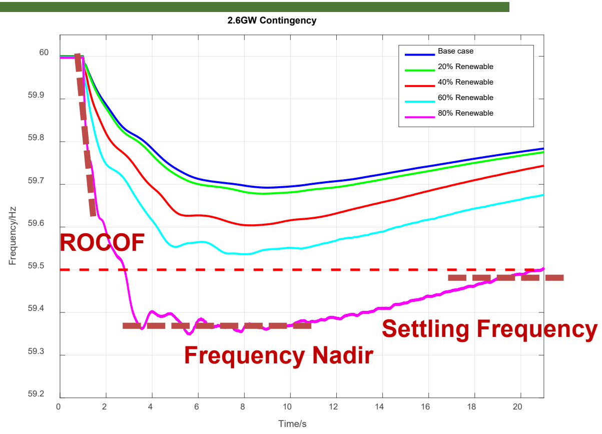


Low inertia requires faster frequency response

Renewable Penetration (20%, 40%, 60%, 80%)



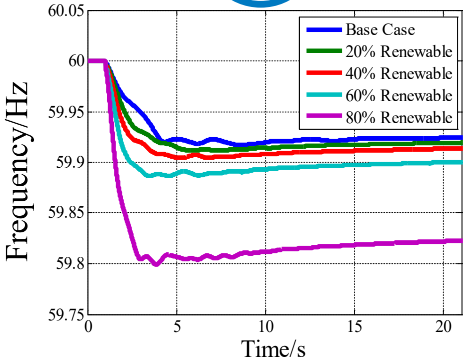




- ☹ High rate of change of frequency (ROCOF)
- ☹ Low frequency nadir
- ☹ Low settling frequency

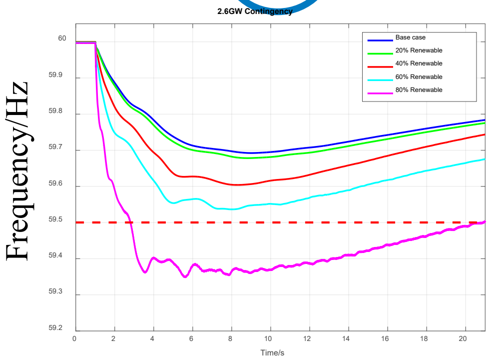
Impact of IBR on Three U.S. Interconnections

EI



[Credit by ORNL]

WECC



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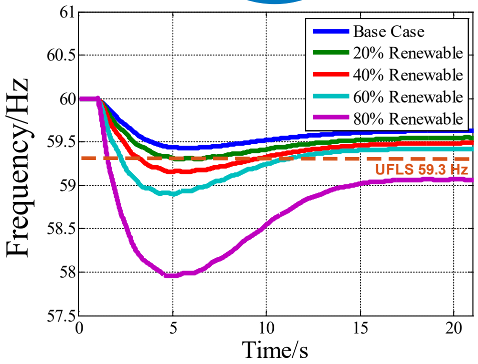
ERCOT



[Credit by UTK]

	EI	WECC	ERCOT
Total Generation(GW)	540	117	75
Maximum Loss of Generation(GW)	4.5(0.8%)	2.6(2.2%)	2.7(3.6%)
Original Equivalent Inertia (20% Case) (s)	2.03	3.17	1.79
Equivalent Inertia (80% Case) (s)	0.53	0.92	0.44
Frequency Nadir (80% Case)	59.8 Hz	**59.35 Hz**	**58.0 Hz**

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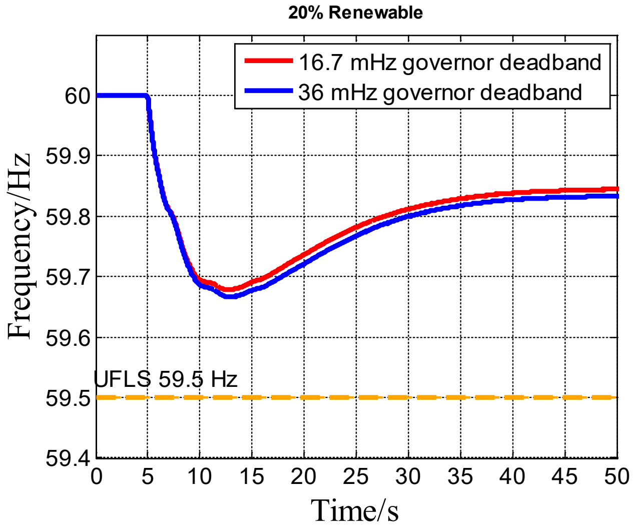
Reference project: DOE SUNLAMP Project titled" Frequency Response Assessment and Improvement of Three Major North American Interconnections due to High Penetrations of Photovoltaic Generation"(2015-2018)

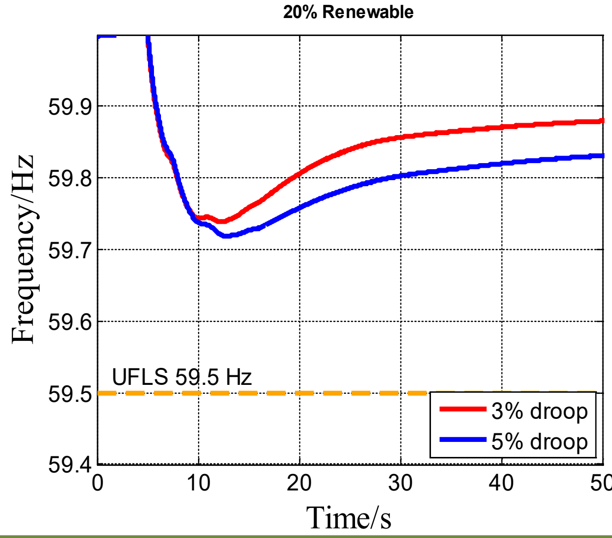
IEEE

Using Existing Resources to Improve Frequency Response in WECC

- Dead-band



- Droop setting



- A narrow governor dead-band makes the governor kick in earlier.
- Improvement is not obvious.

A 3% governor droop can significantly improve the frequency nadir and settling frequency of WECC.

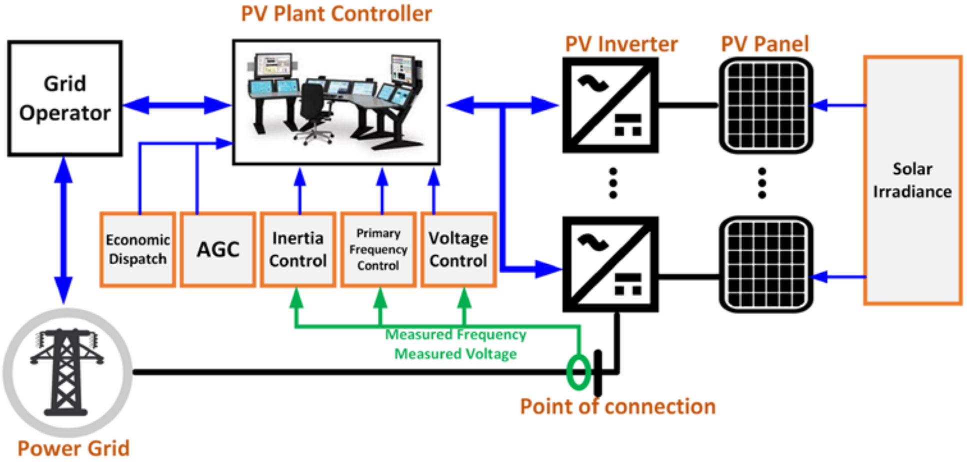
Industry Actions

- – Add frequency control of IBR
- – Increase situational awareness of inertia
- – Develop new ancillary services product
- – Etc.

Advanced frequency control of IBR

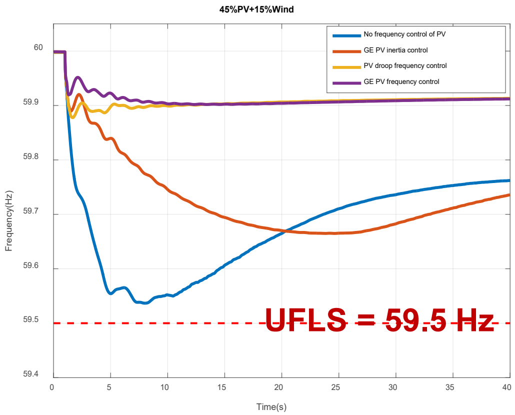
Frequency control from IBR

- AGC control
- Droop control(PFR)
- Fast frequency control
  - Inertia-based FFR
  - Other FFR

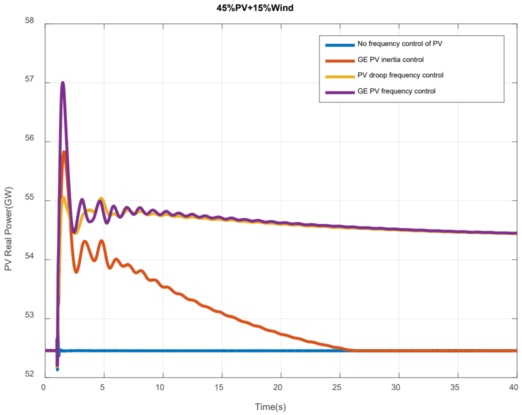


Example: Frequency Control of PV in WECC

Frequency response of WECC and PV output (60% IBR)



(a) Grid frequency



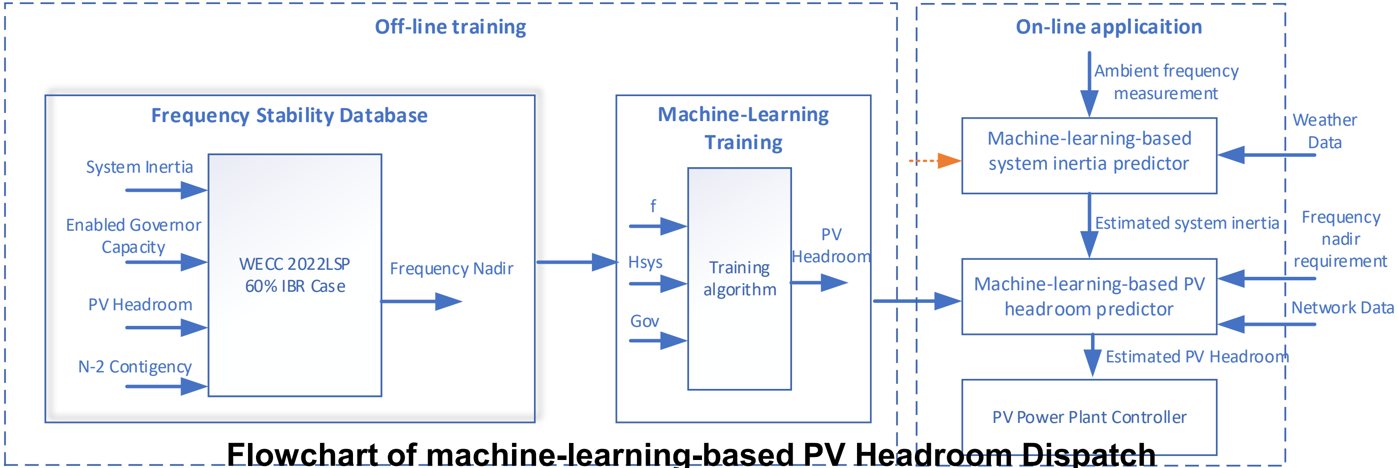
(b) PV real power

- Inertia control → Postpone f_{nadir}
- Droop control → Improve f_{nadir}, f_{settle}

How to decide PV headroom for frequency control?

Smart PV Inertia control based on real-time system inertia awareness

- **Goal:** Fulfil frequency response obligation and maximize energy savings and economic benefits of PV.
- **Method**: Machine-learning-based PV headroom dispatch

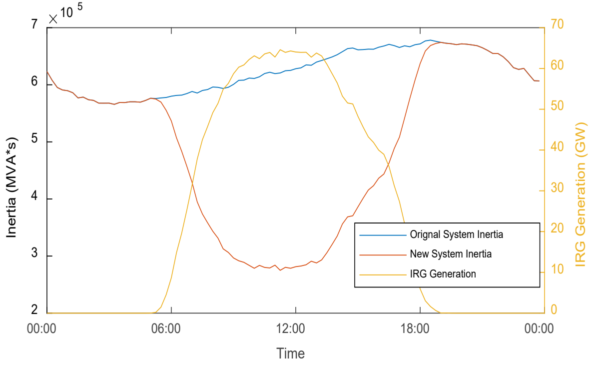


Flowchart of machine-learning-based PV Headroom Dispatch

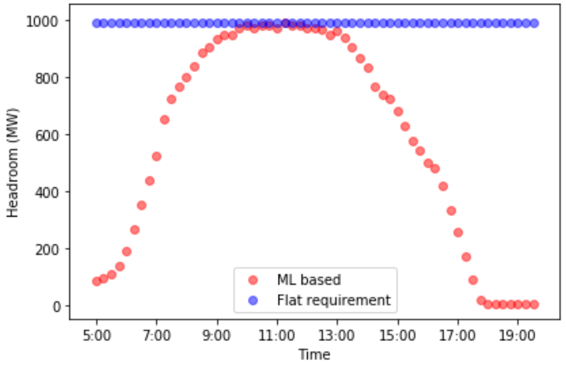
Reference project: DOE SETO Project titled" Smart PV Inertia Control based on Real-time System Inertia Awareness"(2018-2019)

Example: PV headroom saving in WECC

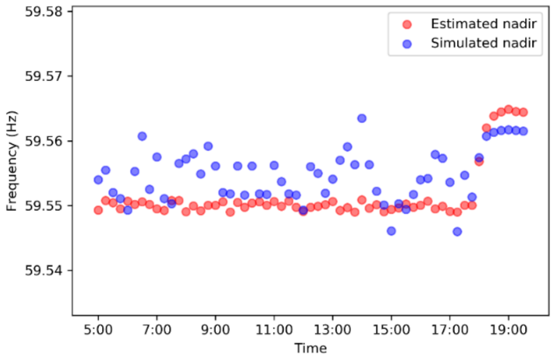
- 1,989 training cases have been completed.
- A neural network model is trained and validated to predict frequency nadir.
- A binary search algorithm to estimate PV headroom is developed.
- 40.69% saving on PV headroom is achieved.



One-day profile of PV output and inertia



Estimated headroom



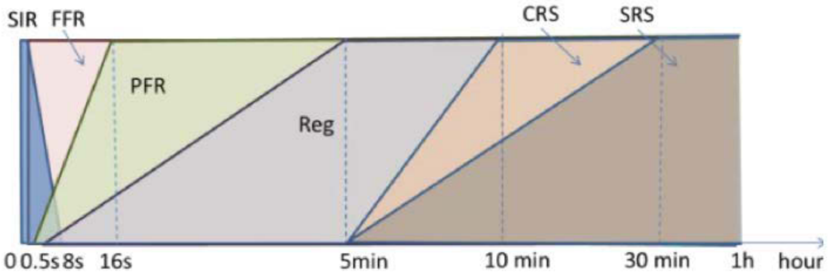
Estimated nadir vs simulated nadir

Need frequency ancillary services products for renewables

- **3H-**How fast, how much and how long?

- **Challenges:**
  - Require a product that is not commercially available.
  - How to validate the product?
  - How do we consider stability constraints while designing the product?
  - Trade-off between reliability and economics

Future Ancillary Services in ERCOT



The ERCOT process is on going. Changes have not yet been approved. http://www.ercot.com/committee/qmwg

Conclusions

- Increasing of renewable penetration levels will pose huge challenges for grid operations.
- Fast frequency control from IBR is necessary for future grid with high renewable penetrations.
- Improve inertia awareness is beneficial for system operator and can be used for maximizing PV headroom saving.
- Properly structured production cost model is required for capturing these new constraints for providing fast frequency support.

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Thank you!

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