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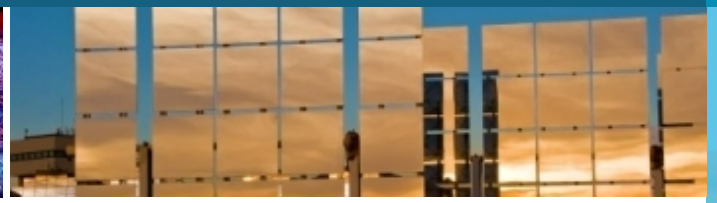
The Impact of Co-Located Clusters of Inverter-Based Resources on a Performance-Based Regulation Market Metric



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Introduction

Need for this work:

- Use of Inverter-Based Resources (IBRs) is increasing.
- IBRs may improve system performance.
- Performance improvements should be quantified using an established metric.

Task of this work:

- Simulate conventional generation and IBRs response to a dispatch following scenario.
- Account for variable resources available to IBRs.
- Compare results via a CAISO Performance-Based Regulation (PBR) market metric.

Main message of presentation:

- IBRs can improve PBR metrics of all connected areas due to their ability to react fast.
- However, adequate reserve capacity and device control to handle variable resources is required.
- Poorly controlled IRBs can negatively affect the PBR metric of all areas.

Presentation Overview

Simulated Power System and Scenario Descriptions

- Three Area IEEE 39 Bus System
- Flexpower Plant (Group of Co-Located Inverter Based Resources)
- System Perturbances (Demand and Wind Profiles)

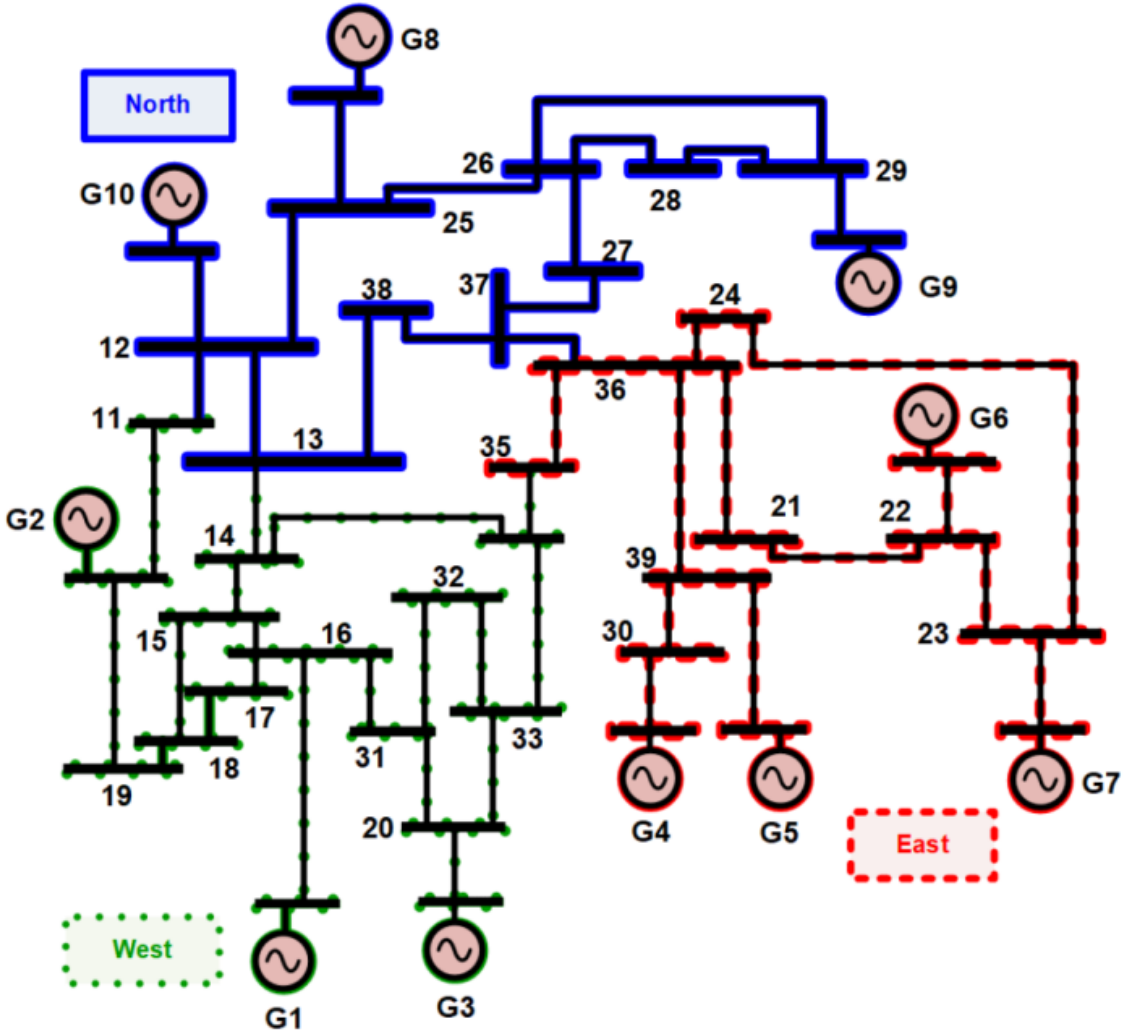
System Controls and Performance-Based Regulation (PBR) Market Metric

- Automatic Generation Control (AGC)
- Plant Control Schemes
- CAISO PBR Metric

Simulation Results

- Case Definitions
- Conventional Generation Only – Base Line
- Flexpower with Constant Resources
- Flexpower with Variable Resources
- Faster Flexpower Control with Variable Resources

Three area IEEE 39 bus system with conventional steam governors and turbines used for the Base Case Scenario.



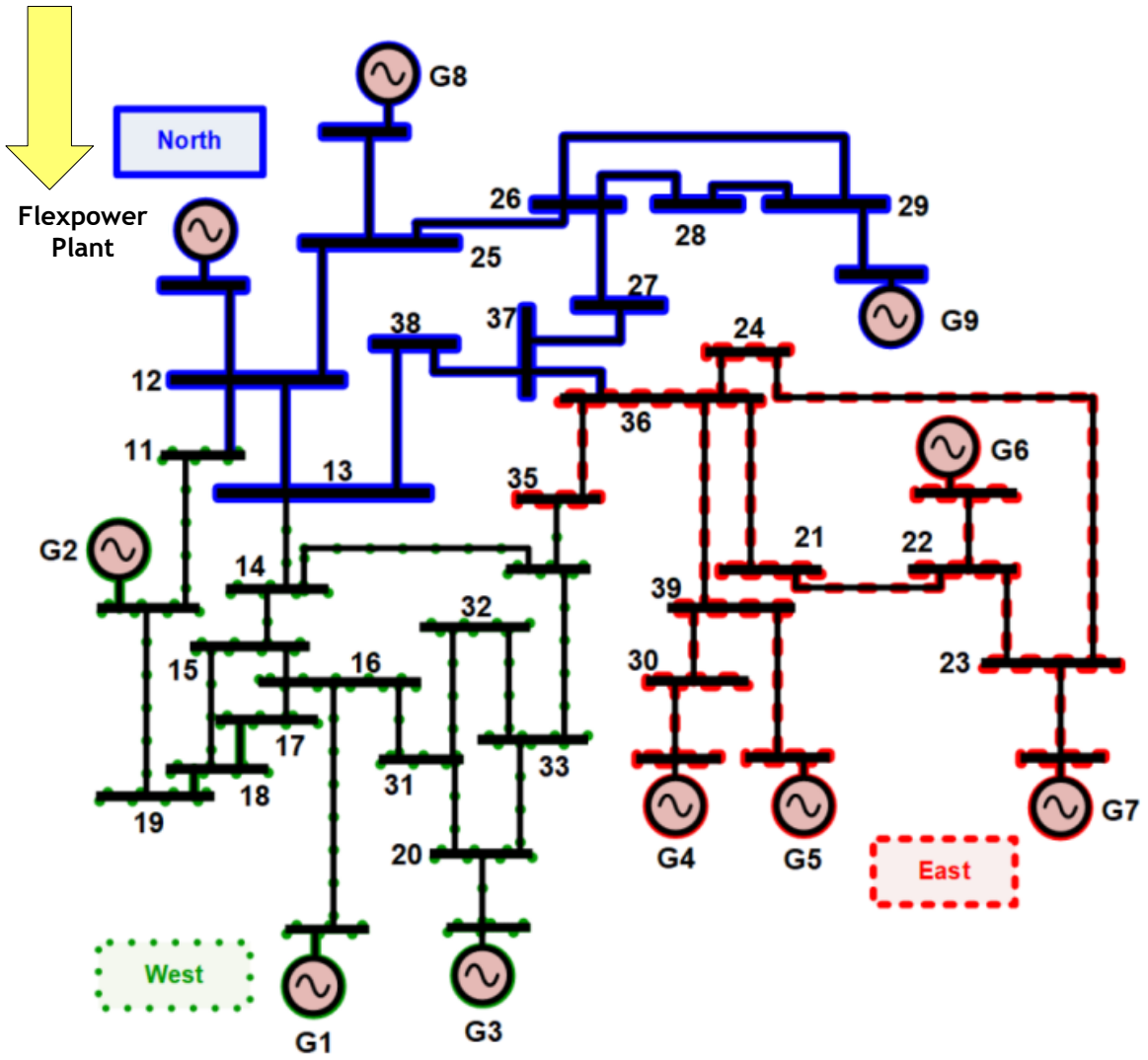
SYSTEM WIDE GENERATION RATING AND CONTROL DESCRIPTIONS.

Area	Source	Machine Base (MVA)	Control
West	G1	3000	-
	G2	1000	Governor
	G3	1000	AGC
East	G4	1000	Governor
	G5	520	-
	G6	1000	Governor
	G7	1000	AGC
North	G8	1000	-
	G9	1000	Governor
	G10	1000	AGC

SYSTEM LOAD AND EXPORT CHARACTERISTICS BY AREA.

Area	Load [MW]	Export [MW]
North	1341	132
East	2107	-425
West	2367	293

G10 replaced by Flexpower Plant (group of co-located IBRs) containing:
Solar Photovoltaic Plant (PV), Wind Turbine (WT), Battery Energy Storage System (BESS)



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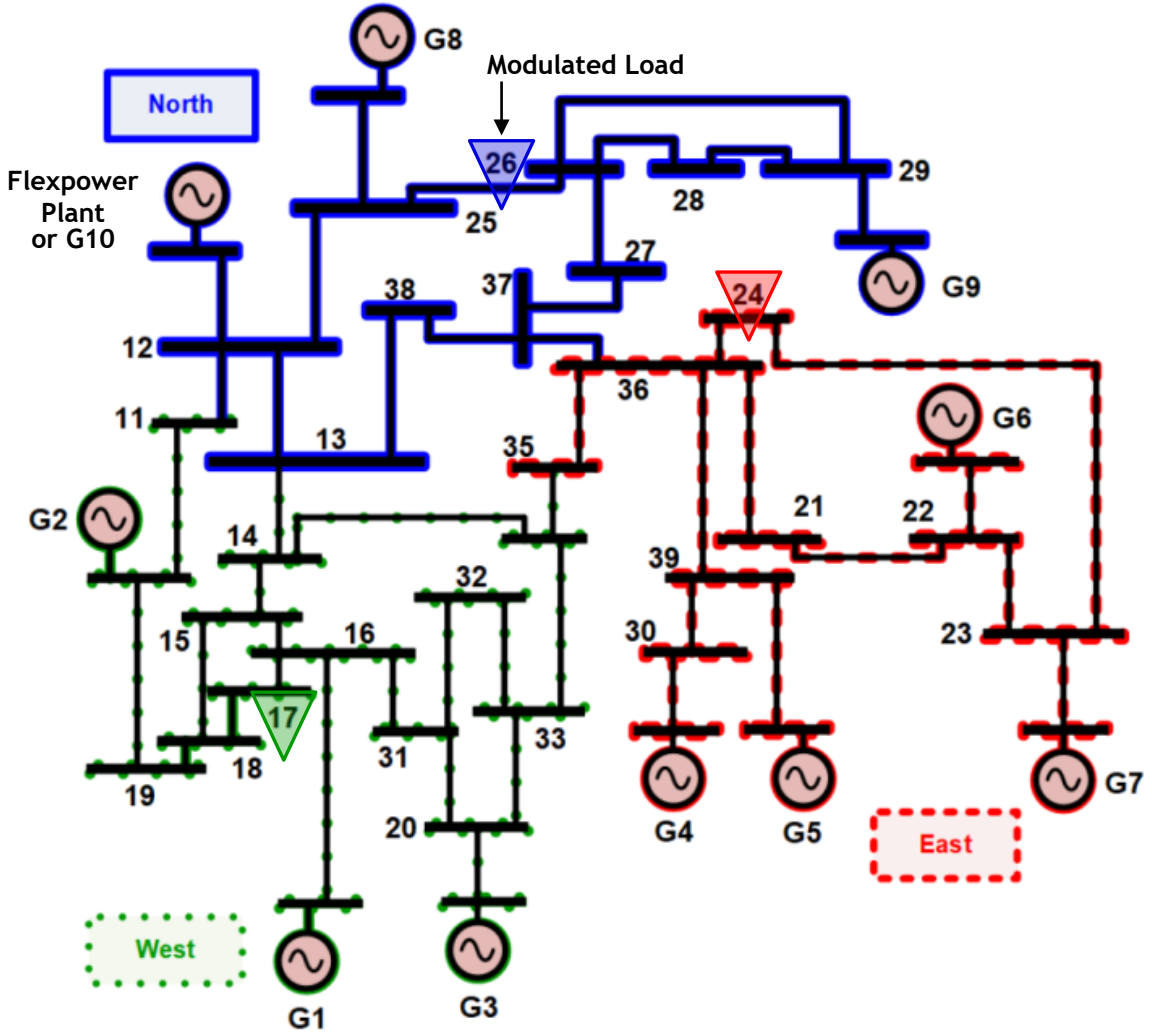
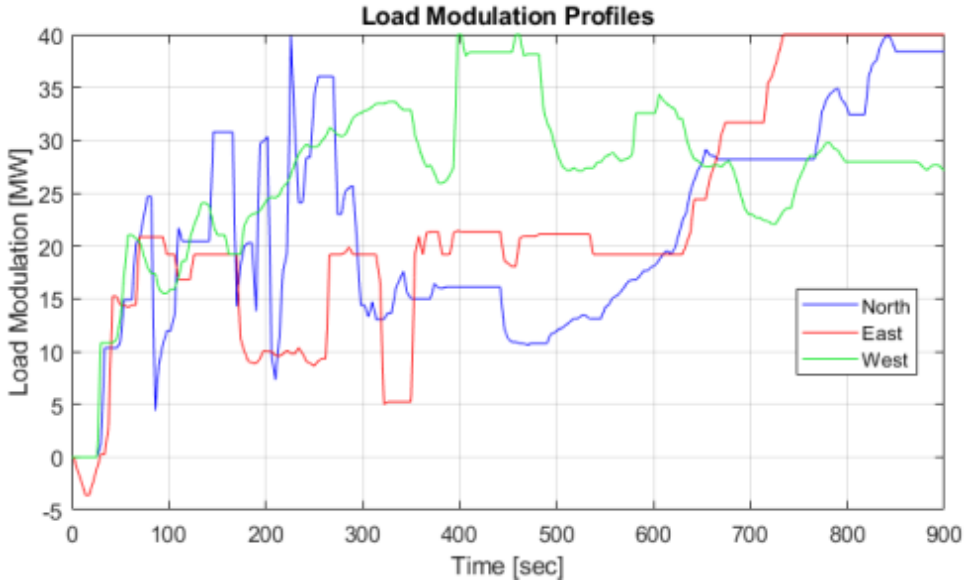
	G5	520	-
	G6	1000	Governor
	G7	1000	AGC
North	G8	1000	-
	G9	1000	Governor
	Flexpower		
	PV+WT	570	-
	BESS	100	AGC

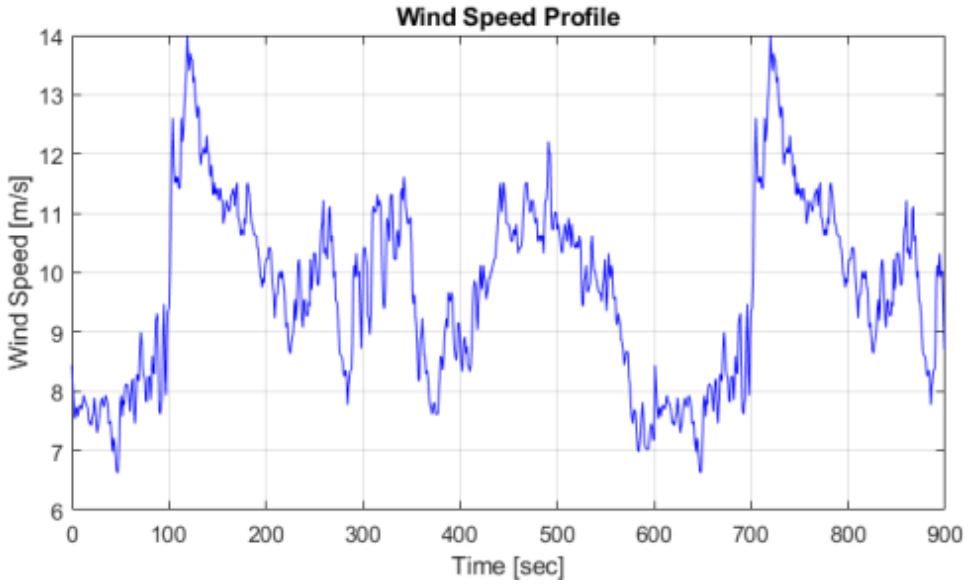
FLEXPOWER GENERATION PARAMETERS.

Technology	Voltage Rating [kV])	Power Rating [MVA]	Power Reference [MW]
PV	0.69	220	120
WT	0.69	350	225
BESS	0.48	100	-30

Load modulation for each area from CAISO dispatch data. Wind speed profile used to represent Variable Resources (VR).

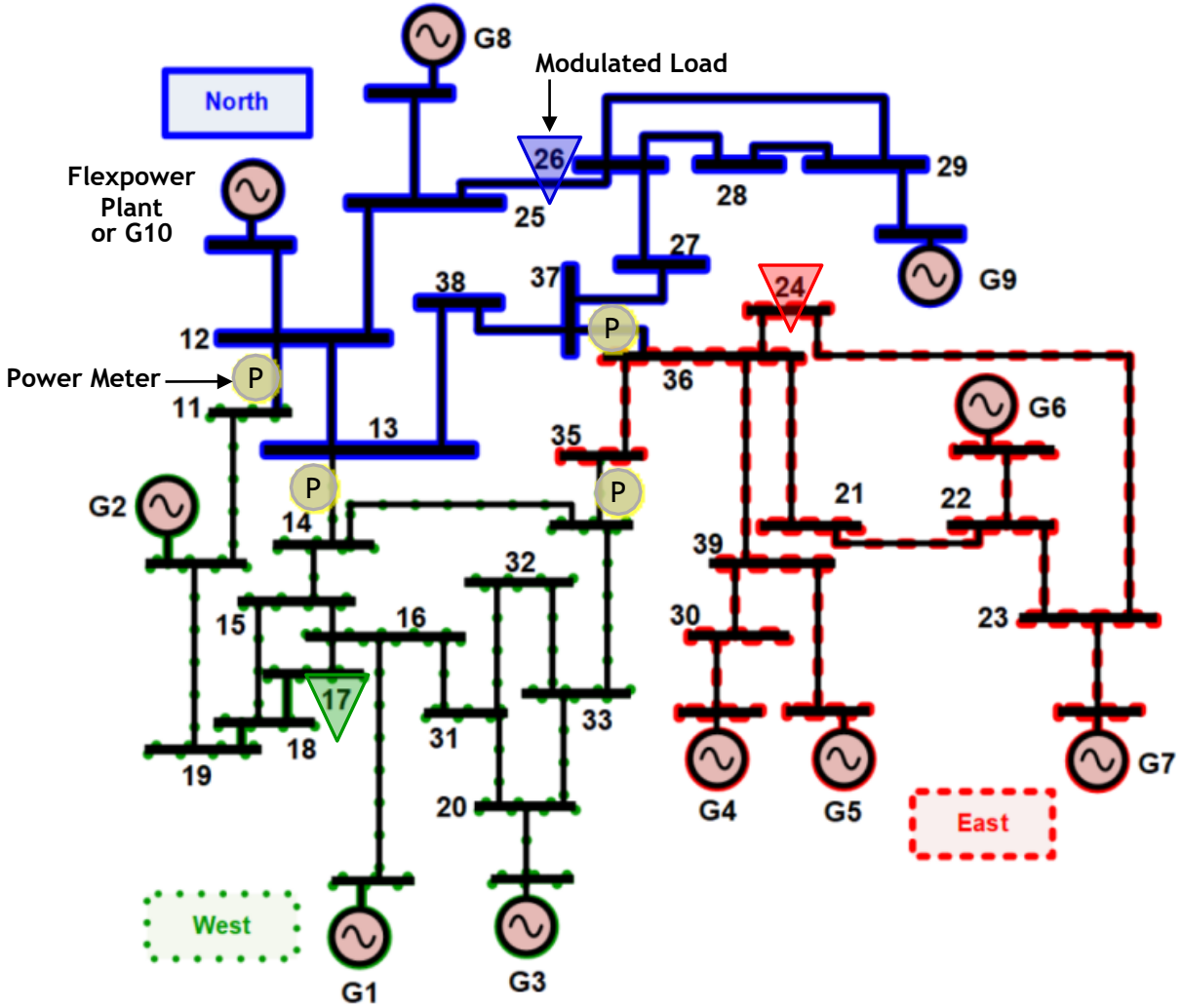


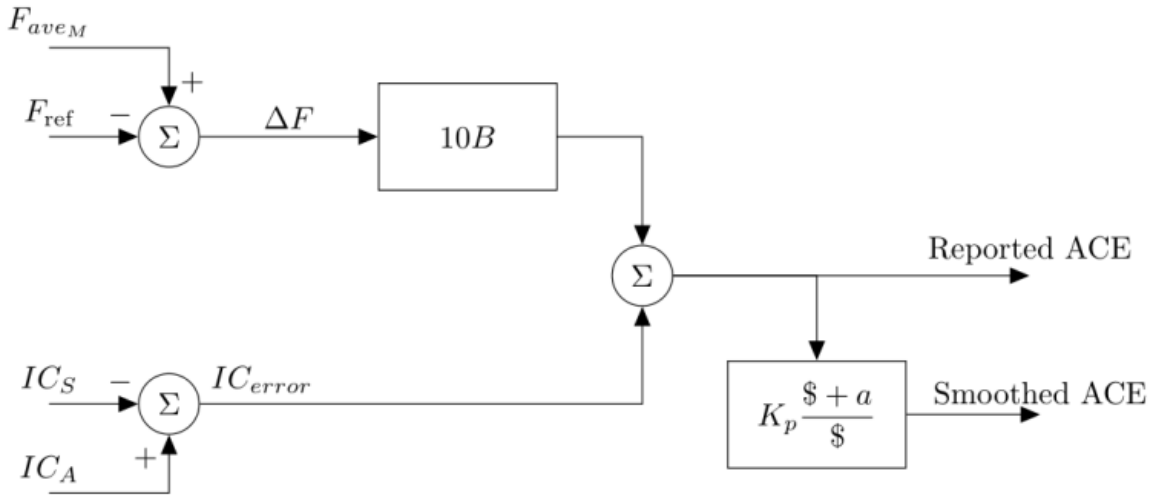




Automatic Generation Control (AGC) sends new dispatch for each area

d Area Control Error (ACE).





F_{ave_M} = Average Measured Frequency
F_{ref} = Frequency Reference
B = Frequency Bias
IC_S = Scheduled Interchange
IC_A = Actual Interchange
K_p = Proportional Gain
a = Controller Zero

$$ACE = (IC_A - IC_S) + 10B(F_{ave_M} - F_{ref}) \qquad (1)$$

Different plant control approaches were used in this work. Uncontrolled plants acted as constant mechanical power generation sources.

Conventional Governor Only	Conventional AGC	Flexpower CTRL A	Flexpower CTRL B
• 5% Droop • No deadband	• AGC signal updates machine power reference • Conventional generators responding to AGC do not provide a governor response	• Plant output responds to AGC at intervals of 2 seconds • Error correction on second dispatch	• Plant output responds to AGC at intervals of 0.5 seconds • Error correction on all dispatches beyond first

CAISO Performance-Based Regulation (PBR) metric used to calculate Performance scores that quantify simulation results.

Performance Score

- Measure of deviation from command setpoint
- Calculated every market period (15 minutes)
- Directly affects payments (mileage ≈ MW):

$$\begin{Bmatrix}\text{Mileage}\\ \text{Payment}\end{Bmatrix} = \begin{Bmatrix}\text{Actual}\\ \text{Mileage}\end{Bmatrix} \times \begin{Bmatrix}\text{Mileage}\\ \text{Price}\end{Bmatrix} \times \begin{Bmatrix}\text{Performance}\\ \text{Score}\end{Bmatrix}$$

- Calculated for up and down regulation periods

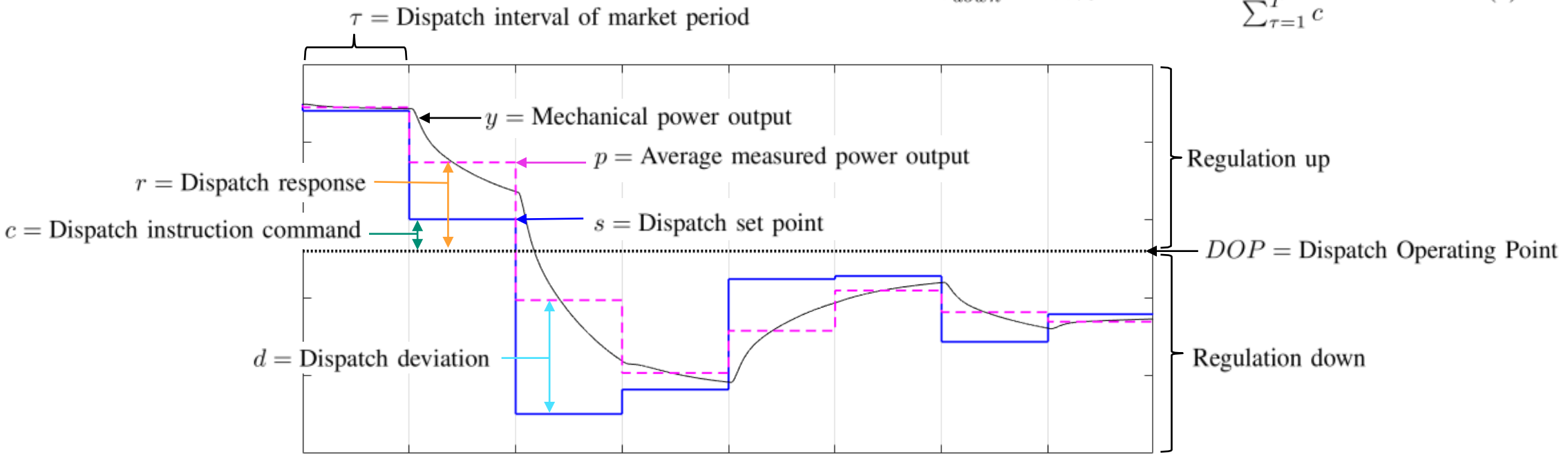
$$c = s - DOP \quad (2)$$

$$r = p - DOP \quad (3)$$

$$d = |c - r| \quad (4)$$

$$PS_{up} = 100\% \times \frac{\text{MAX}\left(0, \sum_{\tau=1}^{T} c - \sum_{\tau=1}^{T} d\right)}{\sum_{\tau=1}^{T} c} \quad (5)$$

$$PS_{down} = 100\% \times \frac{\text{MIN}\left(0, \sum_{\tau=1}^{T} c + \sum_{\tau=1}^{T} d\right)}{\sum_{\tau=1}^{T} c} \quad (6)$$



Four fifteen minute simulations were considered for this work.

Base Case

- Conventional generation only

Flexpower – CTRL A

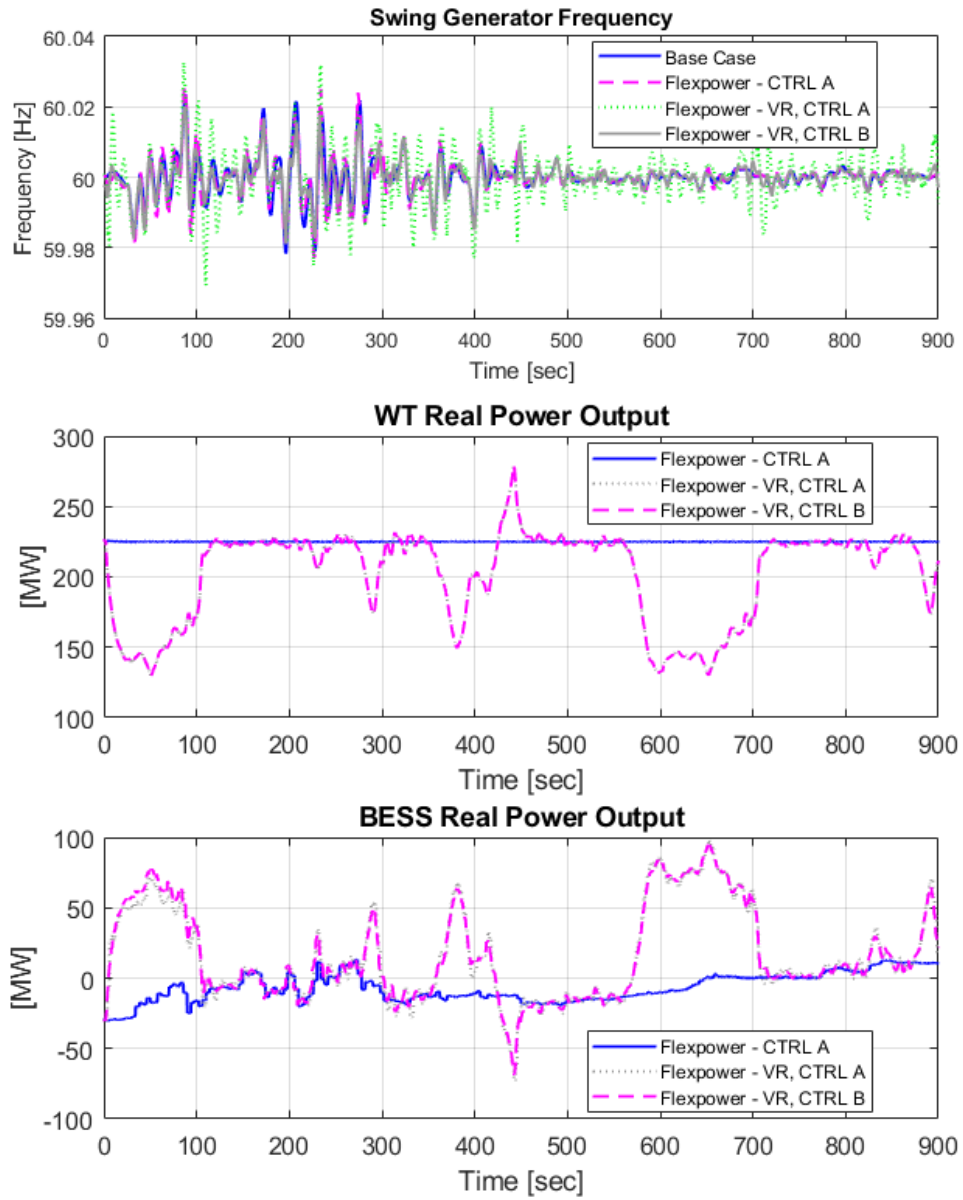
- Plant updates power reference every 2 seconds
- Wind profile not used - constant resource
- BESS responds to AGC signal only

Flexpower – VR, CTRL A

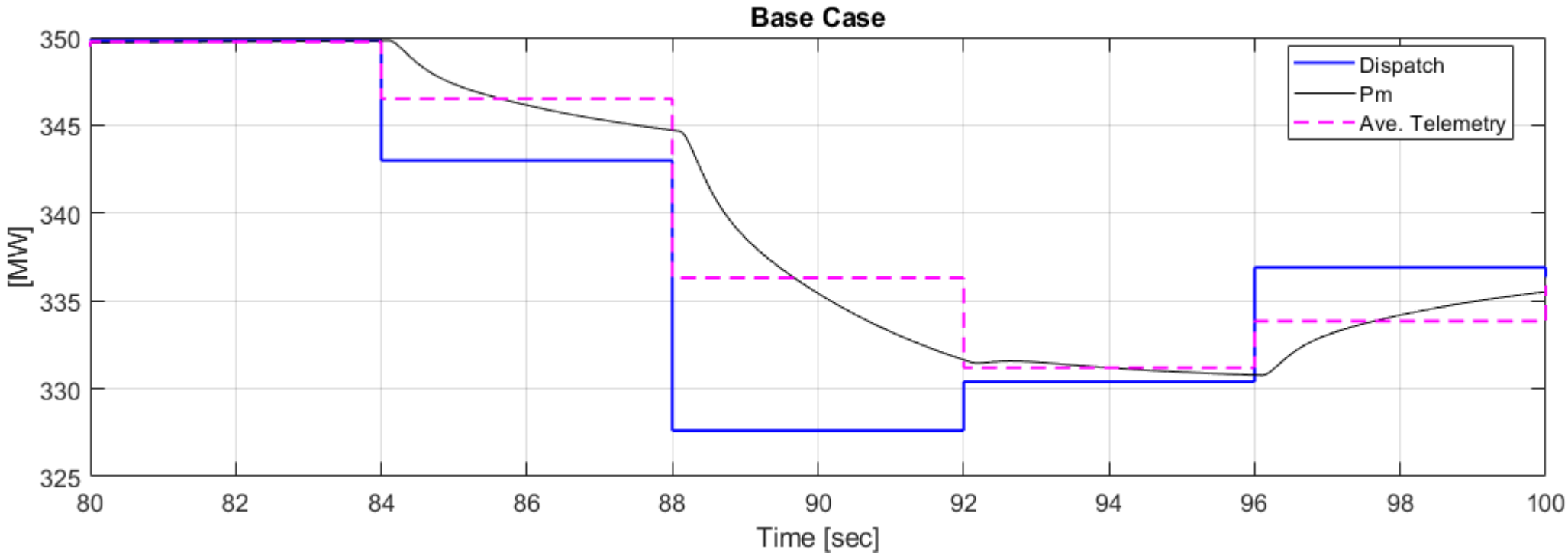
- Wind profile used - variable resources (VR)
- BESS responds to AGC signal and accounts for wind variability

Flexpower – VR, CTRL B

- Plant updates power reference every 0.5 seconds
- BESS responds to AGC signal and accounts for wind variability



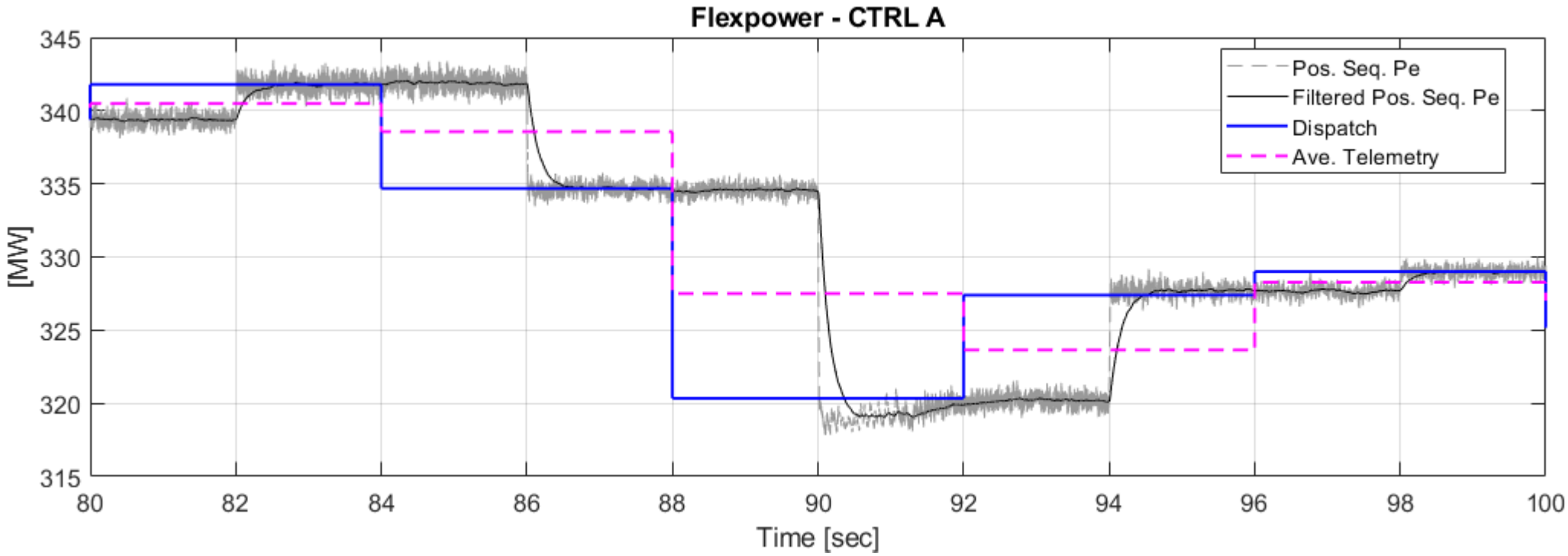
Conventional generation responds like a typical 1st order system. These results were treated as the base case scenario.



SINGLE CASE PERFORMANCE SCORES

	North	Δ	East	Δ	West	Δ
Reg. Up - Conventional Base Case	90.49	-	96.47	-	86.49	-
Reg. Down - Conventional Base Case	83.50	-	87.71	-	88.86	-

Flexpower CTRL A responds very fast but has error in first dispatch.
Performance score results are mixed

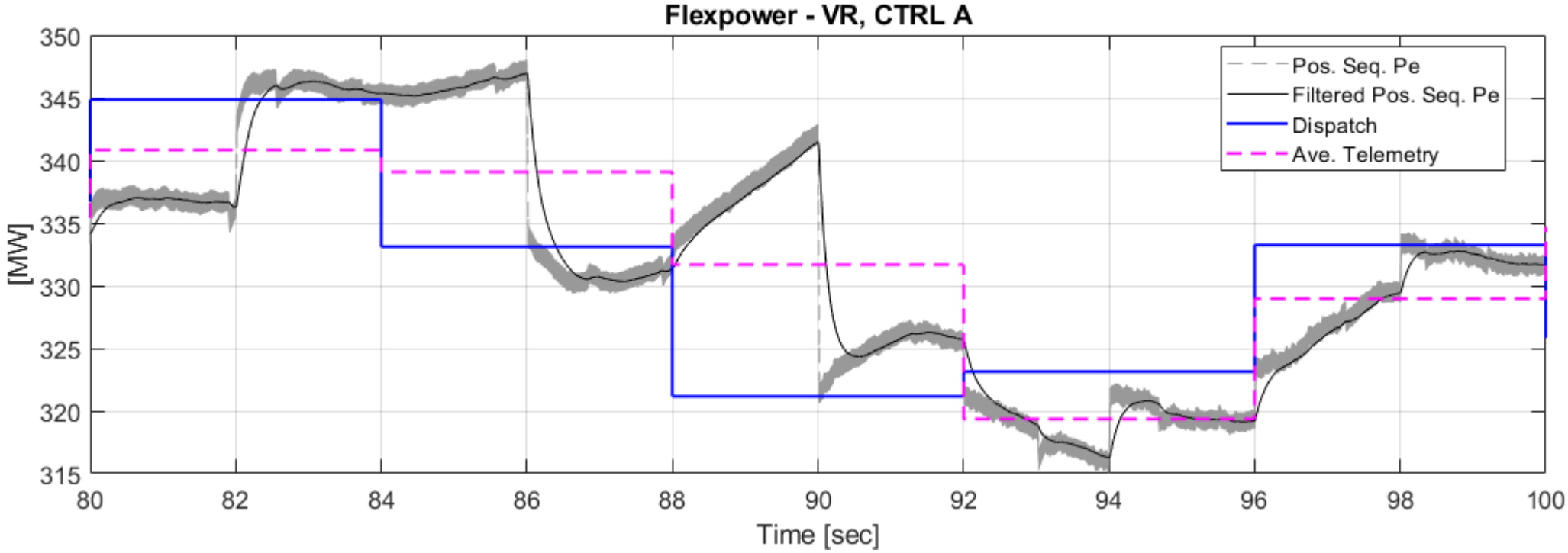


SINGLE CASE PERFORMANCE SCORES

	North	Δ	East	Δ	West	Δ
Reg. Up - Flexpower - CTRL A	91.07	0.58	96.63	0.16	85.73	-0.77
Reg. Down - Flexpower - CTRL A	86.41	2.91	87.26	-0.45	87.40	-1.46

Flexpower CTRL A does not act fact enough to handle variable resources.

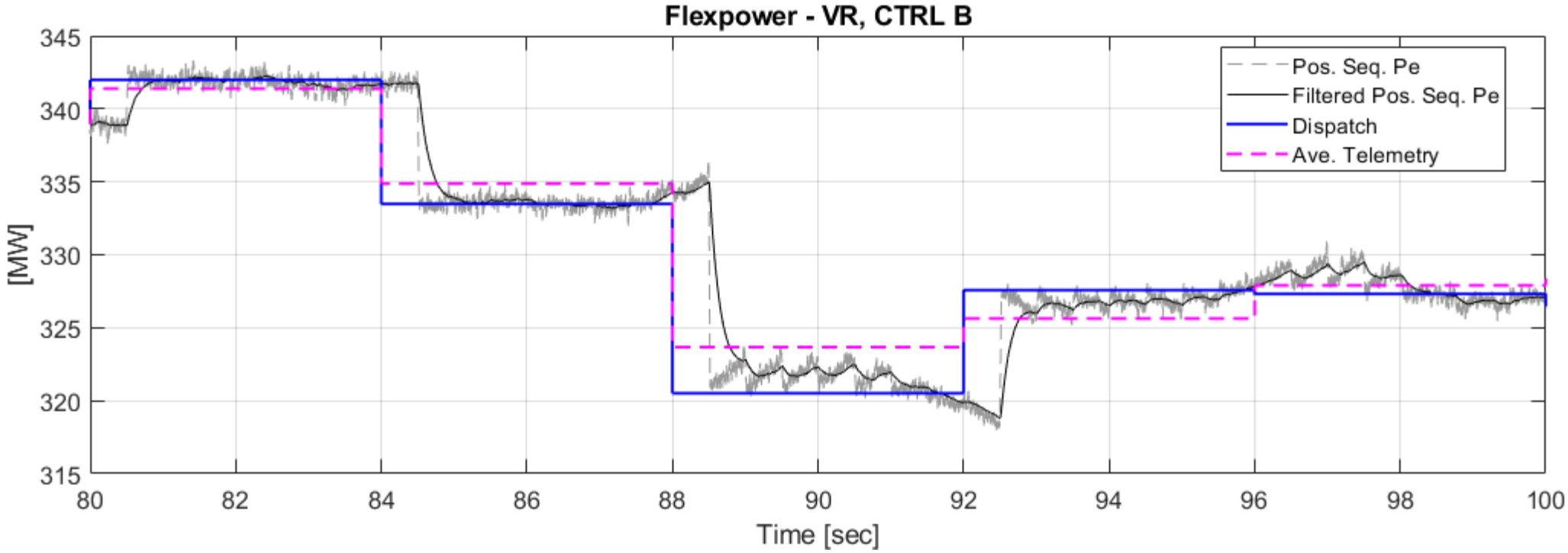
As a result, all performance scores are reduced



SINGLE CASE PERFORMANCE SCORES

	North	Δ	East	Δ	West	Δ
Reg. Up - Flexpower - CTRL A, VR	69.28	-21.21	94.71	-1.76	77.86	-8.63
Reg. Down - Flexpower - CTRL A, VR	57.90	-25.60	85.51	-2.19	81.58	-7.28

Flexpower CTRL B handles variable resources much better than CTRL A.
Performance scores for all areas are improved



SINGLE CASE PERFORMANCE SCORES

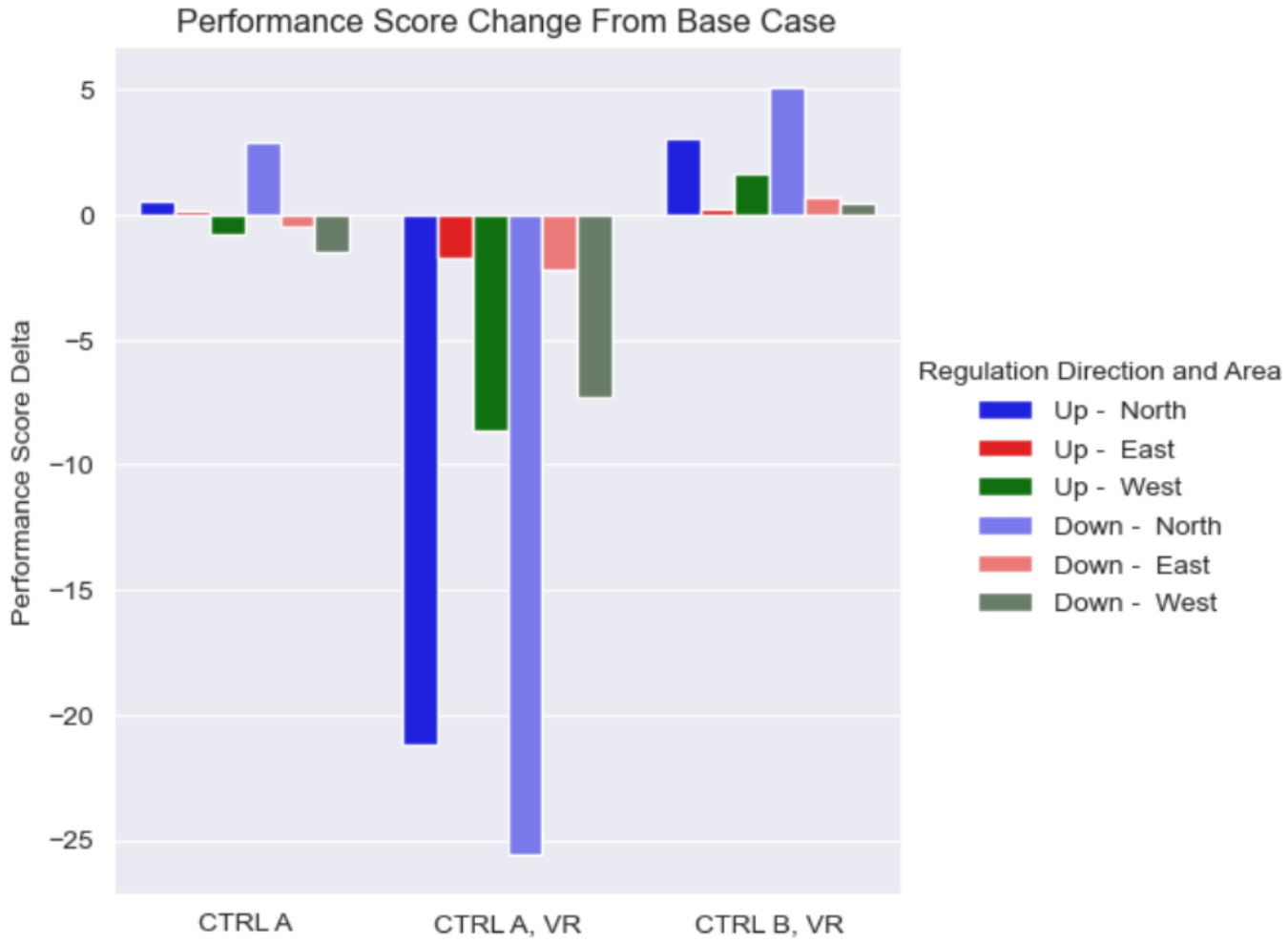
	North	Δ	East	Δ	West	Δ
Reg. Up - Flexpower - CTRL B, VR	93.59	3.10	96.69	0.22	88.12	1.63
Reg. Down - Flexpower - CTRL B, VR	88.64	5.14	88.43	0.72	89.36	0.50

Result Review & Conclusion

Simulation results showed Inverter-Based Resources can improve Performance Scores beyond a typical conventional generation response.

However, this requires adequate resource supply and device control.

Poorly controlled Inverter-Based Resources can negatively affect the Performance Score of all connected areas.



Thanks!

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This presentation described objective technical results and analysis. Any subjective views or opinions that might have been expressed do not necessarily represent the views of the U.S. Department of Energy or the United States Government.

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