

# Simulation of Bifurcated Regulation Products

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## Background

## Simulation Overview

- FESTIV Software
- Input Details

## Results

- Area Control Error and CPS2 Statistics
- Controller Saturation-up and –down
- Resource Mix and Generator Movement
- Additional Results

## Key Takeaways



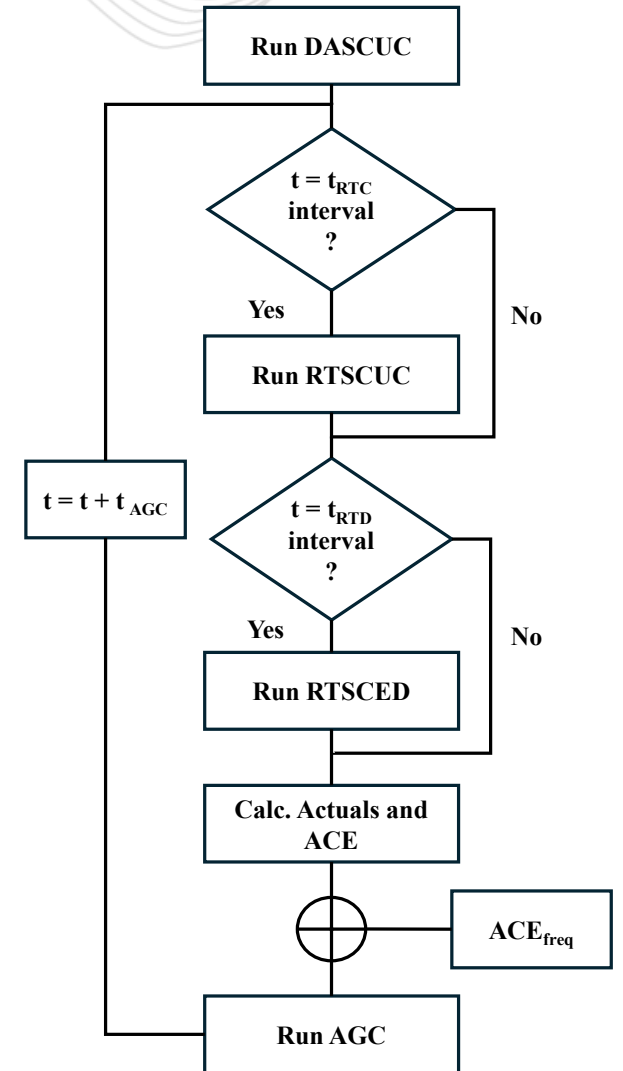
# Background - Phase 1 Summary of Changes (Oct. 1, 2025)

#	Design Components	Summary Description
1	<b>Signals and Products</b>	Change from <b>two</b> signals (RegA and RegD) bidirectional to <b>one</b> signal bidirectional that all resources that are assigned Regulation in a given market interval will follow.
2	<b>Requirement MW</b>	Changes to better reflect operational needs with consideration both to historic and future system conditions
3	<b>Performance Scoring</b>	Change from accuracy, delay and precision to precision only.
4	<b>Offer and Clearing Timing</b>	Eliminate “cost increase in VOM” except for Reg-only resources; change from hour clearing and commitment to 30-minute clearing and commitment.
5	<b>Opportunity Cost Calculation Reform</b>	<ol style="list-style-type: none"><li>1. Use the schedule the resource is running for energy or else the cheaper of available schedule for offline.</li><li>2. Use tracking desired megawatt at LMP ramp rate limited.</li><li>3. Use the area between LMP and the energy schedule the resource is running on.</li></ol>
6	<b>Settlement</b>	<p>For the eligible resources, Settlement will calculate the shoulder interval opportunity cost for two five-minute ramp-in intervals before the resource Regulation operation and two five-minute ramp-out intervals following the resource Regulation operation (currently, three intervals ramp-in and three intervals ramp-out).</p> <p>Also, Settlement will update the calculation for the Regulation Mileage Credit (currently Performance Credit) such that the mileage ratio is equal to (Real-Time Regulation Mileage/Historic Regulation Mileage).</p>

- Change from **one** product (bidirectional) to **two** products (RegUp and RegDown), each with its own requirement and clearing price and settlement
- Implementation: October 1, 2026\*

\*Pending FERC Approval

- FESTIV is an open-source multi-timescale steady-state wholesale market simulation software.
- Utilizes AGC sub-model which can simulate deployment of regulating reserve to correct ACE imbalance.
- Evaluates both economic and reliability metrics
- The functional code and optimization formulation are configurable through mods.
- Different sub-model parameters (e.g., optimization horizon, resolution) and solver options are configurable with customizable inputs.



- Leveraged EPRI/NREL's FESTIV tool to simulate DA-SCUC, RT-SCUC, RT-SCED and AGC deployment for system balancing.
- A zonal PJM system model was developed reflecting its 22 load zones.
- Modeled inter-zonal transmission lines 230kV and above to capture key network constraints.
- Energy, regulation and other reserve products are co-optimized.
- Appropriate PJM hourly regulation requirements (MW) are used for both sets of regulation products.
- The simulations compare two separate regulation products –
  - A single bidirectional regulation product.
  - Separate unidirectional regulation up and down products.

- Conducted simulations for one representative week per season in 2024. Periods simulated:
  - **Spring:** April 30 to May 6, 2024
  - **Summer:** August 5 to 11, 2024
  - **Fall:** October 7 to 13, 2024
  - **Winter:** December 2 to 8, 2024
- Load used in the FESTIV sequences are derived by averaging 15-sec EMS load. Renewable energy source profiles are also derived from actual 15-sec renewable generation.
- Aggregated generator models are used in the FESTIV simulations. Incremental energy values are derived from heat rates as opposed to bid-in values.



# Results - Area Control Error and CPS2 Statistics

- Area Control Error (ACE) is generally the MW imbalance in a balancing area (BA) and is calculated as sum of BA's interchange error and frequency error.
- FESTIV calculates ACE as interchange error; the frequency error component is added after RT-SCED based on actual PJM error values.

	Spring		Summer		Fall		Winter	
Metrics	1 Reg.	2 Reg.	1 Reg.	2 Reg.	1 Reg.	2 Reg.	1 Reg.	2 Reg.
Mean-Absolute ACE	175.09	139.87	239.65	217.22	172.94	136.67	166.17	133.63
ACE-Standard Deviation	235.71	181.13	308.38	268.68	240.04	184.30	218.62	175.18
CPS2 Violations	16	0	203	202	11	0	11	4
CPS2	98.41%	100%	79.86%	79.96%	98.91%	100%	98.91%	99.60%

- Controller saturation-up and -down events are defined as AGC intervals where SACE (smoothed ACE) exceeds regulating reserve requirement in either direction (+/-). Duration is in AGC time steps.

Metrics	Spring		Summer		Fall		Winter	
	1 Reg.	2 Reg.	1 Reg.	2 Reg.	1 Reg.	2 Reg.	1 Reg.	2 Reg.
Total Saturation-Up Events	218	11	104	6	157	15	220	24
Total Saturation-Down Events	183	177	406	423	138	127	178	143
Avg. Saturation-Up Event Duration	4.92	1.45	6.66	2.17	5.57	1.53	4.39	1.46
Avg. Saturation-Down Event Duration	3.10	2.65	17.06	16.92	2.97	2.29	3.60	3.24

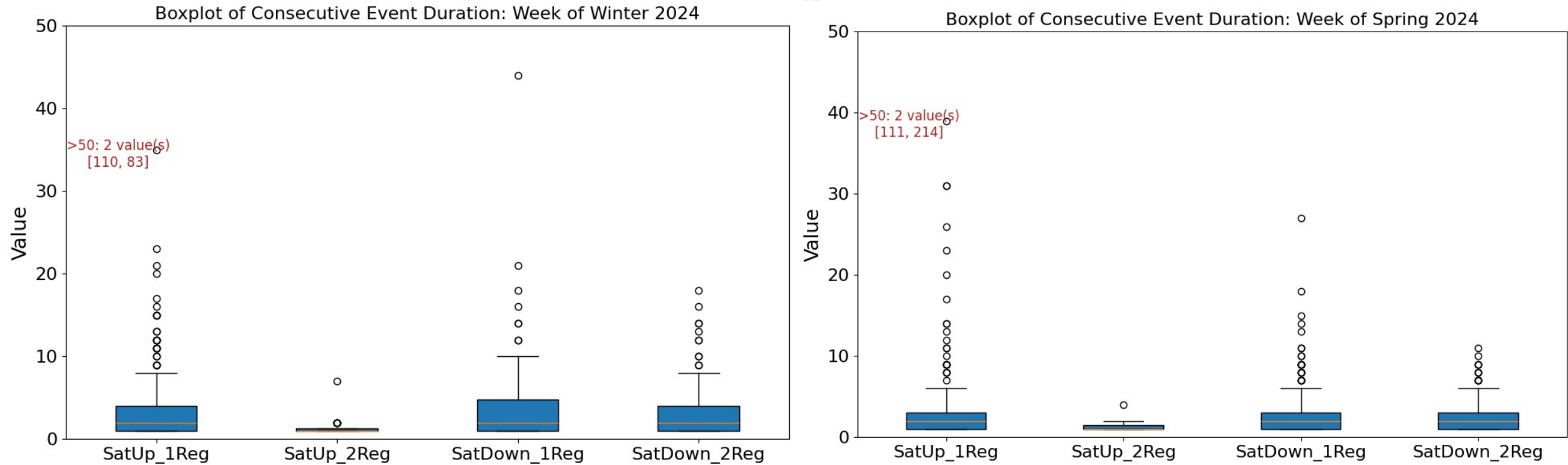


Fig 1: Distribution of Consecutive Saturation-Up and -Down Event Durations

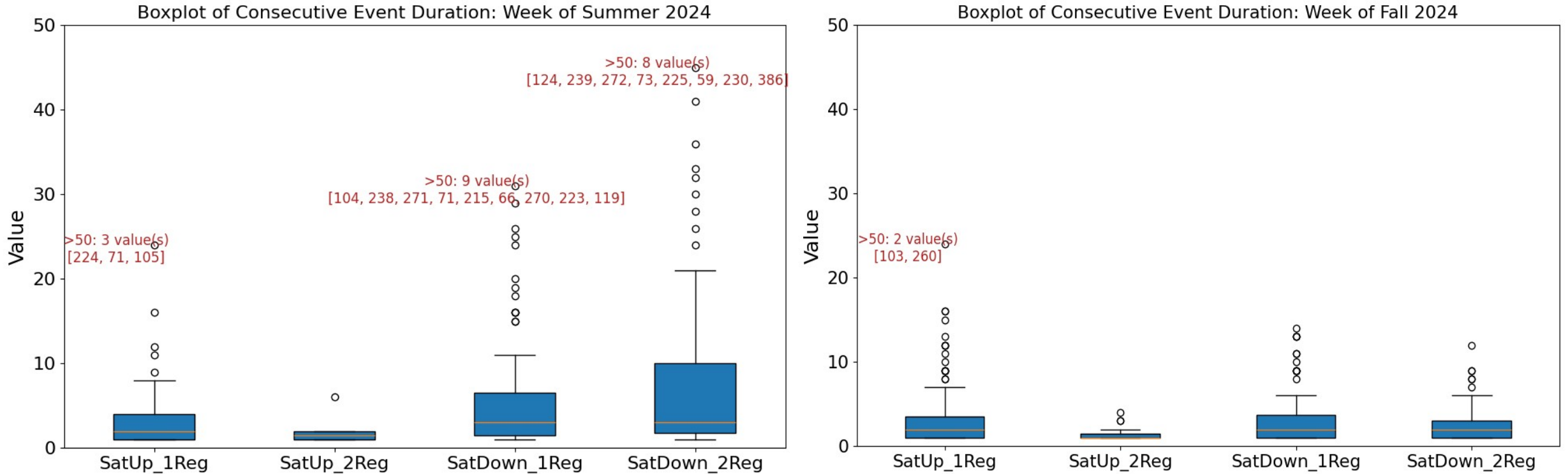


Fig 2: Distribution of Consecutive Saturation-Up and -Down Event Durations

# Results - Regulation Contribution by Generator Type

- Regulation contribution by generator type is the percentage of total real-time regulation awarded, calculated by averaging each generator's award and summing by generator type over the simulation period.

Season	Product	Steam (%)	Combined Cycle (%)	Hydro (%)	Pumped Storage (%)	Storage (%)
Spring	1 Reg.	18.19	72.14	0.00	4.64	5.03
Spring	2 Reg. Up	20.60	68.79	0.00	2.31	8.31
	2 Reg. Down	51.36	34.75	7.26	3.62	3.02
Summer	1 Reg.	25.35	67.35	0.00	2.96	4.33
Summer	2 Reg. Up	26.44	63.87	0.00	1.93	7.75
	2 Reg. Down	55.98	33.69	5.97	1.66	2.70
Fall	1 Reg.	15.14	74.43	0.00	5.74	4.68
Fall	2 Reg. Up	17.15	71.41	0.00	2.50	8.93
	2 Reg. Down	47.85	34.70	8.18	5.60	3.67
Winter	1 Reg.	23.42	64.66	0.00	4.16	7.76
Winter	2 Reg. Up	28.27	60.88	0.00	3.08	7.77
	2 Reg. Down	54.27	34.12	6.02	2.70	2.88

- Generator movement is calculated as the sum of the absolute values of the difference of actual generation (in AGC time steps) of units that are qualified to provide regulation minus the RT-SCED linear trajectory.
- Below numbers are for the 7-day simulation periods by season and generator type.

Season	Product	Steam (MW)	Combined Cycle (MW)	Hydro (MW)	Pumped Storage (MW)	Storage (MW)	Total Movement (MW)
Spring	1 Reg.	376,328	955,936	0	59,631	108,948	1,500,843
Spring	2 Reg.	2,084,323	1,480,838	284,530	25,121	107,347	3,982,159
Summer	1 Reg.	402,153	835,505	0	32,873	62,497	1,333,028
Summer	2 Reg.	1,454,942	1,097,861	153,309	23,664	78,471	2,808,247
Fall	1 Reg.	298,092	972,322	0	71,157	108,436	1,450,007
Fall	2 Reg.	1,896,375	1,489,660	324,599	33,419	128,977	3,873,030
Winter	1 Reg.	465,358	895,565	0	49,825	157,496	1,568,244
Winter	2 Reg.	2,155,477	1,505,208	217,992	36,234	89,982	4,004,893

- 2 Reg\_Eq represents simulations using two separate regulation up and down products and any unit getting a regulation up award will get a regulation down award of same MW and vice versa.

	Spring			Summer			Fall			Winter		
Metrics	1 Reg.	2 Reg.	2 Reg_Eq	1 Reg.	2 Reg.	2 Reg_Eq	1 Reg.	2 Reg.	2 Reg_Eq	1 Reg.	2 Reg.	2 Reg_Eq
Mean-Absolute ACE	175.09	139.87	173.87	239.65	217.22	238.63	172.94	136.67	165.15	166.17	133.63	162.85
ACE-Standard Deviation	235.71	181.13	234.17	308.38	268.68	307.42	240.04	184.30	218.90	218.62	175.18	212.88
CPS2 Violations	16	0	16	203	202	209	11	0	4	11	4	10
CPS2	98.41%	100%	98.41%	79.86%	79.96%	79.27%	98.91%	100%	99.60%	98.91%	99.60%	99.01%



# Additional Results – Saturation-Up and -Down

	Spring			Summer			Fall			Winter		
Metrics	1 Reg.	2 Reg.	2 Reg_Eq	1 Reg.	2 Reg.	2 Reg_Eq	1 Reg.	2 Reg.	2 Reg_Eq	1 Reg.	2 Reg.	2 Reg_Eq
Total Sat-up events	218	11	213	104	6	119	157	15	159	220	24	196
Total Sat-down events	183	177	189	406	423	440	138	127	139	178	143	162
Average Sat-up duration	4.92	1.45	4.91	6.66	2.17	6.08	5.57	1.53	3.69	4.39	1.46	4.27
Average Sat-down duration	3.10	2.65	3	17.06	16.92	15.77	2.97	2.29	2.71	3.60	3.24	3.61

1	2	3
<ul style="list-style-type: none"><li>• Separate regulation products improve ACE performance</li></ul>	<ul style="list-style-type: none"><li>• Reliability metrics improve, but summer remains challenging</li></ul>	<ul style="list-style-type: none"><li>• Improvement comes from changing resource mix and generator movement</li></ul>

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## Simulation of Bifurcated Regulation Products



### Member Hotline

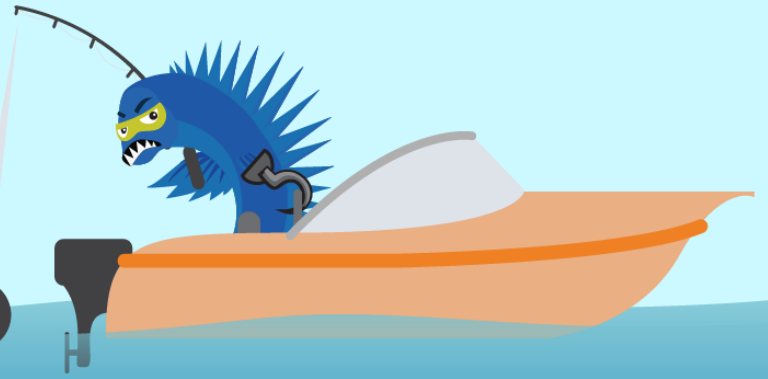
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