

CPQR Simulation Example

RASTF

June 10, 2022

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Competitive Offer

- **Unit specific competitive offer for a CP resource:**
 $p = \text{Net ACR} + \text{Net (Expected Penalties} - \text{Expected Bonuses)}$

$$\text{or, } p = \begin{cases} \text{Net ACR} + \text{CPBR} \times H \times (\bar{B} - \bar{A}), & \text{if } \bar{B} < \bar{A} \\ \text{Net ACR} + \text{PPR} \times H \times (\bar{B} - \bar{A}), & \text{if } \bar{A} < \bar{B} \end{cases}$$

- **Where:**
 - Net ACR = Gross ACR – Net E&AS revenues
 - CPBR is the average bonus payment rate during PAI
 - PPR is the average nonperformance charge rate during PAI (tariff defined).
 - H is the expected number of PAI divided by 12
 - \bar{A} is the expected unit performance during PAI
 - \bar{B} is the expected balancing ratio during PAI

CPQR

- **CPQR includes both the expected net nonperformance charges and the cost to mitigate the risk associated with the estimated net nonperformance charges.**
- **Net nonperformance charges can be simulated to account for uncertainty in the inputs to calculation (A, B, H).**
- **The MMU framework for evaluating the simulation approach was presented on March 24, 2022.**

CPQR

CPQR = E(net penalties) + Cost of mitigating risk

Where:

- ***E(net penalties):*** expected value (mean) from distribution of simulated outcome
 - Can be positive, negative, or zero.
- ***Cost of mitigating risk = Risk Cost x (Extreme Value - Mean)***
- **Extreme Value:** for example 30th percentile or 95th percentile of distribution of simulated outcomes.
- **Risk Cost:**
 - Cost of incurring risk of nonperformance penalties
 - Affected by factors including portfolio

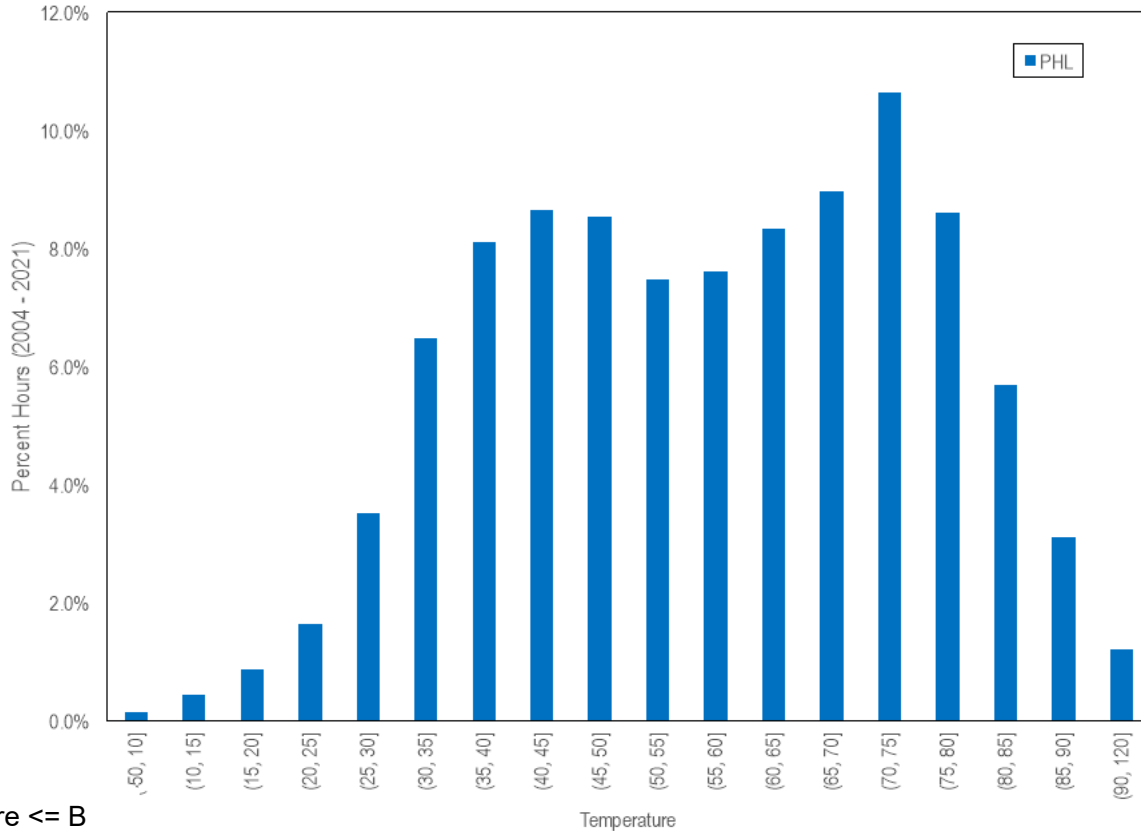
Simulation Model

- **Simulation of CP nonperformance charges and bonus payments.**
- **The key inputs are:**
 - **A: Unit specific performance during PAH**
 - **B: Balancing Ratio during PAH**
 - **H: Number of PAH**
 - **CPBR: Average bonus payment rate during PAI**
 - **PPR: Nonperformance charge rate during PAI for the unit's zone (PPR value in tariff)**
 - **Stop loss limit**
 - **Tax rate**
 - **Historical temperature data.**

Simulation Model – Stage 1

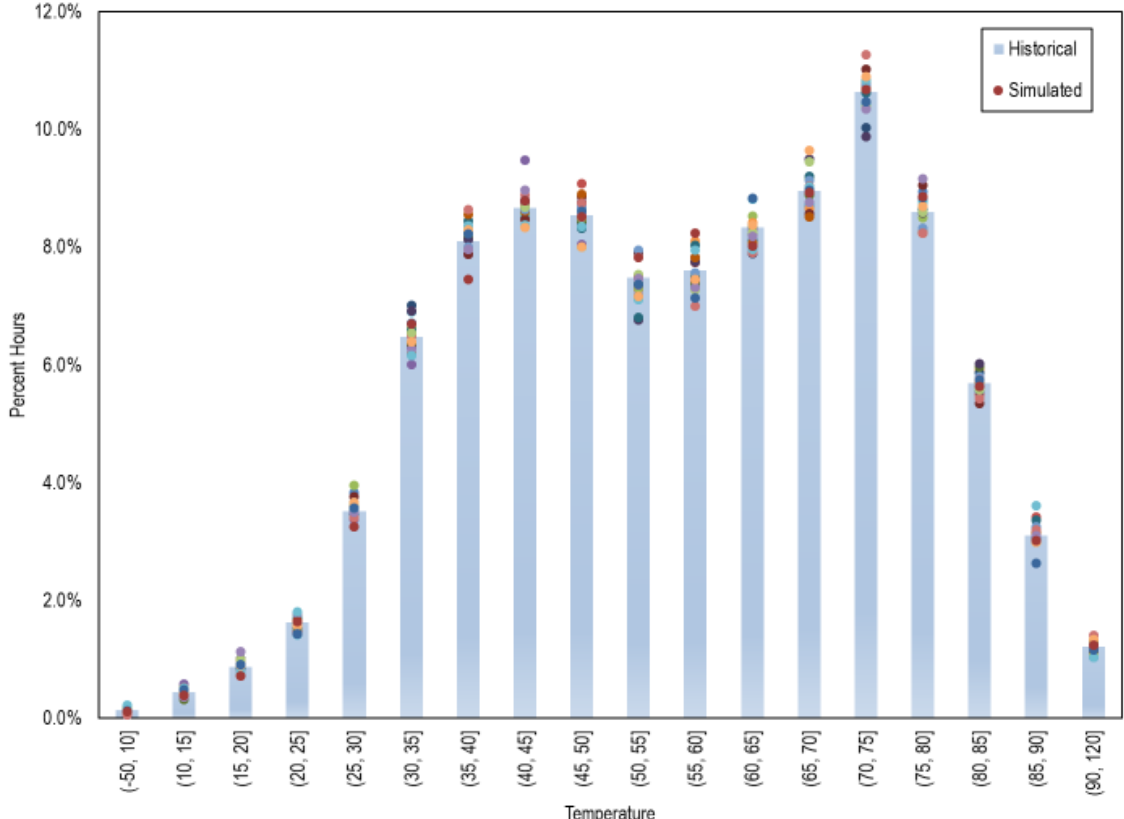
- **Two stage simulation.**
- **First stage simulates future temperature outcomes based on history.**
 - **Location is a proxy weather station close to the unit. For this example, location is PHL.**
 - **Assumes temperature is a multinomial random variable with probability calculated empirically.**
- **500 sample years generated using 18 years (2004 – 2021) of weather history.**
 - **Each sample distributes 8,760 hours into the specified temperature ranges.**

Example: PHL Temperature History



(A, B]: A < Temperature <= B

Sample Simulated Temperature Distributions



Circles show 20 simulated samples based on historical average (bars)

Sample Simulated Temperature Distributions

- Table shows number of hours out of 8,760 that fall into each temperature category from three sample simulated years.

T_i	$N(T_i)$		
	Sample Year 1	Sample Year 2	Sample Year 3
(-50, 10]	9	8	11
(10, 15]	36	45	47
(15, 20]	79	87	66
(20, 25]	155	128	155
(25, 30]	335	304	346
(30, 35]	552	572	580
(35, 40]	721	714	718
(40, 45]	761	765	749
(45, 50]	759	795	701
(50, 55]	629	638	640
(55, 60]	640	651	659
(60, 65]	734	691	747
(65, 70]	758	762	802
(70, 75]	933	938	933
(75, 80]	783	773	745
(80, 85]	500	481	490
(85, 90]	280	299	268
(90, 120]	96	109	103
Total	8,760	8,760	8,760

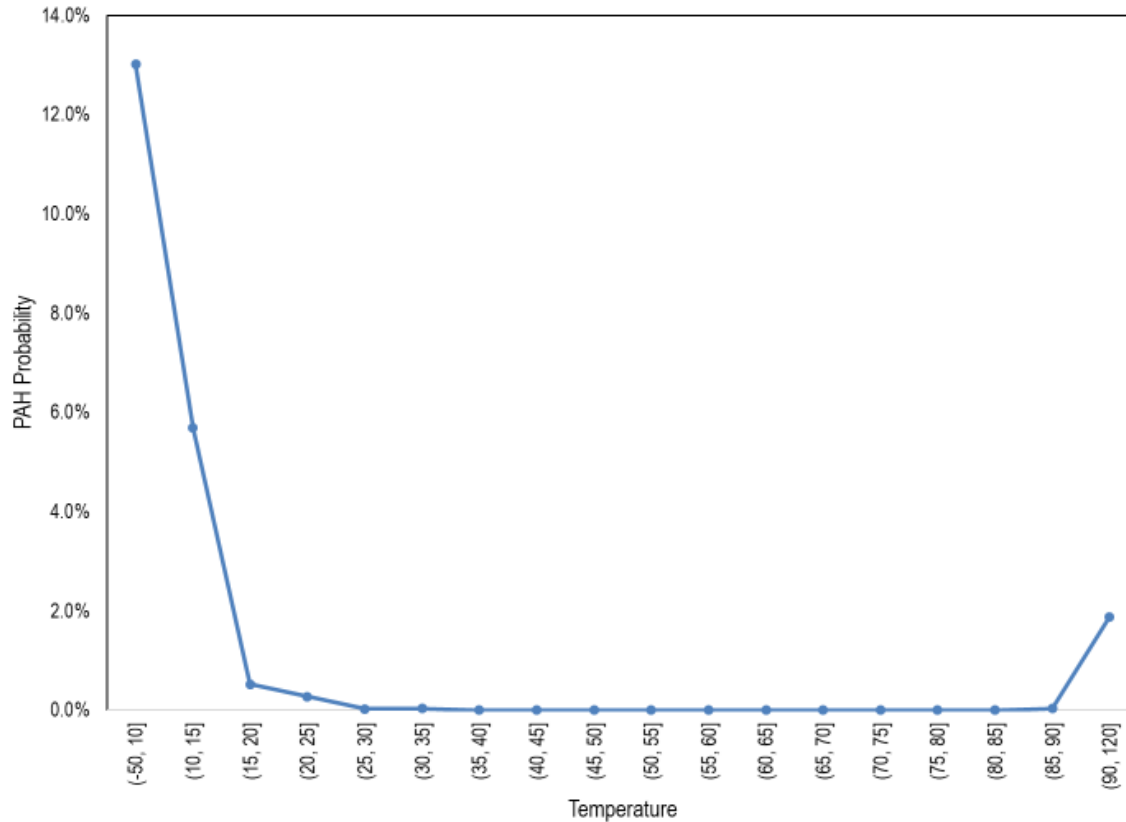
Simulation Model – Stage 2

- **Second stage simulates:**
 - **conditional probability of PAH given temperature,**
 - **conditional probability of forced outage given temperature,**
 - **balancing ratio during PAH given temperature.**

Simulation Model – Stage 2

- **Conditional probability of PAH given a temperature range is based on 10 year history of temperature and PAH or proxy.**
 - **PAH includes emergency actions that would have triggered PAH prior to Capacity Performance.**
 - **Temperature dependent PAH probabilities calculated for the zone where unit is located.**
- **Fewer emergencies since CP implemented.**
- **Ten year history overestimates emergencies.**

PAH Conditional Probabilities

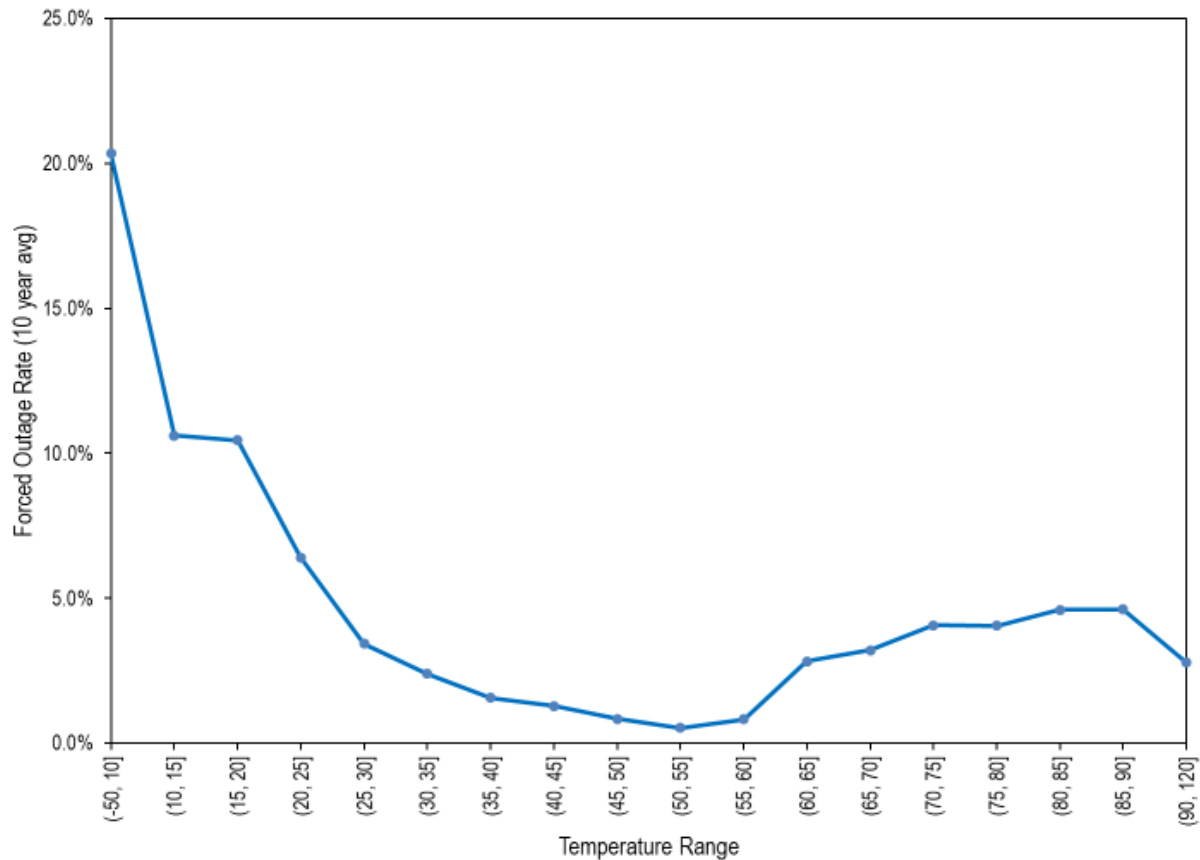


- **Data from 2012 through 2021.**
- **All emergency actions in eastern PJM included:**
 - **RTO**
 - **Mid-Atlantic Dominion**
 - **BGE & Pepco**

Simulation Model – Stage 2

- **Conditional probability of unit forced outages given a temperature range is based on 10 year history of temperature and forced outages**
 - **Unit specific calculation based on GADS reported forced outages.**
 - **Equivalent forced outage rate calculated that includes both derates and full unit forced outages.**
- **Outage rates lower since CP implemented.**
- **Ten year history overestimates forced outage rates.**

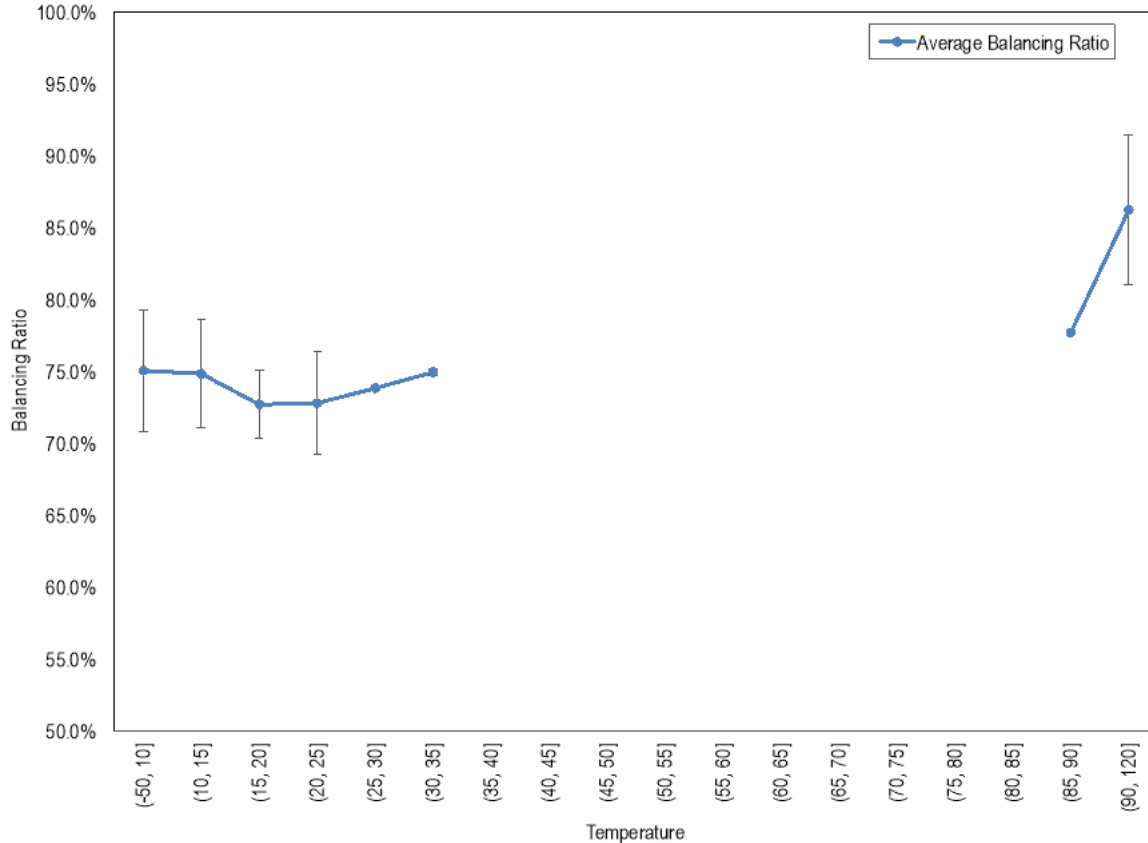
Example Unit Forced Outage Probabilities



Balancing Ratio (B)

- **Conditional value of balancing ratio during a PAH, given a temperature range, is based on 10 year history of balancing ratios during PAH or proxy PAH.**
- **Balancing ratio is used to calculate expected performance for each resource during a PAI.**
- **B calculated for the RTO even if the emergency was regional. Same PAH as used in the PAH history.**
 - **RTO**
 - **Mid-Atlantic & Dominion**
 - **BGE & Pepco**

Balancing Ratio



- **Balancing ratio exists only for categories with historical PAH or proxy PAH.**
- **Error bars show the standard deviation of balancing ratio for each temperature category.**
- **No error bars indicate very few PAH (1 or 2).**

Simulating penalties and bonuses – Stage 2

- For each temperature range, conditional probabilities of PAH and unit forced outages are simulated as results of a binomial process (repeated Bernoulli trials).
- 1,000 Bernoulli trials:
 - PAH = 1 or 0, and FO = 1 or 0.
 - If PAH = 1 and FO = 1, then penalty.
 - If PAH = 1 and FO = 0 then bonus.
 - If PAH = 0, no penalty or bonus regardless of FO.
- For each temperature range, B is simulated as a normal random variable with the historical mean and standard deviation.

Simulating penalties and bonuses – Stage 2

- Each binomial process generates conditional probabilities for a given temperature range, i :
 - *Probability of PAH*, $p^{(PAH/T)} = \sum(PAH)/1,000$
 - *Probability of penalties*, $p^{(penalties/T)} = \sum(PAH * FO)/1,000$
 - *Probability of bonuses*, $p^{(bonuses/T)} = \sum(PAH * (1 - FO))/1,000$
- For each penalty or bonus hour, a unit would pay maximum nonperformance charges for MW = B*UCAP.
- Similarly, a unit is eligible for bonuses for MW = (1 - B)*UCAP.
- Incorporating the simulated B:
 - *Penalty probability* $P^{(pen/T_i)} = \sum(PAH * FO * B_i)/1,000$
 - *Bonus probability* $P^{(bon/T_i)} = \sum(PAH * (1 - FO) * (1 - B_i))/1,000$

Net Penalty Probability – Stage 2

- **1,000 such conditional probabilities are generated for each temperature category.**
- **The net penalty probability for temperature category i is calculated as:**

$$p^{(net/T_i)} = P^{(pen/T_i)} - P^{(bon/T_i)}$$

- **Portion of underperformance can be excused.**
 - **Results in effective penalty rate lower than the tariff defined rate.**
 - **Results in bonus payment rate lower than penalty rate.**

Combining Stage 1 and Stage 2

- Each of the 1,000 stage 2 simulated outcomes is multiplied by the number of hours in that temperature category $N(T_i)$, for each of the 500 simulated years to get the net penalty hours.
- $(Net\ Penalty\ Hours)_i = N(T_i) * P^{(net)/T_i}$
- Total net penalty hours = $\sum_i (Net\ penalty\ hours)_i$
- Results in 500,000 possible outcomes for each unit for net non performance charges in a year.
 - Mean is the expected net penalty hours in a year.
 - Percentiles show the distribution of net penalty hours in a year.

Sample Results: Net nonperformance charges

Net Nonperformance Charges (\$/MW-day) UCAP	
Mean (m)	-\$7.7
Percentiles	
p5	-\$11.2
p10	-\$10.4
p25	-\$9.1
p50	-\$7.7
p75	-\$6.3
p90	-\$5.2
p95	-\$4.4
p95 - Mean (a)	\$3.3
Cost of Risk (b)	10%
Risk Premium (c=a*b)	\$0.33
Mean + Risk Premium (m+c)	-\$7.39

- Using nonperformance charge rate = \$3,366.27 per MWh (EMAAC, 2023/2024 BRA)
- Net nonperformance charges (\$/MW-day) = Net penalty hours*Rate (\$/MWh)/365.

Notes

- **The simulation outcome is the \$/MW-day UCAP value.**
 - Auction EFORd needed to convert to \$/MW-day ICAP terms.
- **No GADS data for intermittent resources.**
 - The source of risk is due to both intermittency and forced outages.
 - ELCC reduces committed UCAP, reduces risk of penalties.
- **Newer units without long history need proxy outage rates if they have not operated under extreme temperatures.**
 - Nonperformance risk is concentrated in extreme temperature ranges.

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