Report: Results of Risk Model Quantitative Analysis

Financial Risk Mitigation Senior Task Force

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I. Purpose

This paper examines the implementation of a Historical Simulation (HS) methodology for Initial Margin (IM) calculation via the development of proof-of-concept models and associated back-testing.

II. Introduction: Variation Margin and Initial Margin

Margin is the amount of **financial** collateral deposited by a market participant with the Central Counter-Party (CCP) to collateralize trade exposures introduced by the participant. Margins are the CCP's first line of defense in the event of the market participant's default, to satisfy the financial obligations of that participant. The margins are designed to cover the market risk of a market participant's portfolio with high level of confidence. There are two principal forms of margin: **Variation Margin (VM)** and **Initial Margin (IM)**.

Variation Margin (VM) has been described in the Variation Margin and Post-Auction Settlement Discussion Paper[1], where several methodologies for VM calculation were proposed. One of the key implications of any variation margin methodology is that if at the time of the variation margin posting one computes the combined value of the participant's portfolio and the cash in the variation margin account, that combined value is never negative. In other words, if the CCP unwinds the participant's portfolio precisely at the moment of variation margin posting there will be no losses to the CCP.

One of the most important features of the Variation Margin is that it is a **forward-looking quantity**. Its value is connected to the Mark-to-Auction value of the participant's portfolio, which in turn is determined by the participants' expectation of future conditions affecting LMPs, including expectations of future demand, generation, fuel prices, outages and changes in grid topology.

The role of Initial Margin is to provide further protection in case the market participant is not able to post Variation Margin, hence triggering default. By definition, Initial Margin (IM) is a good-faith deposit, posted by a trading participant as collateral to protect against the financial consequences of default. It typically reflects the potential losses that would be incurred by the participant's counter-party (in our case, the Central Counter-Party, CCP) should the participant default, calculated to a high degree of statistical likelihood, across the participant's entire portfolio. In order to do this, IM must cover the period between the time when the position was incurred or variation margin (VM) last levied (whichever is the latter), and the time when the position could be liquidated or taken to final settlement (whichever is sooner) in the event of default. This time period is called the **Margin Period of Risk (MPOR)**, and is also known as "liquidation period".

[1] https://www.pjm.com/-/media/committees-groups/task-forces/frmstf/20190717/20190717-item-06-discussion-paper-variation-margin-and-settlement.ashx

III. Notation

Three FTR auctions are defined:

I. Monthly auctions.
For each planning year there are 12 monthly auctions from May to April of the next year at times $t_{May}^{mo}, \dots, t_{April}^{mo}$.

II. Annual auctions.
For each planning year there are 4 rounds of annual auctions at times $t_1^{An}, \dots, t_4^{An}$.

III. Long Term Auctions.
For each planning year YYYY/YYYY+1 there are three rounds of auctions for the long term FTR contracts covering planning years: YYYY+1/YYYY+2, YYYY+2/YYYY+3, YYYY+3/YYYY+4. The times of these rounds are denoted $t_1^{LT}, t_2^{LT}, t_3^{LT}$.

Correspondingly, the auction cleared prices are denoted as $P(t_i^{mo}, MMYYYY)$, $P(t_i^{An}, YYYY^{An})$, $P(t_i^{LT}, YYYY_1^{LT})$, $P(t_i^{LT}, YYYY_2^{LT})$, $P(t_i^{LT}, YYYY_3^{LT})$. Here, $MMYYYY$ is the month and year of the *monthly* FTR contract cleared on the auction date t_i^{mo}, $YYYY^{An}$ is the contract year cleared at the *annual* auction, and $YYYY_1^{LT}, YYYY_2^{LT}, YYYY_3^{LT}$ are three years of the long term contract.

Example 1
FTR contracts bid in the AUG 2018 monthly auction on 07/16/2018 will include Aug2018, Sep2018, Oct2018, Nov2018, Dec2018, Jan2019, Feb2019, Mar2019, Apr2019, May2019.

Example 2
The four rounds of the 18/19 Annual auction run during April of 2018 will clear the price of the annual FTR contract for the 2018/2019 planning year.

Example 3
The three rounds of the 19/22 Long Term auction (May, Sep, Dec) of 2018 will clear the prices of the long term FTR contracts for the planning years 2019/2020, 2020/2021, 2021/2022.

To summarize:

- Monthly auction
  For each *path* the prices of the following contracts are cleared at the auction time t_i^{mo}:

$$P_{path}(t_i^{mo}, MMYYYY_{i+1}), \qquad P_{path}(t_i^{mo}, MMYYYY_{i+2}), \dots, P_{path}(t_i^{mo}, MMYYYY_M) \tag{1}$$

- Annual auction

During the four rounds of the Annual contract auction at t_i^{An}, four prices for the same annual contract are cleared for each *path*:

$$P_{path}\left(t_1^{An}, YYYY\right), \quad P_{path}\left(t_2^{An}, YYYY\right), \quad P_{path}\left(t_3^{An}, YYYY\right), \quad P_{path}\left(t_4^{An}, YYYY\right)$$

- Long Term auction

  During the three rounds of the Long Term contract auction at t_i^{LT}, prices for the three years of the Long Term contract are cleared for each *path*:

$$P_{path}(t_1^{LT}, YYYY_1), \quad P_{path}(t_2^{LT}, YYYY_2), \quad P_{path}(t_3^{LT}, YYYY_3)$$

To simplify and unify the notation we will denote all prices described above as

$$P_\mu(t_i, T_k; \tau)$$

where

μ is the index of a particular path;
t_i is the auction date of the auction i ;
T_k is the beginning of the FTR period, $t_i < T_k$;
τ is the length of the FTR period (e.g., 1 month, 1 year);
$P_\mu(t_i, T_k; \tau)$ is the price for the path μ cleared during the auction i at time t_i; the price is for the contract that starts at $T_k$and has duration τ.

$t_i \leq T_k$. Although the auction month is always before the contract month cleared at this auction, i.e. $t_i < T_k$, we nevertheless allow $t_i = T_k$. In this case the “auction price” means the settled price

Example 4

If t_i is 07/16/2018, T_k is 12/01/2018, $\tau =$ 1 *month*, then $P_\mu(t_i, T_k; \tau)$ denotes the FTR price for the path μ cleared during July 2018 monthly auction for the December 2018 contract.

IV. Simulations using Historical Data: Methodology

A. Monthly Auctions

In this case, $\tau = 1$ month. The historical simulation method (HS) requires a rich set of historical data. Our historical data starts in 2006 and ends in 2019. For each planning year since 2006/2007 we have path prices $P_\mu(t_i, T_k; 1m)$. As was mentioned above $t_i < T_k$. However, to increase the data set, we will allow $t_i = T_k$. In this case the "auction price" is the settled price for the month i.

Assume that a market participant portfolio **Π** includes paths $\{\mu_1, \mu_2, \dots, \mu_m\}$. The HS method requires that we construct many scenarios of past changes of the prices of these paths; the changes should be calculated over the specified period called MPOR (**margin period of risk**, also called **liquidation period**). MPOR can be 2,3, or more months. Thus, each scenario is constructed in the following way:

i. Choose a planning year in the past

ii. Choose a contract month T_k in that planning year

iii. Choose an auction month i and corresponding auction time t_i. The choice of the auction month is constrained by the requirement that $t_{i+MPOR} \le T_k$.

iv. Compute the scenario vector of changes for each path over MPOR:

$$\boldsymbol{D}^{scen} = \begin{bmatrix} P_{\mu_1}(t_{i+MPOR}, T_k; 1m) - P_{\mu_1}(t_i, T_k; 1m) \\ P_{\mu_2}(t_{i+MPOR}, T_k; 1m) - P_{\mu_2}(t_i, T_k; 1m) \\ \vdots \\ P_{\mu_m}(t_{i+MPOR}, T_k; 1m) - P_{\mu_m}(t_i, T_k; 1m) \end{bmatrix}, \quad scen = 1,2, \dots \tag{2}$$

Note that the complete set of scenarios is obtained by varying planning years, contracts within a given planning year, and auction months during which the prices for these contracts are cleared.

v. This step is where we introduce forward-looking data. Namely, assuming that today is the day of the most recent auction, denote by $P_\mu(t_0, T_k; 1m)$ the cleared price for the forward contract month T_k in the current planning year for the path μ. As before, $T_k > t_0$ and it does not exceed May of the second calendar year in the current planning year.

The main question: If we need to unwind the market participant's portfolio Π at the end of the MPOR, what would be our exposure with a high degree of confidence?

To answer this question, we will consider a set of scenarios representing movement of the prices of the paths in the portfolio over MPOR. These price movement scenarios for all paths in the portfolio are generated by adding the historical price moves defined in (ii) to the prices of the forward contracts cleared at today's auction. Thus, in a given scenario we define "shocked" prices for each forward contract cleared in today's auction as follows:

$$\begin{bmatrix} P_{\mu_1}^{scen}(t_0, T_k; 1m) \\ P_{\mu_2}^{scen}(t_0, T_k; 1m) \\ \vdots \\ P_{\mu_m}^{scen}(t_0, T_k; 1m) \end{bmatrix} = \begin{bmatrix} P_{\mu_1}(t_0, T_k; 1m) \\ P_{\mu_2}(t_0, T_k; 1m) \\ \vdots \\ P_{\mu_m}(t_0, T_k; 1m) \end{bmatrix} + \boldsymbol{D}^{scen} \qquad (3)$$

where $\boldsymbol{D}^{scen}$ is defined in Eq. (2).

vi. Once we have generated the complete set of scenarios, we will re-value the participant's portfolio for each vector of shocked prices and then compute its deviation from the base case corresponding to the portfolio value at current auction prices. This deviation is the measure of our risk over MPOR. More precisely, we compute

$$\begin{aligned} \Delta\Pi^{scen} = \Pi\left(P_{\mu_1}^{scen}(t_0, T_k; 1m), \dots, P_{\mu_m}^{scen}(t_0, T_k; 1m)\right) \\ - \Pi\left(P_{\mu_1}(t_0, T_k; 1m), \dots, P_{\mu_m}(t_0, T_k; 1m)\right), \quad scen = 1,2, \dots \end{aligned} \qquad (4)$$

vii. After the vector of portfolio value changes is created using Eq. (4), we can construct the distribution of $\Delta\Pi^{scen}$ and determine the value corresponding to our pre-defined confidence level α. A common choice of α is 1%. In this case, we choose the value δ such that $\Pr(\Delta\Pi^{scen} < \delta) = 1\%$.

Initial Margin. Once we determined that 99% of portfolio deviations over MPOR are above δ, the *initial margin (IM)* is defined as follows:

$$IM = Const \cdot \delta$$

where *Const* is a pre-fixed scaling factor, greater than or equal to 1.

B. Annual and Long Term Auctions

As we enter a given planning year we will need to determine the IM for the remaining balance of the corresponding Annual contract. Our proposal is to split it into the monthly contracts and determine IM the same way we did it for monthly contracts in Sec. 3.A.

To determine IM for every yearly contract cleared in the Long Term auction, we again use the formulas (2) and (3) with the following modifications:

- $\tau = 1yr$ and not 1*m*
- t_i is the time of a particular round of LT auction
- $MPOR$ is now 6-9 months.

C. Price Scenario Structure

conYYYY conMM inAucYYYY inAucMM inPromptNum outAucYYYY outAucMM outPromptNum MPOR PriceIn PriceOut Diff

- *conYYYY, conMM* - year and month of the contract under consideration;
- *inAucYYYY, inAucMM* – year and month of the auction when we enter the contract;
- *inPromptNum* – the distance in months from the in-auction month to the contract month;
- *outAucYYYY, outAucMM* – year and month of the auction when we exit the contract (including the possibility of getting settled prices in the contract month);
- *outPromptNum* – the distance in months from the out-auction month to the contract month;
- MPOR – margin period of risk, the period between in-auction and out-auction;
- *PriceIn, PriceOut, Diff* – respectively, the price of the contract cleared in the in-auction, the price of the contract cleared in the out-auction and the difference between those prices.

Example 5: Data structure

conYYYY	conMM	inAucYYYY	inAucMM	inPromptNum	outAucYYYY	outAucMM	outPromptNum	MPOR	PriceIn	PriceOut	Diff
2017	5	2017	2	3	2017	5	0	3	1.4508	1.9109	0.46017

We have introduced the concept of *promptness* and track the variables inPromptNum and outPromptNum, the numbers that specify the relative position of the contract with respect to the auction (vs absolute position of the contract specified by year and month), because they are often most useful in determining the volatility of the contract under consideration.

D. FTR Volatility Properties

As the price volatility is the main determinant of IM in the current simulation methodology, we will investigate its properties in detail.

Have there been regime changes over time? It is important to know as we use historical volatility for estimating current price distributions. Figure 1 displays moving window (2 years) volatility graphs for several zonal paths. From these graphs we conclude that there were no obvious regime changes.

Figure 1. 2-year moving window volatility of monthly FTR prices for zonal paths

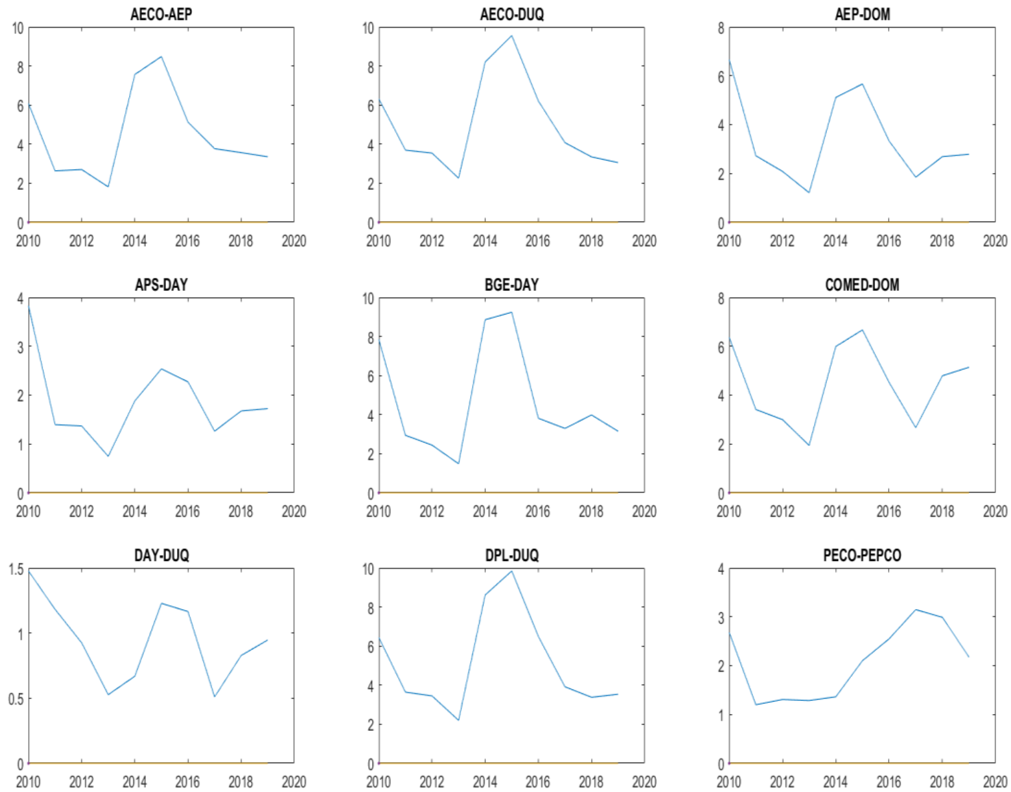


Table 1 below shows common statistics of zonal path FTR price distributions and demonstrate that the *price distribution is far from normal.*

Table 1. Standard deviation, first percentile, and kurtosis of the zonal path FTR price distributions. *MPOR* = 2.

PATH	STD	1%	kurtosis
AECO-AEP	4.19	-10.19	102.3
AECO-APS	2.99	-6.87	166.83
AECO-BGE	2.07	-6.38	7.94
AECO-COMED	4.77	-12.06	91.76
AECO-DAY	4.43	-11	95.1

AECO-DOM	2.03	-5.84	32.01
AECO-DPL	1.08	-3.07	15.22
AECO-DUQ	4.61	-11.61	97.87
AECO-JCPL	1.35	-3.21	68.81
AECO-METED	0.86	-2.74	46.62
AEP-APS	1.74	-5.88	17.17
AEP-BGE	4.56	-12.09	121.66
AEP-COMED	1.28	-3.39	29.53
AEP-DAY	0.39	-1.01	17.12
AEP-DOM	3.56	-10.54	41.46
AEP-DPL	4.33	-10.26	102.8
AEP-DUQ	1.04	-3.12	39.62
AEP-JCPL	4.44	-10.63	100.54
AEP-METED	4.1	-10.63	102.92
APS-BGE	3.31	-7.67	205.09
APS-COMED	2.48	-7.25	25.65
APS-DAY	1.97	-6.49	18.76
APS-DOM	2.23	-5.92	60.11
APS-DPL	3.12	-7.46	166.13
APS-DUQ	2.18	-6.72	33.02
APS-JCPL	3.22	-7.15	161.72
APS-METED	2.83	-6.64	185.43
BGE-COMED	5.12	-13.89	106.76
BGE-DAY	4.79	-12.65	113.06
BGE-DOM	1.66	-4.05	229.33
BGE-DPL	2.19	-6.24	9.26
BGE-DUQ	4.96	-12.69	113.13
BGE-JCPL	2.23	-7.16	11.5
BGE-METED	2	-6.16	9.78
COMED-DAY	1.19	-3.26	22.67
COMED-DOM	4.21	-12.07	39.89
COMED-DPL	4.95	-11.47	88.97
COMED-DUQ	1.55	-4.1	34.25
COMED-JCPL	5	-11.75	91.16
COMED-METED	4.69	-12.53	91.22
DAY-DOM	3.82	-11.04	39.19
DAY-DPL	4.57	-11.24	95.86
DAY-DUQ	0.93	-2.9	27.61
DAY-JCPL	4.67	-11.54	94.34
DAY-METED	4.33	-11.43	95.62
DOM-DPL	2.18	-7.08	37.57
DOM-DUQ	4.02	-11.64	42.47
DOM-JCPL	2.3	-7.37	38.57

DOM-METED	1.93	-5.61	32.98
DPL-DUQ	4.73	-11.11	99.98
DPL-JCPL	1.48	-3.97	33.3
DPL-METED	1.09	-3.4	9.16
DUQ-JCPL	4.85	-11.94	96
DUQ-METED	4.51	-10.91	98.31
JCPL-METED	1.09	-3.43	62.34
PECO-PENELEC	2.65	-6.61	134.11
PECO-PEPCO	2.02	-5.32	10.06
PECO-PPL	0.52	-1.63	15.3
PECO-PSEG	1.22	-3.14	35.8
PECO-RECO	1.51	-3.58	46.5
PECO-ATSI	4.1	-7.84	163.05
PECO-DEOK	4.45	-8.46	144.18
PECO-EKPC	4.92	-10.55	105.35
PENELEC-PEPCO	3.28	-8.21	97.12
PENELEC-PPL	2.58	-6.57	160.28
PENELEC-PSEG	3.26	-8.06	134.02
PENELEC-RECO	3.15	-8.14	94.33
PENELEC-ATSI	1.47	-2.78	110.6
PENELEC-DEOK	1.81	-4.4	64.74
PENELEC-EKPC	2	-4.55	45.53
PEPCO-PPL	2.02	-5.16	11.47
PEPCO-PSEG	2.12	-5.85	9.44
PEPCO-RECO	2.32	-6.66	12.89
PEPCO-ATSI	3.96	-6.93	255.94
PEPCO-DEOK	4.27	-7.63	233.59
PEPCO-EKPC	4.71	-8.65	170.03
PPL-PSEG	1.15	-3.02	28.86
PPL-RECO	1.41	-3.58	42.49
PPL-ATSI	4.11	-7.63	171.64
PPL-DEOK	4.47	-8.31	149.79
PPL-EKPC	4.94	-10.13	109.8
PSEG-RECO	0.75	-2.52	23.58
PSEG-ATSI	4.76	-9.3	161.36
PSEG-DEOK	5.18	-10.31	139.62
PSEG-EKPC	5.68	-11.56	106.73
RECO-ATSI	4.61	-10.88	127.38
RECO-DEOK	5.07	-11.25	107.36
RECO-EKPC	5.49	-12.33	86.07
ATSI-DEOK	0.8	-2.71	26.6
ATSI-EKPC	0.89	-2.79	42.48
DEOK-EKPC	1.12	-2.04	149.72

Term structure of FTR price volatility. The volatility of contracts with higher promptness number is lower – indicating volatility has a decreasing term structure.

Table 2. Example of Volatility Decay: Volatility gets smaller for farther contracts. Standard deviation of each FTR contract is calculated over MPOR=2

PATHS	Auction month + 2	Auction month + 3	Auction month + 5	Auction month + 7	All
AECO-AEP	8.50	2.92	2.50	2.19	4.19
AECO-APS	6.32	1.94	1.50	1.34	2.99
AECO-BGE	3.73	1.96	1.37	1.22	2.07
AECO-COMED	9.78	3.41	2.71	2.38	4.77
AECO-DAY	8.93	3.13	2.65	2.36	4.43
AECO-DOM	3.97	1.78	1.18	0.96	2.03
AECO-DPL	2.08	0.89	0.82	0.48	1.08
AECO-DUQ	9.50	3.12	2.57	2.25	4.61
AECO-JCPL	2.60	1.27	1.06	0.56	1.35
AECO-METED	1.79	0.65	0.49	0.26	0.86
AEP-APS	3.10	1.41	1.33	1.20	1.74
AEP-BGE	9.14	3.15	2.68	2.68	4.56
AEP-COMED	2.48	1.09	0.83	0.56	1.28
AEP-DAY	0.67	0.36	0.26	0.26	0.39
AEP-DOM	6.75	2.76	2.29	2.27	3.56
AEP-DPL	8.79	3.08	2.46	2.24	4.33
AEP-DUQ	2.15	0.71	0.55	0.59	1.04
AEP-JCPL	8.85	3.32	2.75	2.31	4.44
AEP-METED	8.25	2.98	2.43	2.20	4.10
APS-BGE	6.87	2.05	1.64	1.91	3.31
APS-COMED	4.74	1.97	1.66	1.40	2.48
APS-DAY	3.55	1.62	1.47	1.32	1.97
APS-DOM	4.24	1.70	1.26	1.53	2.23
APS-DPL	6.57	2.09	1.49	1.39	3.12
APS-DUQ	4.31	1.68	1.36	1.16	2.18
APS-JCPL	6.62	2.35	1.81	1.56	3.22
APS-METED	5.95	1.94	1.40	1.35	2.83
BGE-COMED	10.41	3.56	2.84	2.85	5.12
BGE-DAY	9.55	3.36	2.83	2.87	4.79
BGE-DOM	3.57	1.05	0.88	0.66	1.66
BGE-DPL	4.11	1.95	1.38	1.16	2.19
BGE-DUQ	10.06	3.43	2.72	2.81	4.96
BGE-JCPL	3.89	2.30	1.64	1.09	2.23

BGE-METED	3.62	1.93	1.35	1.13	2.00
COMED-DAY	2.27	1.04	0.80	0.52	1.19
COMED-DOM	8.21	3.23	2.53	2.48	4.21
COMED-DPL	10.10	3.60	2.77	2.43	4.95
COMED-DUQ	3.07	1.27	1.03	0.76	1.55
COMED-JCPL	10.12	3.73	2.92	2.51	5.00
COMED-METED	9.55	3.43	2.68	2.38	4.69
DAY-DOM	7.22	2.99	2.46	2.47	3.82
DAY-DPL	9.20	3.30	2.61	2.41	4.57
DAY-DUQ	1.90	0.65	0.56	0.55	0.93
DAY-JCPL	9.27	3.52	2.88	2.50	4.67
DAY-METED	8.69	3.19	2.57	2.38	4.33
DOM-DPL	4.41	1.75	1.21	0.92	2.18
DOM-DUQ	7.81	3.07	2.36	2.42	4.02
DOM-JCPL	4.42	2.17	1.48	0.83	2.30
DOM-METED	3.79	1.77	1.06	0.88	1.93
DPL-DUQ	9.76	3.26	2.46	2.30	4.73
DPL-JCPL	2.55	1.53	1.29	0.64	1.48
DPL-METED	2.06	0.95	0.83	0.48	1.09
DUQ-JCPL	9.83	3.49	2.84	2.44	4.85
DUQ-METED	9.24	3.18	2.50	2.27	4.51
JCPL-METED	1.90	1.09	0.96	0.47	1.09
PECO-PENELEC	5.38	1.79	1.48	1.30	2.65
PECO-PEPCO	3.77	1.78	1.27	1.17	2.02
PECO-PPL	0.97	0.42	0.36	0.30	0.52
PECO-PSEG	2.29	0.98	0.85	0.78	1.22
PECO-RECO	2.98	1.20	0.91	0.81	1.51
PECO-ATSI	9.08	2.40	1.79	1.37	4.10
PECO-DEOK	9.67	2.73	2.16	1.54	4.45
PECO-EKPC	10.78	3.13	2.22	1.63	4.92
PENELEC-PEPCO	6.48	2.32	1.87	1.94	3.28
PENELEC-PPL	5.35	1.64	1.41	1.26	2.58
PENELEC-PSEG	6.56	2.09	1.84	1.86	3.26
PENELEC-RECO	6.28	2.22	1.71	1.77	3.15
PENELEC-ATSI	3.24	1.14	0.73	0.44	1.47
PENELEC-DEOK	3.83	1.46	1.02	0.62	1.81
PENELEC-EKPC	4.28	1.67	1.06	0.60	2.00
PEPCO-PPL	3.71	1.82	1.27	1.14	2.02
PEPCO-PSEG	3.84	1.98	1.45	1.20	2.12
PEPCO-RECO	4.23	2.15	1.53	1.21	2.32
PEPCO-ATSI	9.07	1.86	1.27	1.25	3.96
PEPCO-DEOK	9.73	2.00	1.55	1.32	4.27
PEPCO-EKPC	10.76	2.36	1.57	1.33	4.71

PPL-PSEG	2.15	0.90	0.78	0.75	1.15
PPL-RECO	2.80	1.11	0.79	0.78	1.41
PPL-ATSI	9.14	2.35	1.76	1.30	4.11
PPL-DEOK	9.76	2.72	2.13	1.48	4.47
PPL-EKPC	10.86	3.09	2.17	1.55	4.94
PSEG-RECO	1.41	0.70	0.51	0.41	0.75
PSEG-ATSI	10.39	2.82	2.20	1.92	4.76
PSEG-DEOK	11.17	3.17	2.57	2.09	5.18
PSEG-EKPC	12.30	3.55	2.68	2.22	5.68
RECO-ATSI	9.89	3.09	2.15	1.88	4.61
RECO-DEOK	10.74	3.46	2.49	2.05	5.07
RECO-EKPC	11.68	3.82	2.59	2.18	5.49
ATSI-DEOK	1.63	0.69	0.53	0.34	0.80
ATSI-EKPC	1.91	0.78	0.51	0.26	0.89
DEOK-EKPC	2.49	0.86	0.52	0.29	1.12

E. Back-Testing

Back-testing is a standard method for validating a particular trading or risk management methodology. The back-testing procedure works as follows.

- We fix a particular time *t* in the past and calculate IM using historical data for times preceding *t*.
- We then assume that a default happens at time *t* and it takes a time period equal to MPOR to unwind the position.
- We then compare the loss during MPOR with the computed IM.
- We repeat this test for a number of times *t* and compute a percentage of times IM was less than actual loss.
- We check if this frequency is consistent with target risk percentile fixed in IM calculation methodology.

Table 3. Back-testing results for zonal path prices. MPOR = 2, inPromptNum = 3

PATH	# TESTS	# FAILS
AECO-AEP	62	0
AECO-APS	62	0
AECO-BGE	62	0
AECO-COMED	62	0
AECO-DAY	62	0
AECO-DOM	62	1
AECO-DPL	62	2
AECO-DUQ	62	0
AECO-JCPL	62	0
AECO-METED	62	0

AEP-APS	62	0
AEP-BGE	62	0
AEP-COMED	62	0
AEP-DAY	62	0
AEP-DOM	62	0
AEP-DPL	62	0
AEP-DUQ	62	0
AEP-JCPL	62	0
AEP-METED	62	0
APS-BGE	62	0
APS-COMED	62	0
APS-DAY	62	0
APS-DOM	62	0
APS-DPL	62	0
APS-DUQ	62	0
APS-JCPL	62	0
APS-METED	62	0
BGE-COMED	62	0
BGE-DAY	62	0
BGE-DOM	62	0
BGE-DPL	62	0
BGE-DUQ	62	0
BGE-JCPL	62	0
BGE-METED	62	1
COMED-DAY	62	0
COMED-DOM	62	0
COMED-DPL	62	0
COMED-DUQ	62	0
COMED-JCPL	62	0
COMED-METED	62	0
DAY-DOM	62	0
DAY-DPL	62	0
DAY-DUQ	62	0
DAY-JCPL	62	0
DAY-METED	62	0
DOM-DPL	62	0
DOM-DUQ	62	0
DOM-JCPL	62	0
DOM-METED	62	1
DPL-DUQ	62	0
DPL-JCPL	62	0
DPL-METED	62	2
DUQ-JCPL	62	0

DUQ-METED	62	0
JCPL-METED	62	0
PECO-PENELEC	62	0
PECO-PEPCO	62	0
PECO-PPL	62	0
PECO-PSEG	62	0
PECO-RECO	62	0
PECO-ATSI	42	0
PECO-DEOK	32	0
PECO-EKPC	32	0
PENELEC-PEPCO	62	0
PENELEC-PPL	62	0
PENELEC-PSEG	62	0
PENELEC-RECO	62	0
PENELEC-ATSI	42	1
PENELEC-DEOK	32	0
PENELEC-EKPC	32	0
PEPCO-PPL	62	0
PEPCO-PSEG	62	0
PEPCO-RECO	62	0
PEPCO-ATSI	42	0
PEPCO-DEOK	32	0
PEPCO-EKPC	32	0
PPL-PSEG	62	0
PPL-RECO	62	0
PPL-ATSI	42	0
PPL-DEOK	32	0
PPL-EKPC	32	0
PSEG-RECO	62	1
PSEG-ATSI	42	0
PSEG-DEOK	32	0
PSEG-EKPC	32	0
RECO-ATSI	42	0
RECO-DEOK	32	0
RECO-EKPC	32	0
ATSI-DEOK	32	1
ATSI-EKPC	32	0
DEOK-EKPC	32	1

TOTAL NUMBER OF TESTS 10724

TOTAL NUMBER OF FAILS 139

Fail/Total=.013

Table 4. Fail-to-Total Ratio for different MPORs and inPromptNum

Const = 125%

MPOR	inPromptNum	numFails/numScenarios
2	2	0.0092
2	3	0.0053
2	4	0.0043
2	5	0.0034
2	6	0.0029
2	7	0.0026
3	3	0.0041
3	4	0.0042
3	5	0.0038
3	6	0.0035
3	7	0.0032

Const = 100%

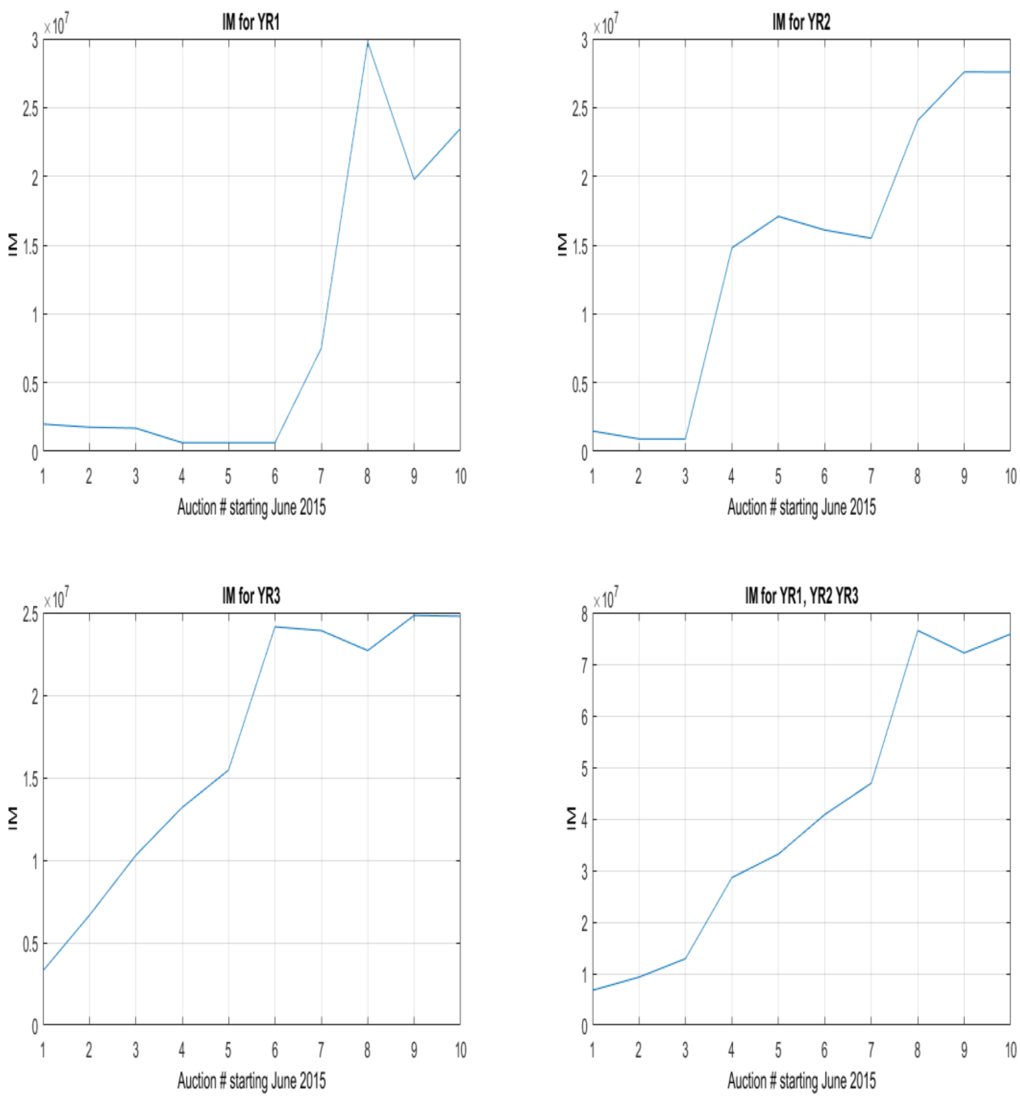
MPOR	inPromptNum	numFails/numScenarios
2	2	0.0226
2	3	0.0130
2	4	0.0106
2	5	0.0085
2	6	0.0073
2	7	0.0065
3	3	0.0106
3	4	0.0113
3	5	0.0103
3	6	0.0096
3	7	0.0090

F. GreenHat Portfolio Back-Test

In this section we will apply our IM methodology to the GreenHat portfolio. We will concentrate on their long term portfolio. Figure 2 shows IM requirements as computed by the HS methodology for consecutive auctions starting June 2015.

From graphs in Figure 2 it follows that by the beginning of 2018 the IM requirements for LT contracts will be ~$80M. If we add ~$40M of variation margin (by 2018 GreenHat MTA was ~-$40M), we get total margin requirement of ~$120M.

Figure 2. IM for the GreenHat LT portfolio (HS methodology)



V. Discussion and Conclusions

- In general, the concepts underlying the approach are fairly common and preferred by regulators and market governing bodies. See, for example, Standard Initial Margin Model for Non-cleared Derivatives, ISDA, 2013, https://www.isda.org/a/cgDDE/simm-for-non-cleared-20131210.pdf
- Although it is called Historical Simulations, the method uses historical data only to determine the distribution around the forward prices and *not* the forward prices themselves. The forward prices, which at any auction reflect participants' expectations of future settled FTR prices, are determined at the auction time and, ideally, incorporate all information participants have about the future, including topology changes, outages, fuel prices, etc. The movements of these prices result in the fluctuations of Mark-to-Auction values of the participants' portfolios and, correspondingly, impact their Variation Margin. Unlike Variation Margin, which is affected by the participants' long term expectations, Initial Margin is determined by relatively short term movements of these expectations. Hence, the stable statistical properties of these movements are of paramount importance, as we need to assume that price movement distributions in the past are applicable now as well. So far, this assumption holds (at least for zonal paths), although it has to be checked regularly and, if necessary, the methodology should be updated.
- One of the strongest arguments in favor of HS methodology is that it produces joint distribution of price movements without requiring such inputs as correlation matrix or covariance matrix. That's good news as these parameters imply a particular family of joint distributions which may not be the best choice for the case of FTRs. With HS approach we don't need correlations because by construction price movements for each scenario are taken from the same time period in the past thus ensuring correct joint behavior.
- More work required:
    - Adjustment for liquidity. More analysis is needed to determine how to adjust IM in the case of illiquid paths.
    - Choice of MPOR and other parameters for IM calculation. We need to do more back testing of different portfolios to establish a definitive choice of these parameters.
- As POC is concerned, based on our back tests, HS has proved to be a reasonable methodology to be considered for computing IM. Even if this methodology is not selected, we can use it as a simple and reliable back-up method in production or for testing purposes.