Transmission Expansion Advisory Committee

June 9, 2010

Issues Tracking

Open Issues:

Owner	Requestor	Issue ID	Issue Title	Issue Description	Issue Status	Stakeholder Body	Date Created
PJM	Patty Esposito / NRG	Raised at May 12 TEAC	MAAC and EMAAC Reactive Analysis Details	Request for more detail for MAAC and EMAAC reactive issues. Suggestion to order the list of issues by severity.	Open	TEAC	5/12/2010
PJM	Ron Chu / Exelon Corporation	Raised at May 27 TEAC	At-Risk Generation used in sensitivity studies	Request that notes be added to the May 27th TEAC slides to clarify that the at-risk generation used in the sesitivity slides was only coal generation	Open	TEAC	5/27/2010

New Issues:

2010 RTEP Analysis Update

Review MAAC Baseline Violations Without Considering Alternatives

- Criteria Violations
  - 15 Year Thermal
    - Generation Deliverability
    - Load Deliverability
  - 2015 Load Deliverability Voltage
  - 2015 N-1-1 Thermal
  - 2015 N-1-1 Voltage
- Sensitivity Analysis

15 Year Thermal

- Cases:
  - 2015 generator deliverability case and 2015 load deliverability thermal cases
- Applicable Ratings:
  - Conductor ratings
- Case Assumptions:
  - PATH, MAPP, Branchburg – Roseland – Hudson all not included
  - Susquehanna – Roseland included
- Overload Year:
  - The overload year is the earliest year for a violation for the generator deliverability or any load deliverability test

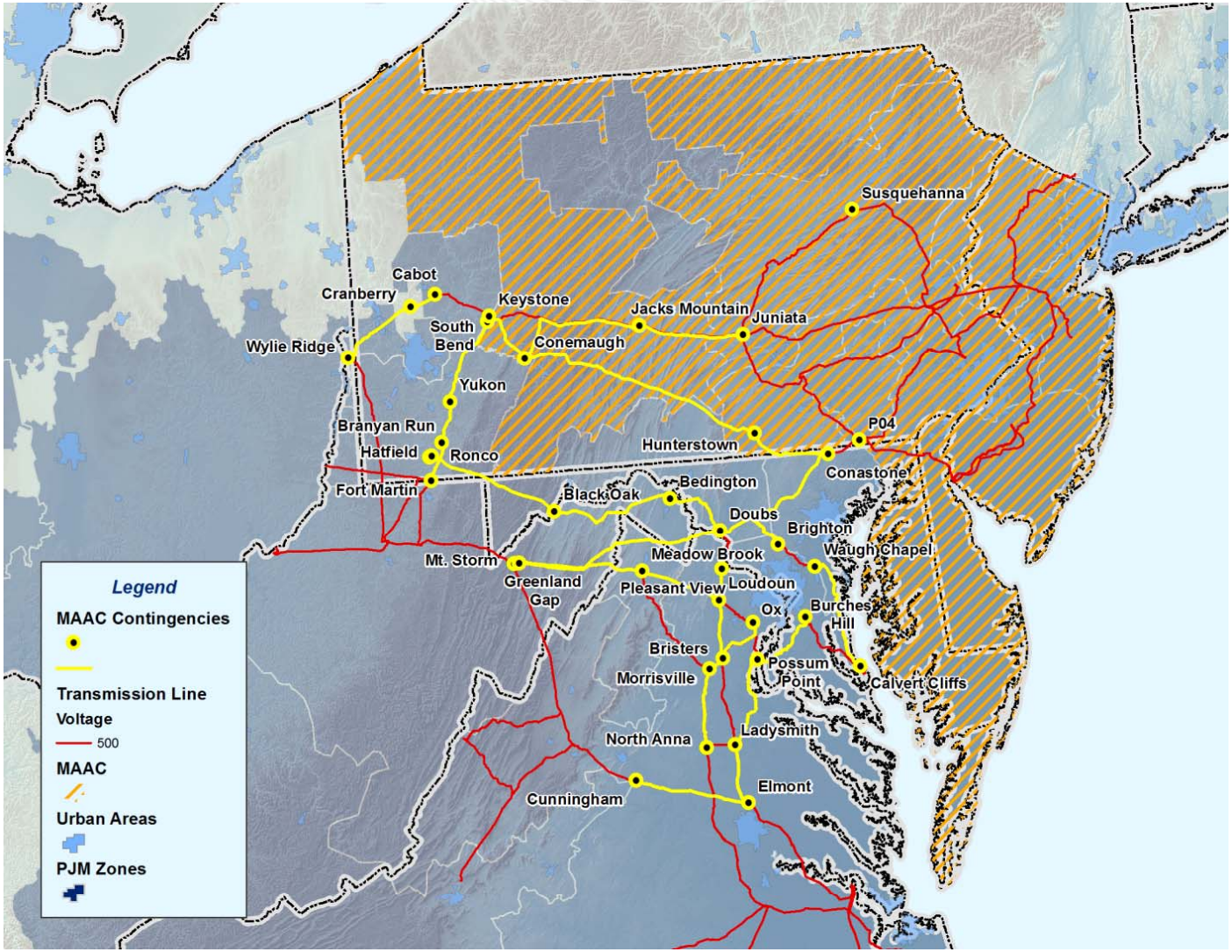
From Bus	To Bus	Overload Year
Lexington	Dooms	2017
Mt. Storm	T157 Tap	2017
T157 Tap	Doubs	2017
Pruntytown	Mt. Storm	2019
Jacks Mountain	Juniata #1	2019
Jacks Mountain	Juniata #2	2020
Greenland Gap	Meadow Brook	2021
Mt. Storm	Greenland Gap	2022
Bath County	Valley	2022
Keystone	Jacks Mountain	2023
Harrison	Pruntytown	2024

2015 MAAC Load Deliverability - Voltage

- Several critical contingencies did not converge for the 2015 baseline system with PATH removed

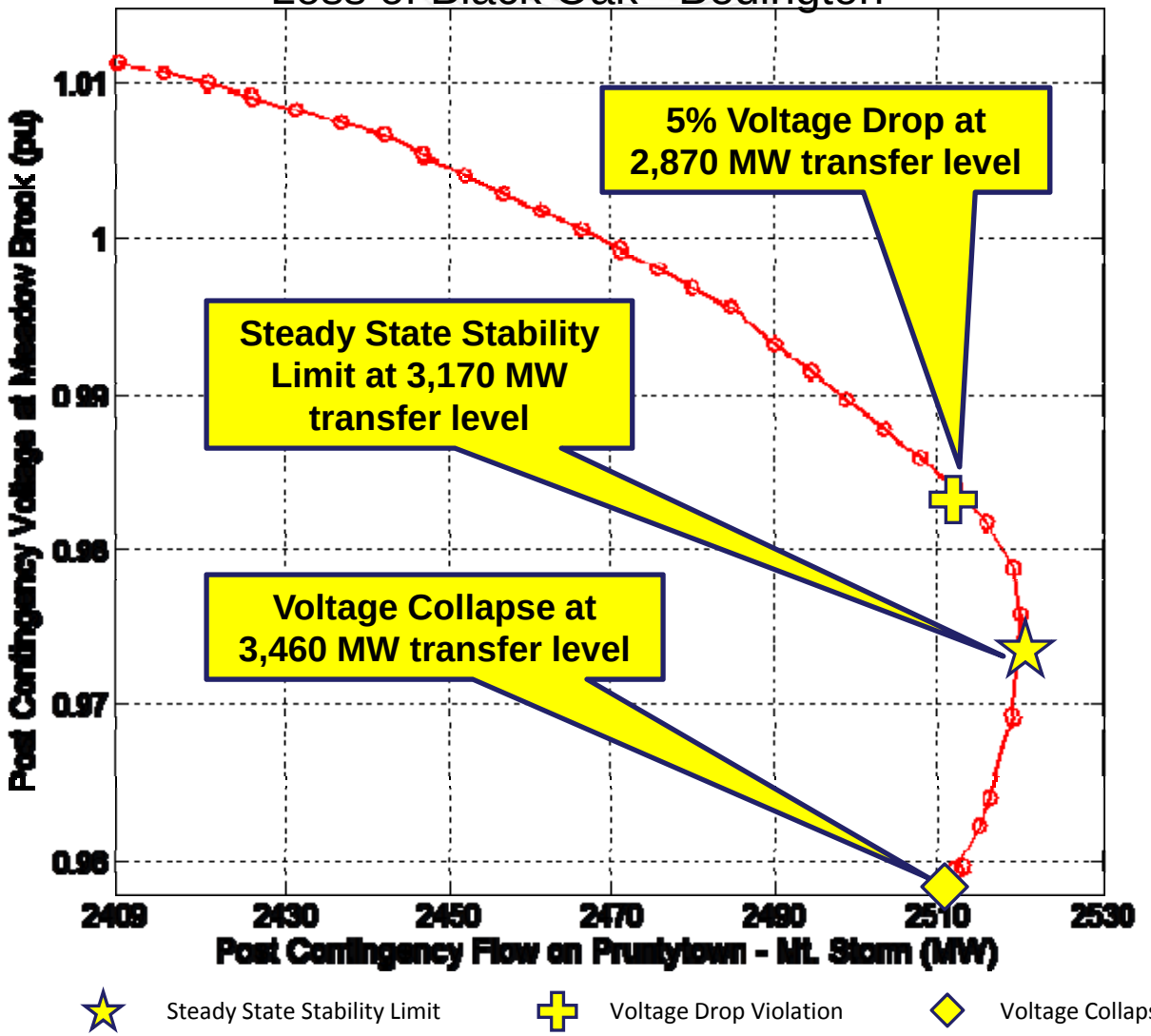
- Keystone - South Bend 500 kV
- Conemaugh - Keystone 500 kV
- Conemaugh - Jacks Mountain 500 kV
- Keystone - Jacks Mountain 500 kV
- Jacks Mountain - Juniata 1&2 500 kV
- Conemaugh - Hunterstown 500 kV
- Hunterstown - Conastone 500 kV
- Conastone - Brighton 500 kV
- Brighton - Doubs 500 kV
- Calvert Cliffs - Waugh Chapel 500 kV
- Burches Hill - Possum Point 500 kV
- Brister - Ox 500 kV
- Elmont - Cunningham 500 kV
- Elmont - Ladysmith 500 kV
- Ladysmith - Possum Point 500 kV
- Loudoun - Morrisville 500 kV
- Morrisville - North Anna 500 kV
- Loudoun - Pleasant View 500 kV
- Meadow Brook - Loudoun 500 kV
- Mount storm - Meadow Brook 500 kV
- Mount Storm - Greenland Gap 500 kV
- Mount Storm - T157 Tap 500 kV
- T157 Tap - Doubs 500 kV
- Hatfield - Black Oak 500 kV
- Hatfield - Ronco 500 kV
- Hatfield - Banyan Run 500 kV
- Bedington - Black Oak 500 kV
- Bedington - Doubs 500 kV
- Fort Martin - Ronco 500 kV
- Yukon - South Bend 500 kV
- Yukon - Banyan Run 500 kV
- Cabot - Cranberry 500 kV
- Cranberry - Wylie Ridge 500 kV
- Calvert Cliffs 1&2 500 kV
- P04 500 kV
- Susquehanna #2

2015 MAAC Load Deliverability – Voltage Non-Converged Contingencies



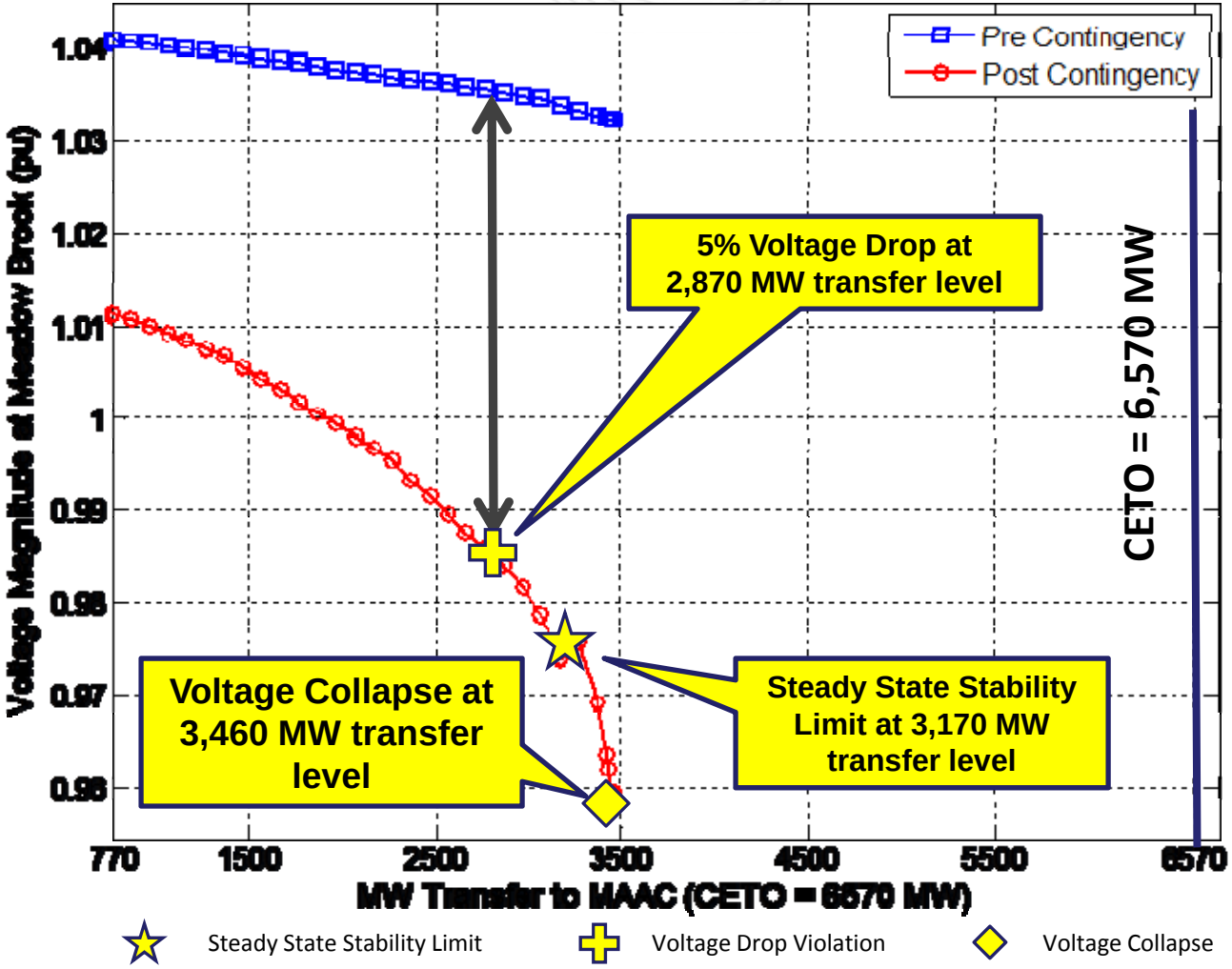
MAAC Load Deliverability - Voltage

Loss of Black Oak - Bedington



MAAC Load Deliverability - Voltage

Loss of Black Oak - Bedington



- Without PATH
  - Voltage
    - 46 N-1-1 contingency pairs are non-converged
  - Thermal
    - 8 potential thermal overloads
    - Investigating limiting equipment to determine if any conductor is limiting
- With PATH
  - Voltage
    - 2 N-1-1 contingency pairs are non-converged
  - Thermal
    - 2 potential thermal overloads
    - Terminal equipment is limiting for both potential overloads

Sensitivity Studies

Sensitivity Analysis Inputs

RPS Magnitude	DR/EE Magnitude	Participation Factor	Capacity Factor	At-Risk Generation
Determined by State mandates	Determined by State Mandates	Locational Distribution of individual RPS generation	Locational Value of RPS generation	Sink for RPS generation

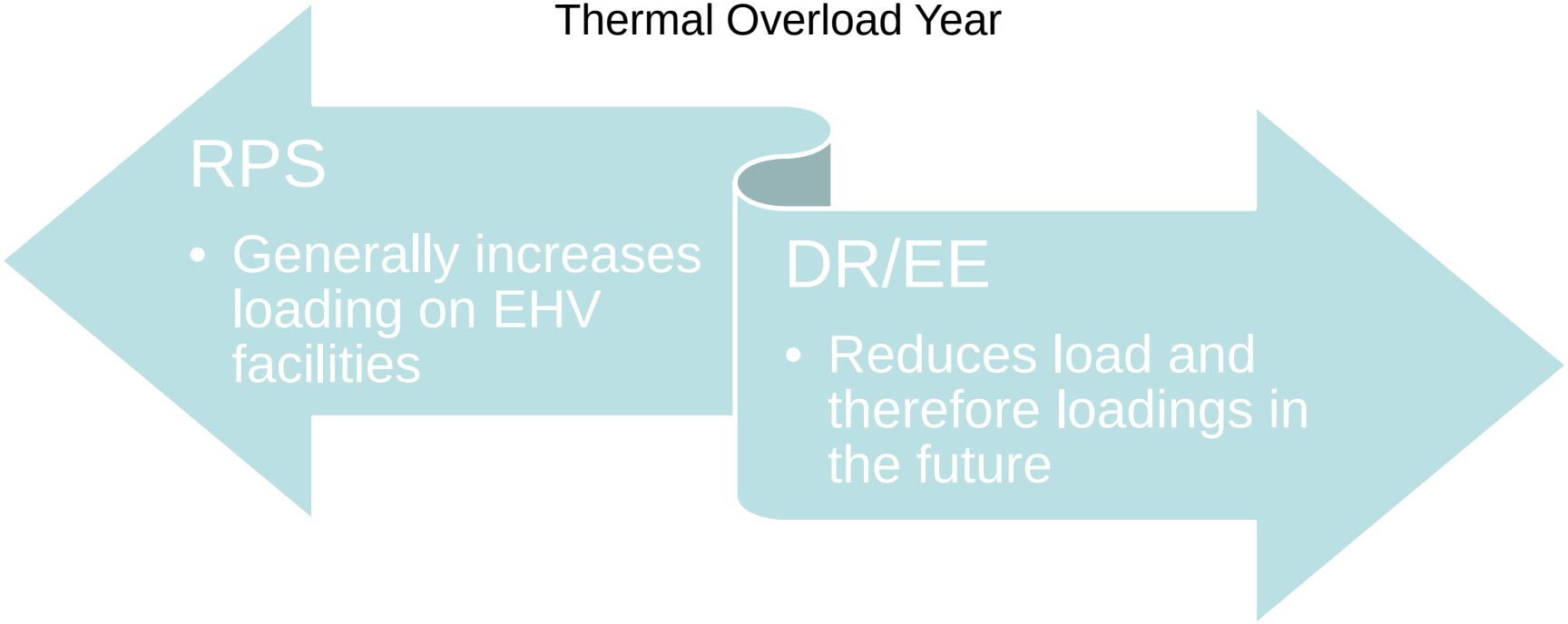
Table 1: Sensitivity Reliability Criteria Violation Year – Thermal Result

From	To	CKT	KVs	Base	RPS to Existing	RPS to At-Risk*	RPS+DR+EE to At-Risk*
Lexington	Dooms	1	500/500	2017	2016	2016	2016
T157 Tap	Doubs	1	500/500	2017	2016	2016	2016
Pruntytown	Mt. Storm	1	500/500	2019	2016	2017	2016
Jacks Mt. 1	Juniata	1	500/500	2019	2016	2016	2022
Mt. Storm	T157 Tap	1	500/500	2017	2016	2016	2016
Jacks Mt. 2	Juniata	1	500/500	2020	2016	2016	2023
Keystone	Jacks Mt. 1	1	500/500	2023	2017	2018	2024
Bath County	Valley	1	500/500	2022	2018	2019	2020
Mt. Storm	Greenland Gap	1	500/500	2022	2019	2019	2020
Greenland Gap	Meadowbrk	1	500/500	2021	2019	2019	2020
Keystone	Conemaugh	1	500/500	>2024	2020	2022	>2024
Harrison	Pruntytown	1	500/500	2024	2021	2021	2022
Doubs	Brighton	1	500/500	>2024	2021	>2024	>2024
Black Oak	Bedington	1	500/500	>2024	2023	2023	2024
Conemaugh	Jacks Mt. 2	1	500/500	>2024	2024	>2024	>2024

•Note that the Mt. Storm – Meadowbrook circuit appeared in previous sensitivity analysis but has been removed from this table since terminal equipment was subsequently found to be the limiting thermal element. Also, the at-risk generation only considered coal generation

Sensitivity Analysis Outputs

Thermal Overload Year



MAAC Alternative Analysis

- Alternative Description
- Alternative Reactive Comparison
- Alternative Thermal Comparison
- Reactive Only Sensitivity

MAAC Alternative Analysis

Alternative 1

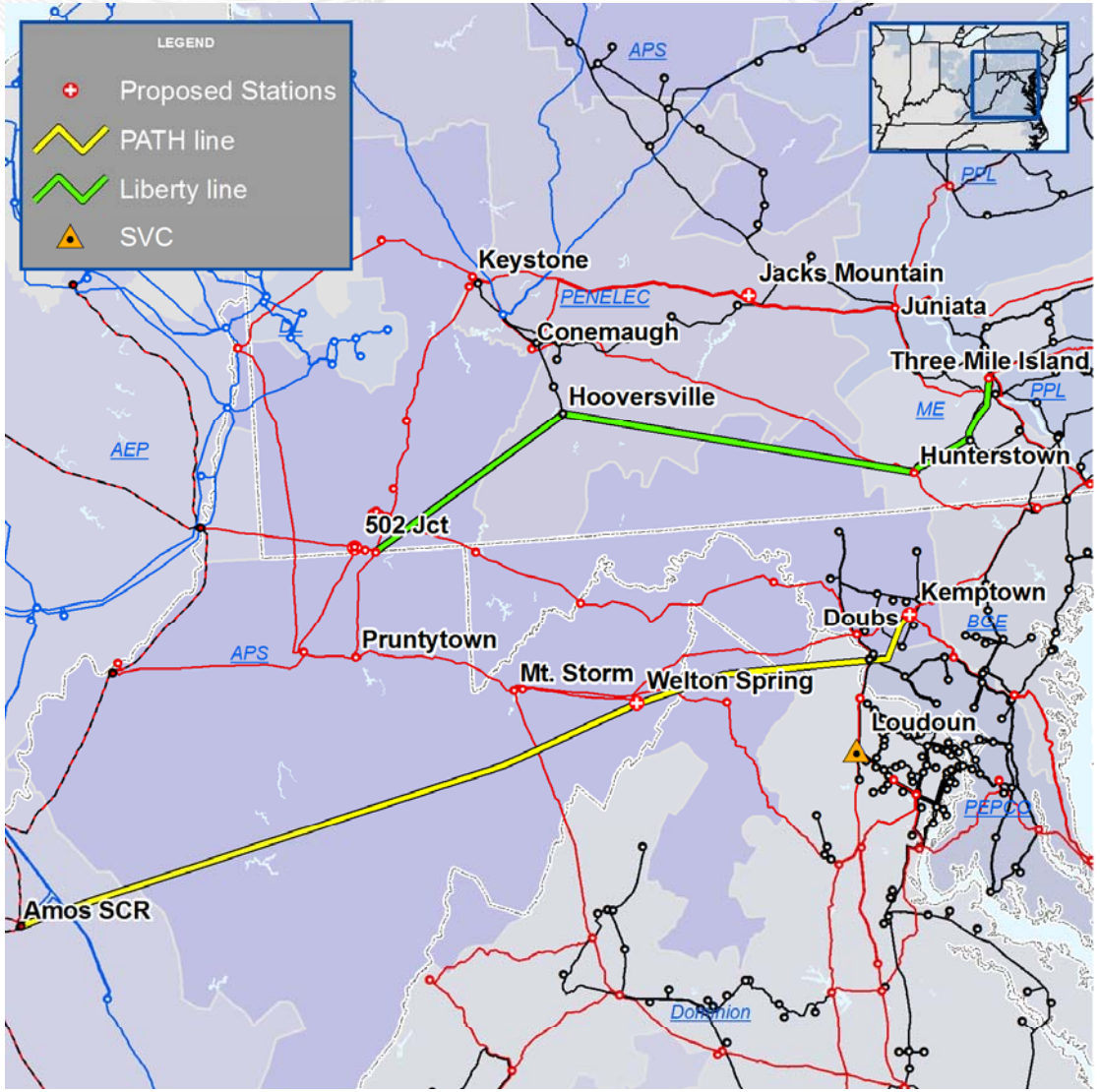
- 900 MVAR SVC at Loudoun 230 kV

Alternative 2

- Liberty / LS Power Proposal
- 502J – Hooversville – Hunterstown – TMI
- Meadow Brook - Doubs

Alternative 3

- PATH
- Description: Amos – Welton Spring – Kemptown
- Includes baseline reactive upgrades of 1000 MVAR shunt and 500 MVAR SVC at Welton Spring



MAAC Alternative Analysis

Alternative 4

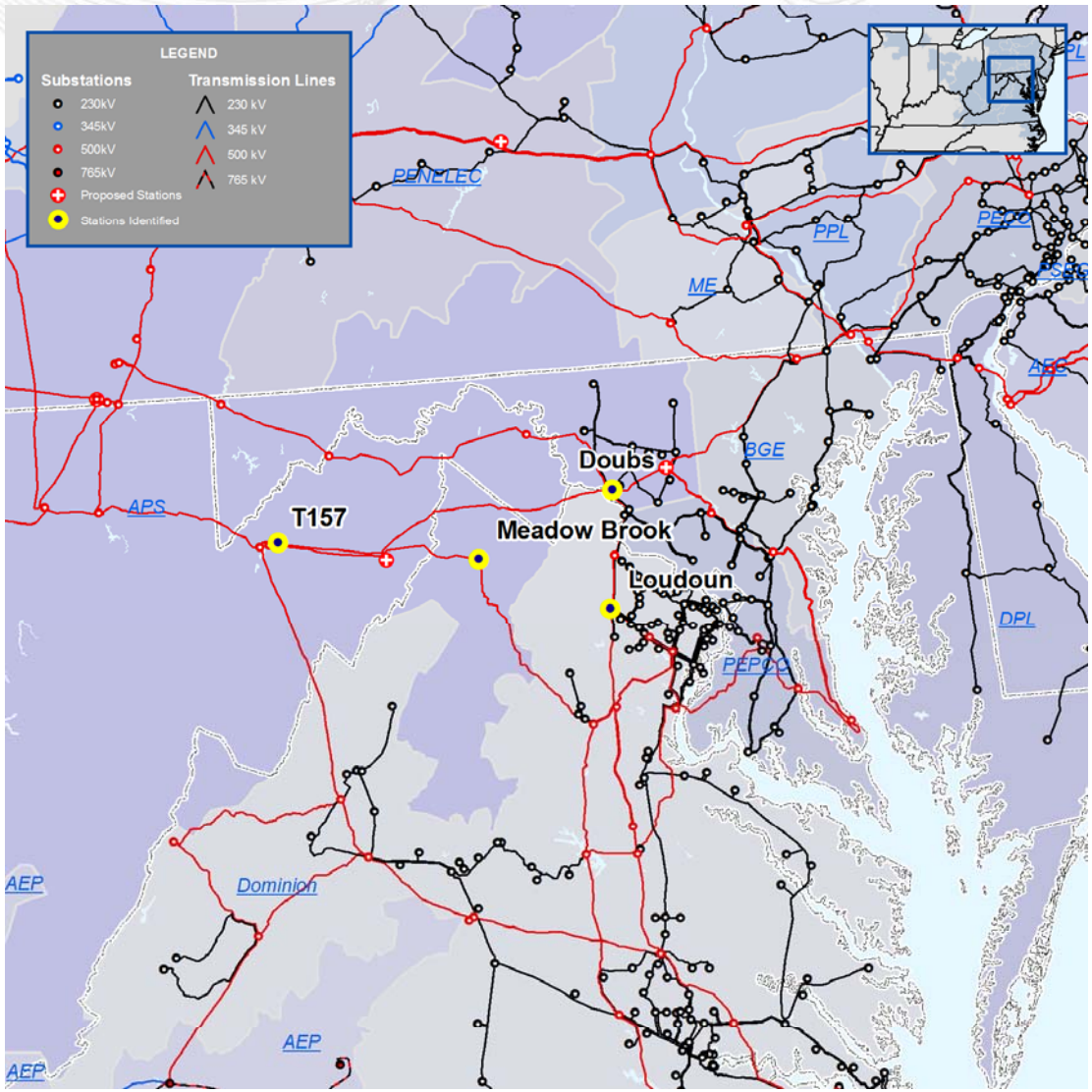
- 900 MVAR SVC at Loudoun 230 kV
- 900 MVAR static caps
  - 300 @ Meadow Brook 500 kV
  - 300 @ Loudoun 500 kV
  - 300 @ Doubs 500 kV

Alternative 5

- 900 MVAR SVC at Loudoun 230 kV
- 900 MVAR SVC at T157 Tap 500 kV

Alternative 6

- 900 MVAR SVC at Loudoun 230 kV
- 900 MVAR SVC at T157 Tap 500 kV
- 900 MVAR static caps
  - 300 @ Meadow Brook 500 kV
  - 300 @ Loudoun 500 kV
  - 300 @ Doubs 500 kV



MAAC Alternative Analysis

Alternative 7

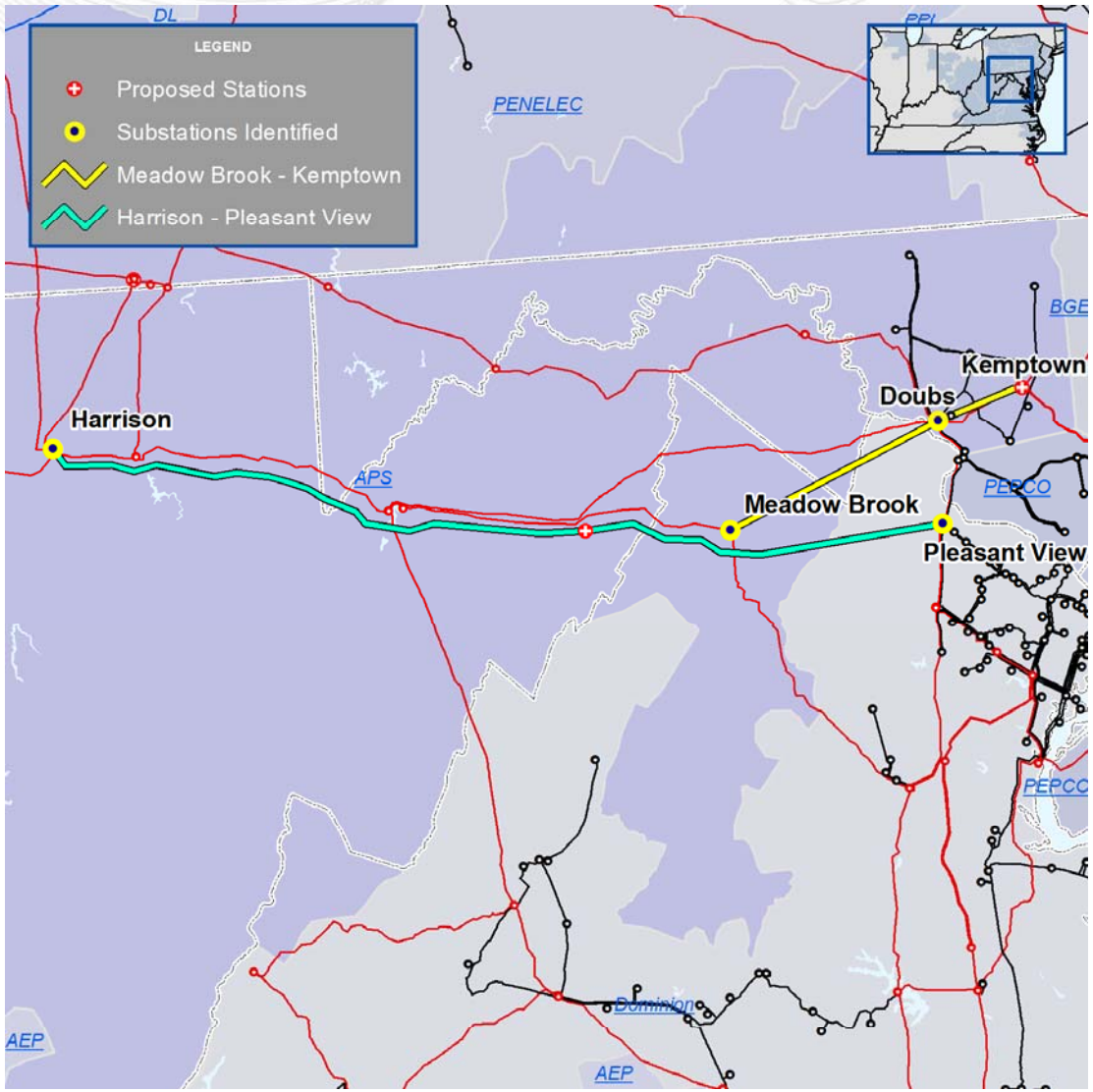
Harrison – Pleasant View 2000 MW HVDC

Meadowbrook – Kemptown 500 kV

500 MVAR SVC at Meadow Brook 500 kV

500 MVAR switched shunts

- 250 MVAR @ Kemptown 500 kV
- 250 MVAR @ Pleasant View 500 kV



MAAC Alternatives

Alternative 1 - Reactive

- 900 MVAR SVC at Loudoun 230 kV

Alternative 2 - Transmission

- Liberty / LS Power Proposal

502J – Hooversville – Hunterstown – TMI

Meadow Brook - Doubs

Alternative 3 – Transmission & Reactive

- PATH
- Description: Amos – Welton Spring – Kemptown

Alternative 4 - Reactive

- 900 MVAR SVC at Loudoun 230 kV
- 900 MVAR static caps
  - 300 @ Meadow Brook 500 kV
  - 300 @ Loudoun 500 kV
  - 300 @ Doubs 500 kV

Alternative 5 - Reactive

- 900 MVAR SVC at Loudoun 230 kV
- 900 MVAR SVC at T157 Tap 500 kV

Alternative 6 - Reactive

- 900 MVAR SVC at Loudoun 230 kV
- 900 MVAR SVC at T157 Tap 500 kV
- 900 MVAR static caps
  - 300 @ Meadow Brook 500 kV
  - 300 @ Loudoun 500 kV
  - 300 @ Doubs 500 kV

Alternative 7 – Transmission & Reactive

Harrison – Pleasant View 2000 MW HVDC

Meadowbrook – Kemptown 500 kV

500 MVAR SVC at Meadow Brook 500 kV

500 MVAR switched shunts

- 250 MVAR @ Kemptown 500 kV
- 250 MVAR @ Pleasant View 500 kV

2015 MAAC Reactive Alternative Analysis

	Type	Description	CETO	Margin (CETL – CETO)	Criteria Violation (If negative margin)
Alternative 1	Reactive Only	900 MVAR SVC	6570	-1500	Vdrop
Alternative 2 (Liberty)	Transmission Only	502J – Hooversville – Hunterstown – TMI - Meadow Brook - Doubs		-800	Vdrop
Alternative 3 (PATH)	Transmission + Reactive	Amos - Welton Spring - Kemptown		100	
Alternative 4	Reactive Only	900 MVAR SVC + 900 MVAR Caps		-1000	Vdrop
Alternative 5	Reactive Only	900 X 2 MVAR SVC		197	
Alternative 6	Reactive Only	900 X 3 MVAR SVC		1068	
Alternative 7	HVDC + Transmission + Reactive	Harrison – Pleasant View 2000 MW HVDC & Meadowbrook - Kemptown 500 kV & 500 X 2 MVAR SVC		1883	

15 Year MAAC Thermal Alternative Analysis

From Bus	To Bus	2015 Baseline Case – no alternatives	Reactive Reinforcement (5500 MVAR SVC)	Reconductor Mt. Storm - Doubs	Alt 3: PATH	Alt 2: Liberty	Alt 7: Harrison - P. View & Meadow Bk. - Kemptown
Lexington	Dooms	2017	2017	2017	>2025	2018	2022
Mt. Storm	T157 Tap	2017	2017	> 2025	>2025	> 2025	> 2025
T157 Tap	Doubs	2017	2016	> 2025	>2025	> 2025	> 2025
Pruntytown	Mt. Storm	2019	2019	2019	2025	2020	2024
Jacks Mountain	Juniata #1	2019	2021	2019	>2025	> 2025	> 2025
Jacks Mountain	Juniata #2	2020	2022	2020	>2025	> 2025	> 2025
Greenland Gap	MeadowBrook	2021	2022	2021	>2025	2022	2025
Mt. Storm	Greenland Gap	2022	2023	2022	>2025	2023	2025
Bath County	Valley	2022	2024	2022	>2025	2023	> 2025
Keystone	Jacks Mountain	2023	2024	2023	>2025	> 2025	> 2025
Harrison	Pruntytown	2024	2025	2024	>2025	2024	> 2025

- Reactive upgrades alone are not adequate to solve thermal violations through the 15 year horizon

Criteria Violation Solution Overview

Thermal Violations

Transmission Solutions –

Potential for major improvement

Reactive Only Solutions –

Minor indirect improvements

Reactive Violations

Transmission Solutions –

Potential for major improvement

Reactive Only Solutions –

Potential for major improvement

Consideration of Alternatives for MAAC

Transmission Solutions

- Able to intuitively target thermal violations
- Provide a strong solution to reactive violations
- Complemented by reactive support

Reactive Solutions

- Difficult to size & locate when the voltage issues are widespread
- May require new stations due to the potentially large amount of reactive devices needed at specific locatons

MAAC Load Deliverability Reactive Sensitivity Analysis

- Purpose:
  - Determine the approximate magnitude of reactive devices to achieve transfer levels into MAAC in future years as needed due to load growth alone
- Input:
  - 2015 MAAC load deliverability case
- Sensitivity Variable:
  - Up to 1000 MVAR SVC's located at Juniata, Jack's Mountain, Doubs, Meadowbrook, T157 Tap, and Loudoun
  - The SVC's output MVAR's based on demand
- Test Procedure:
  - Find maximum transfer into MAAC before collapse
  - Record the SVC output at that transfer level
- Result:
  - The output of the SVC's was recorded while a transfer study was run for each Alternative

MAAC Load Deliverability Reactive Sensitivity Analysis

- Maximum Transfer:
  - Maximum transfer above the 2015 CETO before collapse
- CETO Extrapolation:
  - Estimate future increases in the CETO purely due to load growth
- Conclusion:
  - 2311 additional MW's can be transferred into MAAC in 2015
  - Load growth in MAAC exceeds 1876 MW by 2018 and 3273 MW by 2019
  - Does not account for increased reactive losses due to required increase in transfer in future years
  - At best, a reactive only solution could meet the increased CETO into MAAC through 2018 and would not meet the increased CETO in 2019 and beyond
  - Additional transmission is required

		No Transmission (Reactive Only)
New SVC Location	Juniata	169
	Jack's Mountain	848
	Doubs	1000
	Meadowbrook	1000
	T157 Tap	1000
	Loudoun	1000
Total MVAR supplied by SVC		5016
Maximum Transfer into MAAC above the 2015 CETO:		2311 MW

Year	90/10 Forecast	Delta Load from 2015
2015	79622	-
2016	80470	848
2017	81345	1723
2018	81498	1876
2019	82895	3273
2020	83843	4221

MAAC Load Deliverability Reactive Sensitivity Analysis With Transmission Alternatives

- Test Procedure:
  - Same procedure as detailed in previous slides – with transmission alternatives added
  - Find maximum transfer into MAAC before collapse
  - Record the SVC output at that transfer level
- Alternatives Considered:
  - No transmission
  - Liberty
  - PATH
  - Alternative 7 (HVDC + Transmission)
- Result:
  - The output of the SVC's was recorded while a transfer study was run for each Alternative

MAAC Load Deliverability Reactive Sensitivity Analysis

		Alternative		
		Liberty	PATH	HVDC + Transmission
SVC Locations	Juniata	270	17	500
	Jack's Mountain	148	361	852
	Doubs	716	1000	757
	Meadowbrook	1000	600	1000
	T157 Tap	836	0	822
	Loudoun	357	986	386
Total MVAR supplied by SVC		3326	2965	4318
Maximum Transfer into MAAC above the 2015 CETO:		3088 MW	3405 MW	3942 MW

- From a reactive perspective the alternatives that involve transmission are comparable.
- Differences in max transfer are less than one year in load growth in MAAC

System Reactive Losses

- Significant reactive losses due to many lines loaded in excess of Surge Impedance Loading (SIL)
- Post-contingency flows on lines will be even higher, which will increase reactive losses further
- New Transmission reduces losses

MVAR LOSS COMPARISON IN 2015 MID-ATLANTIC CETO Base Case (no contingency)

	Without PATH	With PATH	Difference
Areas	**(MVAR)**	**(MVAR)**	**(MVAR)**
500 kV only: APS + DOM + MAAC	20,049	18,557	-1,492
All kV Levels: APS + DOM + MAAC	50,752	48,296	-2,456

MAAC Conclusion

- Reactive upgrades alone are insufficient to resolve criteria violations
  - They have minimal impact on thermal violations
  - Addition of significant amounts of dynamic reactive doesn't provide a long term solution
  - Reactive losses on the system due to excessive thermal loading on EHV
- Upgrades that include new transmission are comparable at resolving reactive violations
- PATH project is better than the other alternatives at resolving thermal violations
- PJM is recommending we move forward with the PATH project

- Alternative Analysis for EMAAC continues
  - Coordinating thermal and reactive solutions in EMAAC

- Analysis done to date suggests new transmission will be required to provide a long-term solution to the identified violations

- Comparison of effectiveness of reactive upgrades versus combined new transmission and reactive upgrades
- Reactive only upgrades are less effective than transmission + reactive upgrades

2015 - 2019 EMAAC Maximum Import for Keeney - Rock Springs 500 kV Outage with MAPP

Year	EMAAC Import Requirement (MW)	Current EMAAC Import Limit (MW)	Reactive Support Only		MAPP + Reactive Support			
			Maximum EMAAC Import Limit (MW)	Reactive Compensation To Maximize EMAAC Import Limit (MVAr)	EMAAC Import (MW)	Reactive Compensation At EMAAC Import Level (MVAr)	Maximum EMAAC Import Limit (MW)	Reactive Compensation To Maximize EMAAC Import Limit (MVAr)
2015	8270	**8223**	8810	1094	8271	392	10403	720
2016	8643	**7650**	8689	1311	8644	486	10364	840
2017	9006	**7215**	**8591**	1472	9006	537	10343	940
2018	9192	**--**	**8534**	1574	9195	596	10328	983
2019	9579	**--**	**8382**	1730	9583	755	10272	1102

Next Steps

Review Issues Tracking