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Greater Boston Preferred Solution

Planning Advisory Committee

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Purpose

- Review the latest solution alternatives for the AC and HVDC Plans, discuss the cost and project attributes of each plan and select a preferred solution

Major Takeaway from the December PAC meeting

- The common theme discussed at the December PAC meeting was an urgent need for ISO New England (ISO-NE) to select an alternative so that siting and construction can begin as soon as possible
- ISO-NE has taken the additional information provided in December into account and has also worked with the transmission owners to gain a greater understanding of each alternative, as necessary
- ISO-NE is prepared to select a preferred solution for the Greater Boston study today

Agenda

- History of the Greater Boston study
- Discussion of the solution alternatives and cost estimates
- Transmission Owners' perspectives on the alternatives
- Cost containment proposal evaluation
- Selection of the preferred solution

HISTORY

Study History Summary

- The Greater Boston study has gone to the PAC 15 times
  - Details of some of the major PAC presentations can be found in the Appendix
- The geographic map of the study area and links to all the PAC presentations can be found in the Appendix to this presentation

Original Needs Presented in December 2009 - Updated at the July 2013 PAC Meeting

- Peak load results show numerous thermal overloads and low-voltage violations for N-1 and N-1-1 conditions
  - Critical load level was calculated for the thermal overloads and several of these violations could occur at current (2014 or earlier) load levels if the studied conditions were to materialize. The region has been exposed to some of these violations since pre-2013
- Minimum load N-1-1 testing demonstrated high voltages on the downtown Boston cable systems
- Short-circuit results showed over-dutied circuit breakers at two stations and heavily-dutied breakers (between 95% - 100%) at five stations

THE SOLUTION ALTERNATIVES

Solution Alternative Objective and Process

- The primary objective of the Greater Boston Solutions Study is to develop the most cost-effective transmission solution that meets the needs identified in the 2023 Needs Assessment
- Process
  - Began with the 2023 Needs Assessment base cases
  - Developed an AC Plan based on the preferred plan presented in March 2012
    - Tested whether all the components are still needed and incorporated any modifications to reduce the cost of the plan
  - Developed the HVDC Plan
    - Started with the HVDC line and added upgrades to complete the hybrid HVDC plan with AC components
- The result is a set of upgrades common to all plans and some unique upgrades in the AC Plan and the HVDC Plan (See the Appendix for a list and map of all common upgrades)

Solution Alternative Process

- The solutions to the needs in the Greater Boston area have been developed under the Tariff language found in Attachment K
  - As ISO-NE has been doing for many years, ISO-NE works with TOs and stakeholders to develop several alternative solutions to consider and then compares those alternative solutions
  - Then ISO-NE selects the most cost-effective solution, which then will be regionally supported

Previously Approved Upgrades

- To address pressing reliability concerns, several upgrades were presented and advanced at previous PAC meetings
- Reconductor the following:
  - 320-507 / 508 Lexington – Waltham 115 kV
  - 128-518 / P-168 Chelsea – Revere 115 kV
  - B-154N, C-155N, S-145, T-146 and portions of the Y-151 in response to the Salem Harbor NPR
  - C-129N / 201-502 Depot St. Tap – Medway 115 kV
  - D-130 / 201-501 Depot St. Tap – Medway 115 kV
  - 211-508 Woburn – Burlington 115 kV
- Add 115 kV capacitors at Hartwell and Chelsea

Upgrades Common to Both AC and HVDC Plans

- Both plans require a common set of upgrades that totals $221M which is included in the Appendix[1]
- Additionally the two plans require similar upgrades, but they are not identical in terms of configuration and/or required ratings, therefore the cost estimates are different for the two plans for these three solution components

AC Plan			HVDC Plan		
	Length (Miles)	Cost (in 2017$)		Length (Miles)	Cost (in 2017$)
2nd Mystic 345/115 kV Autotransformer	N/A	$32.2M	2nd Mystic 345/115 kV Autotransformer	N/A	$28.1M
New Mystic – Chelsea 115 kV underground cable	1	$53.4M	New Mystic – Chelsea 115 kV underground cable	1	$55.6M
Replace Woburn 345/115 kV Autotransformer and Woburn Reconfiguration	N/A	$38.8M	New Woburn 345/115 kV Autotransformer and Woburn Reconfiguration	N/A	$37.4M
Total Transmission Owner's Cost Estimate for Additional Common Plans		**$124.4M**	**Total Transmission Owner's Cost Estimate for Additional Common Plans**		**$121.1M**

[1] There are four projects where ISO-NE is still awaiting cost estimates

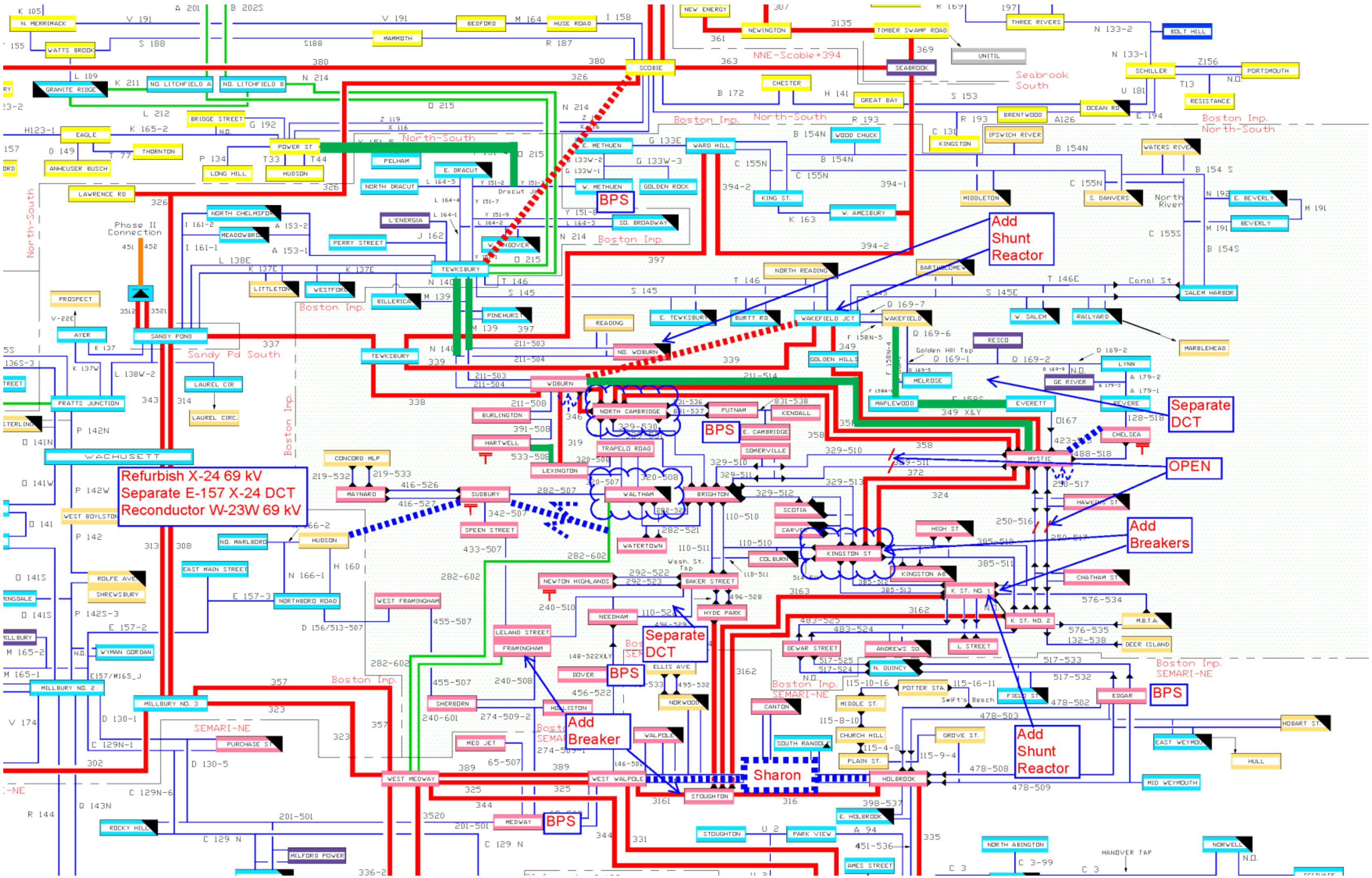
Major Unique AC Plan Upgrades

Proposed Facilities	Length (Miles)	Cost (in 2017$)
North – New Scobie – Tewksbury 345 kV	25	$122.9M
North – Reconductor Y-151 from NU[2]/NGRID border to Dracut Junction	9	
North – New Wakefield – Woburn 345 kV XLPE cable plus two 345 kV shunt reactors	8	$107.3M
North - Reconductor F-158S Maplewood – Everett 115 kV	3	$3.7M
North - Reconductor M-139 Billerica – Pinehurst 115 kV	3	$4.4M
North - Reconductor N-140 Tewksbury – Pinehurst 115 kV	7	$8.8M
North - Reconductor M-139/211-503 and N-140/211-504 115 kV lines Pinehurst – North Woburn tap	5	$6.3M
Downtown – Bifurcate a new Woburn – Mystic 115 kV cable and existing cable	8	$75.0M
Downtown - Open the Mystic 115 kV downtown ties	N/A	$0.3M
Downtown - Close the 115 kV bus tie breakers and add a series 115 kV breaker at K Street	N/A	$2.6M
Western - Upgrade the 533-508 Lexington – Hartwell 115 kV terminal equipment	N/A	$0.4M
All locations – Upgrade 5 substations to BPS standards	N/A	$36.6M
ME – Add a 200 MVAR STATCOM (**based on 2014 dollars**)	N/A	$26.0M
Total Transmission Owner's Cost Estimate for AC Upgrades		**$394.3M**

[2] Northeast Utilities (NU), which includes PSNH and NSTAR, has recently changed its name to Eversource Energy. Northeast Utilities is used in this presentation for consistency with past Greater Boston presentations.

One-line of the AC Plan Upgrades

The 200 MVAR STACOM in ME is not shown



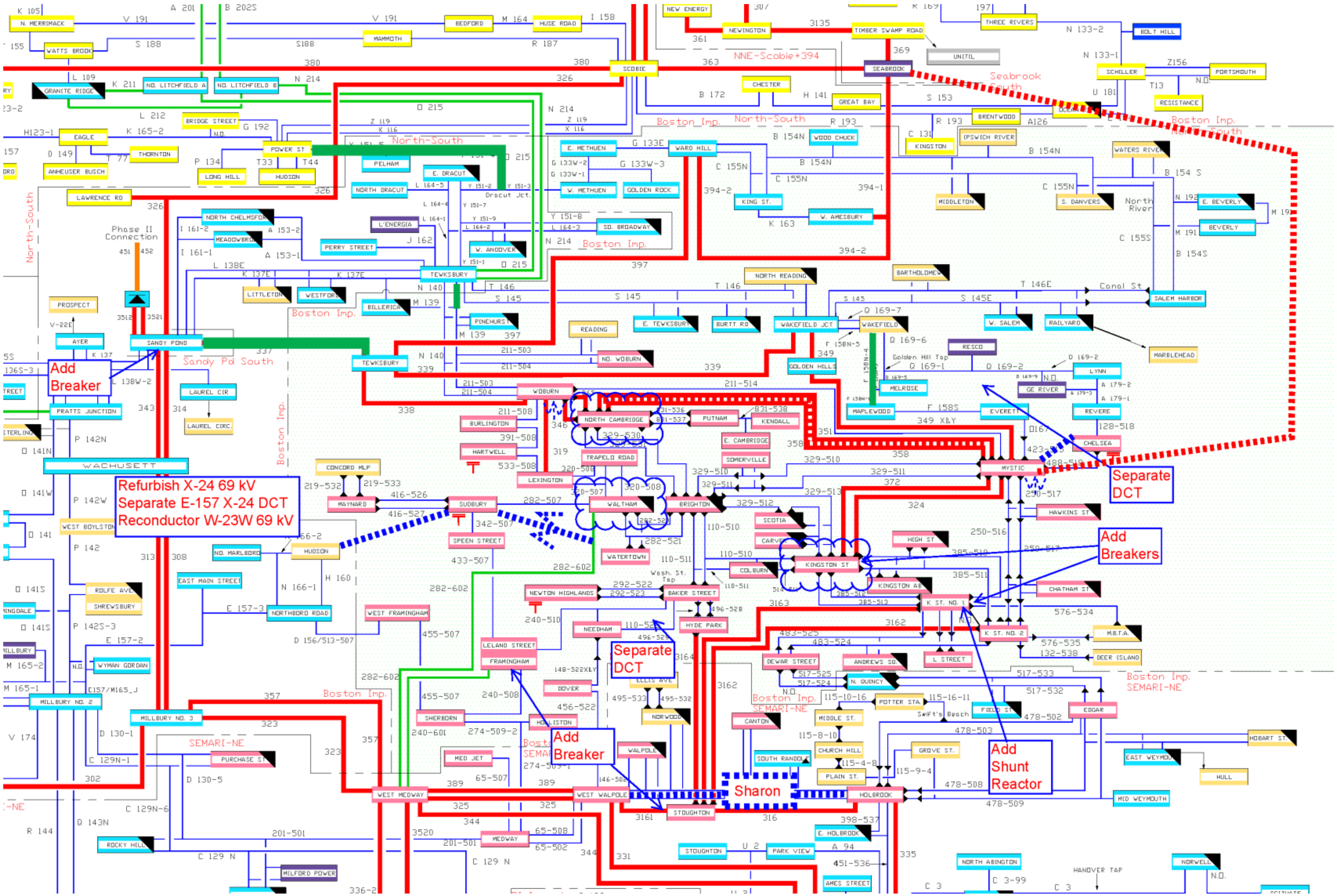
Major Unique HVDC Plan Upgrades

Proposed Facilities	Length (Miles)	Cost (in 2017$ unless otherwise noted)
North – New Seabrook – Mystic 520 MW HVDC cable, two terminals and interconnection at Mystic 115 kV – **The cost estimates for the HVDC line ($543.0M) and the Seabrook interconnection ($31.7M) total $574.7M and are estimated in 2018 dollars**	68	$604.6M
North - Additional upgrade to the Y-151 115 kV (larger conductor) from NU/NGRID border to Dracut Junction	9	$16.6M
North - Reconductor 337 Sandy Pond – Tewksbury 345 kV	16	$46.4M
Downtown - Bifurcate the Mystic – North Cambridge 345 kV cables	N/A	$12.5M
North - Add Sandy Pond 345 kV breaker	N/A	$3.2M
Downtown – Upgrades to address 250-516/517 overloads – **will not be substantial when compared to the HVDC Plan's total cost**		**Not yet provided**
Total Transmission Owner's Cost Estimate for AC Upgrades		**$683.3M**

One-line of the HVDC Plan Upgrades

Common Upgrades

HVDC Plan Upgrades



Transmission Owners' Cost Estimates

AC Plan	Cost (in 2017$ unless otherwise noted)	HVDC Plan	Cost (in 2017$ unless otherwise noted)	Delta ($M)
Common Upgrades (See Appendix for projects and cost estimates)	A $221.0M	Common Upgrades (See Appendix for projects and cost estimates)	D $221.0M	$0
Additional Common Upgrades	B $124.4M	Additional Common Upgrades	E $121.1M	-$3.3M
		AC projects in the HVDC Plan – **$31.7M estimated in 2018 $**	F $140.3M	
		HVDC Line Only – **estimated in 2018$**	G $543.0M	
Major Unique AC Plan Upgrades – **cost of the STATCOM in ME ($26.0M of the $394.3M) is estimated in 2014$**	C $394.3M	Major Unique HVDC Plan Upgrades (F + G)	$683.3M	$289.0M
Total Transmission Owners' Cost Estimates (A + B + C)	**$739.7M**	**Total Transmission Owners' Cost Estimates (D + E + F + G)**	**$1,025.4M**	**$285.7M**

Independent Consultant Review of Project Cost Estimates

- Electrical Consultants, Inc. (ECI) was hired to develop conceptual cost estimates for the design, engineering, construction and commissioning of the 11 projects based on project scope information provided from the transmission owners

- The 11 projects are:

Selected Major Unique AC Plan Components	Selected Major Unique HVDC Plan Components
New Scobie – Tewksbury 345 kV	New Seabrook – Mystic 520 MW HVDC cable with two terminals
Reconductor Y-151 from NU/NGRID border to Dracut Junction	Seabrook 345 kV interconnection for HVDC
New Wakefield – Woburn 345 kV XLPE cable add two 345 kV shunt reactors	Mystic 115 kV interconnection for HVDC
Bifurcate a new Woburn – Mystic 115 kV cable and existing cable	Upgrade the Y-151 115 kV from NU/NGRID border to Dracut Junction
200 MVAR STATCOM at Coopers Mills station in ME	Reconductor 337 Sandy Pond – Tewksbury 345 kV
	Bifurcate the Mystic – North Cambridge 345 kV cables

Independent Consultant Review of Project Cost Estimates[3], cont

Selected Major Unique AC Plan Components	TO	ECI 2017[4] Dollar Cost Estimate	TO 2017[5] Dollar Cost Estimate	Delta ($M / %)
Scobie – Tewksbury 345 kV and Y-151 Reconductor	NU/NGRID	$132.3M	$101.6M	$30.7M / 30.2%
Wakefield – Woburn 345 kV UG cables plus 345 kV shunt reactor	NU	$93.5M	$80.3M	$13.2M / 16.4%
Wakefield – Woburn 345 kV UG cables plus 345 kV shunt reactor	NGRID	$14.8M	$16.3M	-$1.5M / -9.2%
Bifurcate a new Woburn – Mystic 115 kV cable with the existing cable	NU	$73.9M	$69.1M	$4.8M / 6.9%
200 MVAR STATCOM at Coopers Mills station in ME	CMP	$40.4M[6]	$27.9M[6]	$12.5M / 44.8%
Totals		**$354.9M**	**$295.2M**	**$59.7M / 20.2%**

[3] The details of the independent consultant review from the November 18, 2014 PAC meeting. http://www.iso-ne.com/static-assets/documents/2014/11/a4_eci_greater_boston_solutions_presentation.pdf

[4] The ECI cost estimate was escalated from 2014 to 2017

[5] All contingency was removed from the TO cost estimate and any costs not in 2017 dollars were escalated/deescalated to 2017 dollars

[6] The TO estimate was escalated from 2014 to 2017 dollars and ECI's estimate was escalated from 2015 to 2017 dollars

Independent Consultant Review of Project Cost Estimates

Selected Major Unique HVDC Plan Components	TO	ECI 2017 [7] Dollar Cost Estimate	TO 2017 [8] Dollar Cost Estimate	Delta ($M / %)
HVDC submarine cable and two terminals	NHT	$534.6M	$519.0M	$15.6M / 3.0%
Seabrook 345 kV interconnection for the HVDC	NHT	$30.4M	$28.9M	$1.5M / 5.2%
Mystic 115 kV interconnection for the HVDC	NU	$27.0M	$27.6M	-$0.6M / -2.2%
Reconductor Y-151	NGRID	$11.3M	$13.2M	-$1.9M / -14.4%
Reconductor Sandy Pond – Tewksbury 345 kV	NGRID	$36.9M	$36.7M	$0.2M / 0.5%
Bifurcate Mystic – North Cambridge 345 kV	NU	$15.8M	$11.5M	$4.3M / 37.4%
Totals		**$656.0M**	**$637.0M**	**$19.0M / 3.0%**

[7] The ECI cost estimate was escalated from 2014 to 2017

[8] All contingency was removed from the TO cost estimate and any costs not in 2017 dollars were escalated/deescalated to 2017 dollars

Independent Consultant Review of Project Cost Estimates - Summary

Selected Major Unique Plan	ECI 2017 Dollar Cost Estimate	TO 2017 Dollar Cost Estimate	Delta ($M / %)
AC Plan	$354.9M	$295.2M	$59.7M / 20.2%
HVDC Plan	$656.0M	$637.0M	$19.0M / 3.0%

- The results show the TO's cost estimates are viable based on the independent consultant's analysis and fall well within the Planning Procedure 4, Attachment D accuracy of +50% / -25% for the 11 proposed projects
- When ECI's cost estimates for the 10 projects (Excludes ECI estimate for STATCOM in ME) are used with the TO's cost estimates excluding contingency costs, the difference in cost between the HVDC Plan and AC Plan is $257.7M[9]
- Since the November PAC presentation, ECI has estimated the cost for the STATCOM in ME and taking this into account would narrow the gap between the two plans by $12.5 M to $245.2 M

9 http://www.iso-ne.com/static-assets/documents/2014/12/a4_greater_boston_solution_study_cost_comparisons.pdf

NHT COST CONTAINMENT PROPOSAL

NHT Cost Containment Proposal

- NHT commits that it would exclude capital costs that are more than 25% above its current estimate of $543M for the HVDC portion only, or $679M, from its rate base. The majority of the project would not be covered by the containment proposal. The cost cap thus limits cost overruns for the HVDC section only to $136 million over NHT's estimate
- NHT commits that it would only earn the New England base return on equity (ROE) on any HVDC Plan costs that exceed $543M and up to the capped amount of $679M
- NHT commits to exclude $20M of HVDC Plan capital costs from its rate base if the project is not in service by December 31, 2018 as long as ISO-NE selects the HVDC Plan as the preferred alternative by February 2015
- Since cost containment is not part of the existing tariff, this proposal would only be in effect if filed with and approved by the FERC

Cost Containment Cost Evaluation

- NHT's cost containment proposal only applies to the HVDC portion

AC Plan			HVDC Plan			
	Cost (from Slide 17)	Cost + 50%		Cost (from Slide 17)	Cost + 50%	Cost + 25%
Common Upgrades	$221.0M	A $331.5M	Common Upgrades	$221.0M	D $331.5M	N/A
Additional Common Upgrades	$124.4M	B $186.6M	Additional Common Upgrades	$121.1M	E $181.7M	N/A
Major Unique AC Plan Upgrades	$394.3M	C $591.5M	Major Unique HVDC Plan Upgrades - AC projects	$140.3M	F $210.5M	N/A
			Major Unique HVDC Plan Upgrades - HVDC projects	$543.0M	G $814.5M	H $679.0M
			HVDC Plan (Cost + 50%) Subtotal No Cost Containment (D + E + F + G)		$1,538.2M	
AC Plan (Cost + 50%) Subtotal (A + B + C)		**$1,109.6M**	**HVDC Plan {(AC Portion Cost + 50%) + (HVDC Portion Cost + 25%)} Subtotal Includes Cost Containment (D + E + F + H)**		**$1,402.7M**	
Cost Containment Proposal Delta Difference between the HVDC and AC Plans = $293.1M						

- The cost containment proposal only reduces the worst case cost scenario by $135.5M ($1,538.2M - $1,402.7M)
- Because the HVDC Plan is much more expensive and the cost cap is established by using a factor of 1.25, the AC Plan remains less expensive even when accounting for significant cost overruns

Potential Cost Outcomes Analysis - Cost Estimate Delta between Plans

Potential Cost Outcomes	HVDC Plan	AC Plan	Delta (HVDC – AC)
Scenario 1 – Actual costs match estimate	Cost Estimate $1,025.4M	Cost Estimate $739.7M	$285.7M
Scenario 2 – Actual costs at high end of estimate accuracy (+50%)	Cost Estimate + 50% $1,538.2M	Cost Estimate + 50% $1,109.6M	$428.6M
Scenario 3 – Actual costs respecting Cost Cap proposal for the HVDC line and 50% for all other components	(HVDC line cost estimate + 25%) + (All other HVDC Plan cost estimate + 50%) $1,402.7M	Cost Estimate + 50% $1,109.6M	$293.1M
Scenario 4 – Actual costs using the estimate for HVDC line and 50% for all other components	HVDC Cost Estimate + (All other HVDC Plan cost estimate + 50%) $1,266.7M	Cost Estimate + 50% $1,109.6M	$157.1M

- There is no scenario in which ISO-NE would expect the HVDC Plan to be cost competitive with the AC Plan

COMPARISON OF PLANS FROM THE TRANSMISSION OWNER PERSPECTIVE

Comparison of Plans from the transmission owner perspective

NHT	NU/NGRID
Scobie to Tewksbury 345 kV line cannot be built without taking new land, reconfiguring the existing right of way or creating double circuit towers	There are portions of Scobie to Tewksbury 345 kV line which will require the existing right of way to be reconfigured, however no additional land is needed and no double circuit towers will be created
When comparables (similar projects recently completed) are taken into consideration, the NU/NGRID cost estimates are hundreds of millions of dollars below actual comparables. NU/NGRID's cost estimates are being under estimated	The comparables used by NHT for overhead 345 kV construction are for projects that were more complex to construct because they had more intricate right of way (ROW) reconfiguration (4 structures on the majority of ROW) and 75% of the circuits needed vertical monopole construction which is more expensive. With respect to UG construction NU/NGRID's estimate of $7.8M a mile is comparable to the $8.0M a mile estimate provided by NHT for the UG land potion of HVDC Plan. Also, recent quotes from XLPE cable vendors are lower than in 2008 (when the last major 345 kV UG cable additions were made) since oil and copper prices are lower. NU/NGRID stand by the accuracy of their cost estimates
When comparables (similar projects recently completed) are taken into consideration, the NU/NGRID in-service dates are understated by 2 to 3 years in some cases. A faster in-service date affects the reliability and cost to customers	NU/NGRID stand by their estimated in-service dates of December 2017 for their projects reported in the October 2014 Project Listing

Comparison of Plans from the transmission owner perspective, cont

NHT	NU/NGRID
The HVDC project is more storm resilient because the majority of the new facilities will be undersea and won't be subjected to extreme weather or tree contact	345 kV line forced outages are rare and quickly repaired. The October 2011 snow storm resulted in only one 345 kV outage due to tree contact and did not result in any customer outages. Undersea cable failures are less frequent however repairs could take months and are more costly than AC overhead repairs
The HVDC Plan has less permitting risk than the AC Plan	Comparable HVDC projects in other parts of the country have had permitting durations from 25 to 45 months. Both plans have to go before 10 agencies for reviews, licenses or permits. The HVDC Plan has to go before an additional 7 agencies while the AC Plan only needs to go before 2 agencies. The HVDC Plan will need to coordinate the construction with marine life time of year restrictions

Comparison of Plans from the transmission owner perspective, cont

NHT	NU/NGRID
Through their consultant, The Brattle Group, NHT claims that AC Plan will cost an additional $163M due to the higher cost of electricity during construction and would require certain critical lines to be out of service for seven months. In addition, the AC Plan will cost an additional $349M if the AC Plan is delayed one year due to permitting issues. Under any of these scenarios, the HVDC Plan is more cost-effective project for customers	NU/NGRID would be flexible in scheduling outages during shoulder months to minimize congestion costs. The Scobie to Tewksbury 345 kV line construction schedule only requires multiple short duration outages and a 3 week outage which potentially contribute to congestion costs in the thousands of dollars not millions of dollars. ISO-NE Operations has analyzed NU/NGRID's proposed outage schedule and they concluded there would not be any significant congestion costs. NHT fails to consider any congestion costs for their work to reconductor the Sandy Pond – Tewksbury 345 kV line. NGRID estimates many daily outages along with two 6 week outages. This project has the potential to create out-of-merit generation commitment

THE SELECTION OF THE PREFERRED SOLUTION ALTERNATIVE

The Selection of the Preferred Solution Alternative

- Typically, ISO-NE has selected the solution alternative which has the lowest cost estimate and fully addresses the identified reliability needs unless the cost estimates of competing solution alternatives have been similar. In these situations, ISO-NE would consider other criteria to evaluate other benefits to the transmission system that the competing solution alternative may bring. After careful consideration, ISO-NE would select the most cost effective solution alternative

The Selection of the Preferred Solution Alternative, cont

- In this case, the cost estimates for the AC and HVDC plans are hundreds of millions of dollars apart. In cases such as this, ISO-NE would typically conclude its review on this basis. However, as requested by the stakeholders, ISO-NE evaluated the merits of each plan by considering other criteria which includes but is not limited to:
  - Constructability
  - Construction outage requirements/cost impacts
  - Expected in-service dates
  - Interface impacts
  - Losses
  - Extreme contingency analysis results
  - Expansion capabilities
  - Lifetime maintenance requirements
  - Incremental costs for potential retirements
  - Siting issues
  - Storm hardening
  - Operational performance

Constructability

- NHT has conducted both marine and land surveys and have the confidence that their upgrade plans can be executed
- NU/NGRID have demonstrated at the December PAC and meetings with ISO-NE that the Scobie Pond to Tewksbury 345 kV line can be constructed without expansion of the existing right of way, without taking any homes along the right of way and doesn't require any double circuit towers (DCTs)
- ***ISO-NE's position is both plans are constructible***

Construction Outage Requirements/Cost Impacts

- NU/NGRID have demonstrated at the December PAC and meetings with ISO-NE that outages associated with construction for the AC Plan are not expected to be significant
  - Extensive ROW reconfiguration is needed for only a small portion of the ROW (0.5 miles)
  - Outage durations are short – longest outage is a three week period
  - Outages are flexible and can be scheduled during the shoulder months or during generator annual inspections
- NHT's HVDC Plan has the potential for significant generation reductions or outages that could result in congestion costs
  - More extensive work required at the Mystic 115 kV Station (Discussed in the following slides)
  - Seabrook 345 kV Station
  - Sandy Pond – Tewksbury 337 Line (345 kV) Reconductoring
- Outage information and potential congestion concerns have been discussed with ISO-NE Operations
- ***ISO-NE's position is the AC Plan will not significantly contribute to congestion costs and more analysis would be needed to determine the congestion cost impact of the HVDC Plan***

Comparison of Impact at Mystic

Upgrades Common to Both AC and HVDC Plans	
• Add a new 345/115 kV autotransformer at Mystic • Add a new 115 kV line that connects to the GIS portion of the Mystic 115 kV bus	
AC Plan	**HVDC Plan**
• Relocate a 345 kV line at Mystic 345 kV • Swap terminations of two 115 kV lines on the GIS portion of the Mystic 115 kV bus	• Relocate a 345 kV line at Mystic 345 kV to the location of an existing 345 kV line (Requires outages on both 345 kV lines) • Relocate a 115 kV line from the GIS portion of the bus to the open air portion of Mystic 115 kV • Interconnect the HVDC line to one of the buses via an existing breaker • Relocate two 115 kV breakers, one of which is connected to one of the Mystic block 9 gas turbines • Add two bus sections to connect the GIS portion of the Mystic 115 kV bus to the open air portion of the Mystic 115 kV bus • Relocate two distribution transformers at Mystic 115 kV which includes the addition of a new 115 kV breaker

Mystic Configuration - Existing

Mystic Configuration – AC Plan

Mystic Configuration – HVDC Plan

[redacted]

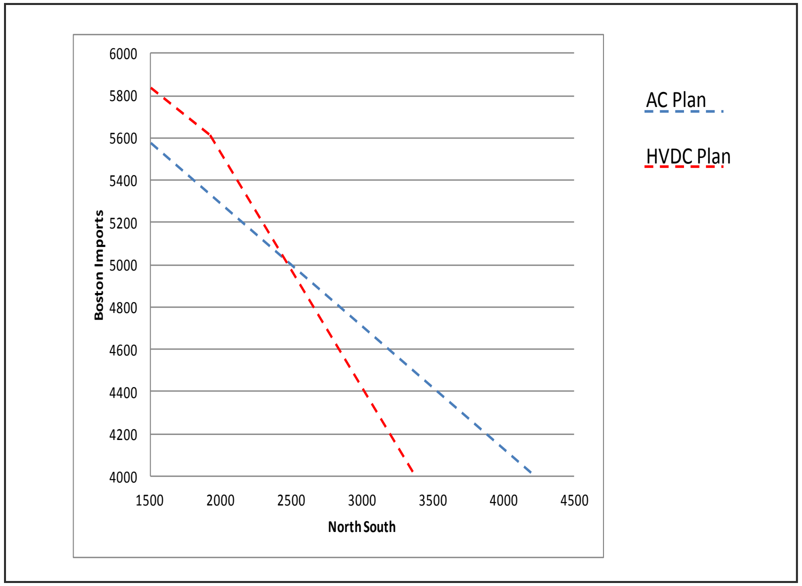
Expected In-service Dates

- Once through siting, both plans can be in-service in a reasonable amount of time
- All entities involved, NHT, NU and NGRID have expressed confidence in meeting their proposed in-service dates
- Both plans, as per the information provided to ISO-NE, have a final in-service date in 2018
- ***ISO-NE does not believe that one plan would have a substantially earlier in-service date over the other plan***

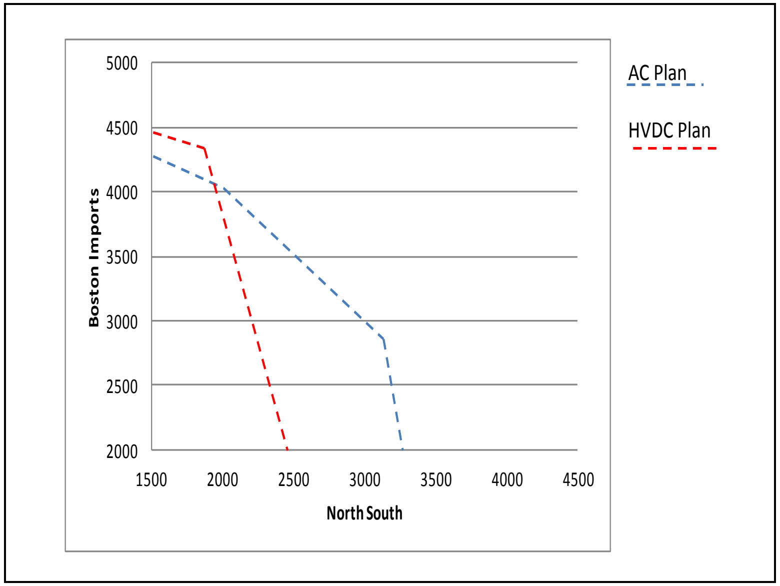
Interface Impacts

- The Greater Boston Working Group (GBWG) performed an N-1 and N-1-1 assessment on the Boston Import versus North/South for both plans

N-1



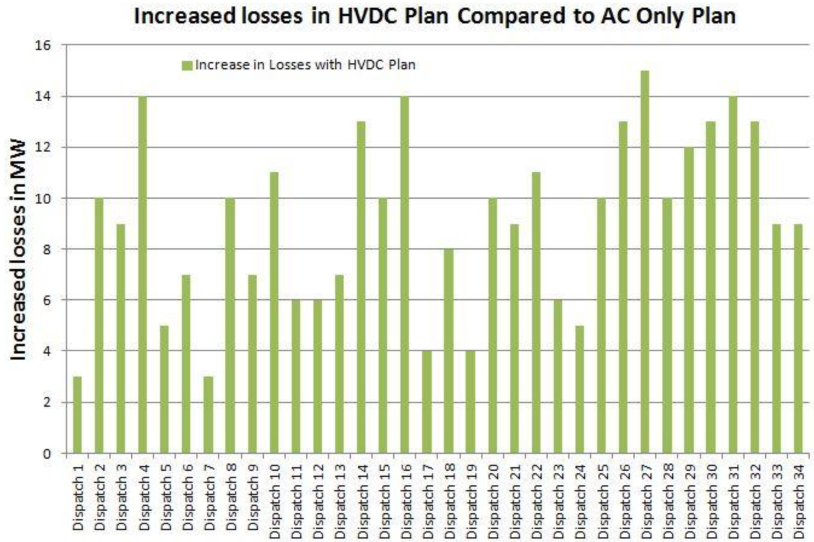
N-1-1



- Both plans result in a comparable increase in the N-1 Boston import transfer capability
- The AC Plan provides higher N-1-1 Boston Import transfer capability at higher levels of North / South transfers
  - The higher levels of North / South transfers may not be achievable due to Northern New England-Scobie+394 interface limits
- ***ISO-NE's position is that both plans improve the Boston Import transfer capability, but the AC plan could potentially provide improved N-1-1 performance if the Northern New England-Scobie+394 interface limit was increased***

Losses

- The basecases that were used for the peak load analysis were reviewed for system losses across New England
- The New England system total losses varied from 600 to 700 MW
- The HVDC plan had losses between 3 to 15 MWHr/Hr more than the AC plan



- ***ISO-NE's position is the AC Plan results in slightly lower system losses compared to the HVDC plan***

Extreme Contingency (EC) Analysis Results

- A screening analysis was performed for a limited set of extreme contingencies:
  - Line crossings
  - Loss of lines in a common right of way (ROW)
  - Loss of a substation
- All the line crossing contingencies showed no overloads or voltage violations for both plans
- For the loss of ROW and loss of substation contingencies the HVDC plan resulted in fewer violations
- ***ISO-NE's position is the HVDC Plan resulted in better extreme contingency performance***

Expansion Capabilities

- The following summarizes the highest short circuit duties at stations post project:

Station Name	AC Plan	HVDC Plan
Mystic 115 kV	86%	85%
Kingston 115 kV	88%	95%
K Street 115 kV	88%	90%

- The AC Plan provides benefit in terms of available short circuit margin for future transmission and generation additions
- The future expansion of the HVDC system would be costly
  - To interconnect a resource into an HVDC facility, a new terminal needs to be installed, a significant expenditure (Note that approximately 50% of the HVDC Line cost is for two land-based terminals)
  - As time progresses the ability to procure additional terminals whose technology can work in concert with the existing terminals becomes more difficult
  - May require the additional terminals to be procured by the same manufacturer to ensure functionality
- ***ISO-NE's position is the AC Plan provides better expansion capabilities than the HVDC Plan***

Lifetime Maintenance Requirements

- ISO-NE's prior experience with HVDC and FACTS technology suggests that with technological advances in state-of-the-art equipment in the future, there will be a need for costly upgrades:
  - Highgate HVDC facility needed a $38M refurbishment upgrade in 2012[10]
  - Chester SVC needed a $6M control system upgrade in 2013[11]
- HVDC plan has both larger sized equipment and two locations where such upgrades might be necessary
  - HVDC Plan requires two 520 MW HVDC terminals
  - AC Plan requires a 200 MVAR STATCOM in ME
- ***ISO-NE's position is the AC Plan provides better lifetime maintenance requirements than the HVDC plan***

[10] https://smd.iso-ne.com/committees/comm_wkgrps/prtcpnts_comm/pac/ceii/mtrls/2011/feb162011/highgate.pdf
[11] https://smd.iso-ne.com/committees/comm_wkgrps/prtcpnts_comm/pac/ceii/mtrls/2012/jan182012/chester_svc.pdf

Incremental Costs for Potential Retirements

- The GBWG tested the AC and HVDC plans on a Mystic 7 retirement scenario to determine additional upgrades needed

AC Plan

	Length (miles)	Cost (in 2017$)
New Mystic – K St. 345 kV Cable	6.8	$94.5M
345 kV Phase Angle Regulator at K. St.	N/A	
160 MVAR Shunt Reactor at K. St.	N/A	
Series Reactor on the Stoughton – K St. 3162 Cable	N/A	$4.7M
Re-conductor M-139 115 kV Pinehurst to N. Woburn Tap	0.6	$3.2M
Re-conductor N-140 115 kV Pinehurst to N. Woburn Tap	0.6	$3.2M
Total		$105.6M

ISO-NE's position is that while the costs of both expansion plans are similar, the cost for the AC Plan is less expensive

HVDC Plan

	Length (miles)	Cost (in 2017$)
New Golden Hills – Woburn 345 kV Cable	6.5	$88.4M
160 MVAR Shunt Reactor at Woburn	N/A	
Re-conductor F-158N Golden Hills – Maplewood 115 kV (larger conductor	4.0	$4.5M
Re-conductor F-158S 115 kV Maplewood to Everett	3.0	$3.8M
Re-conductor S-145 Wakefield to N. Reading Tap	5.6	$3.6M
Re-conductor T-146 Wakefield to N. Reading Tap	5.6	$3.6M
Upgrade West Medway 345/115 kV auto	N/A	$7.9M
Re-conductor E-157 Millbury to Centech	5.7	$6.4M
Total		$118.2M

Siting Issues

- ISO-NE does not take the complexity in siting a particular alternative into account unless the costs for the alternatives under consideration are similar
  - As an example, ISO-NE did not support the regional cost allocation of underground cables in the Middletown-Norwalk and Bethel-Norwalk Project
- Applicable guidance from the tariff and ISO-NE Planning procedures are as follows:
  - Attachment K, Section 4.2(b) states:
    - "Through this process, the ISO may identify the most cost-effective and reliable solutions for the region that meets a need identified in a Needs Assessment. These solutions may differ from a transmission solution proposed by a transmission owner."

Siting Issues, cont.

- PP-4, Attachment A states:
  - "The following…is provided for illustration of the types of projects that would be considered to contain Localized Costs: The Project includes underground transmission cable, which is selected (a) at the direction of a local or state siting board, or (b) to address other local concerns, and the cost of overhead transmission lines is less expensive, taking into account all relevant costs.
- PP-4, Section 1.6.1(C)3(i) states:
  - "The proposed Project, and any feasible and practical transmission alternatives that were considered, including those offered in the most recent RSP report and, if applicable, discussed at the PAC. Note - A feasible and practical transmission alternative means a transmission alternative that is feasible and practical from an engineering design and construction perspective. An alternative that is not or may not be approved by a siting or local review board may still be considered a feasible and practical transmission alternative."

- ***ISO-NE's position is that both AC and HVDC plans are feasible from an engineering perspective and siting is not a determining factor***

Storm Hardening

- The majority of the HVDC Plan consists of an buried cable which should be resistant to most storms
  - Cable failures may require a month or more to repair
- The AC Plan is more exposed to the environment than the HVDC Plan
  - Overhead line repairs are generally made within a day or two
- History has shown that buried cables are not impervious to storm interruption because their terminals are still exposed
- ***ISO-NE's position is that the HVDC plan has less exposed facilities, yet the time required to repair such facilities causes the ISO to view the AC and HVDC plans as equal***

The Selection of the Preferred Solution Alternative - Summary

Selection Criteria	AC Plan	HVDC Plan
Cost	✔	✘
Constructability	✔	✔
Construction outage requirements/cost impacts	✔	✘
Expected in-service dates	✔	✔
Interface impacts	✔	✘
Losses	✔	✘
Extreme contingency analysis results	✘	✔
Expansion capabilities	✔	✘
Lifetime maintenance requirements	✔	✘
Incremental costs for potential retirements	✔	✘
Siting issues	✔	✔
Storm hardening	✔	✔

✔ Is applied to the Alternative which better achieves the objective

✘ Is applied to the Alternative which does not achieve the objective as well as the other competing Alternative

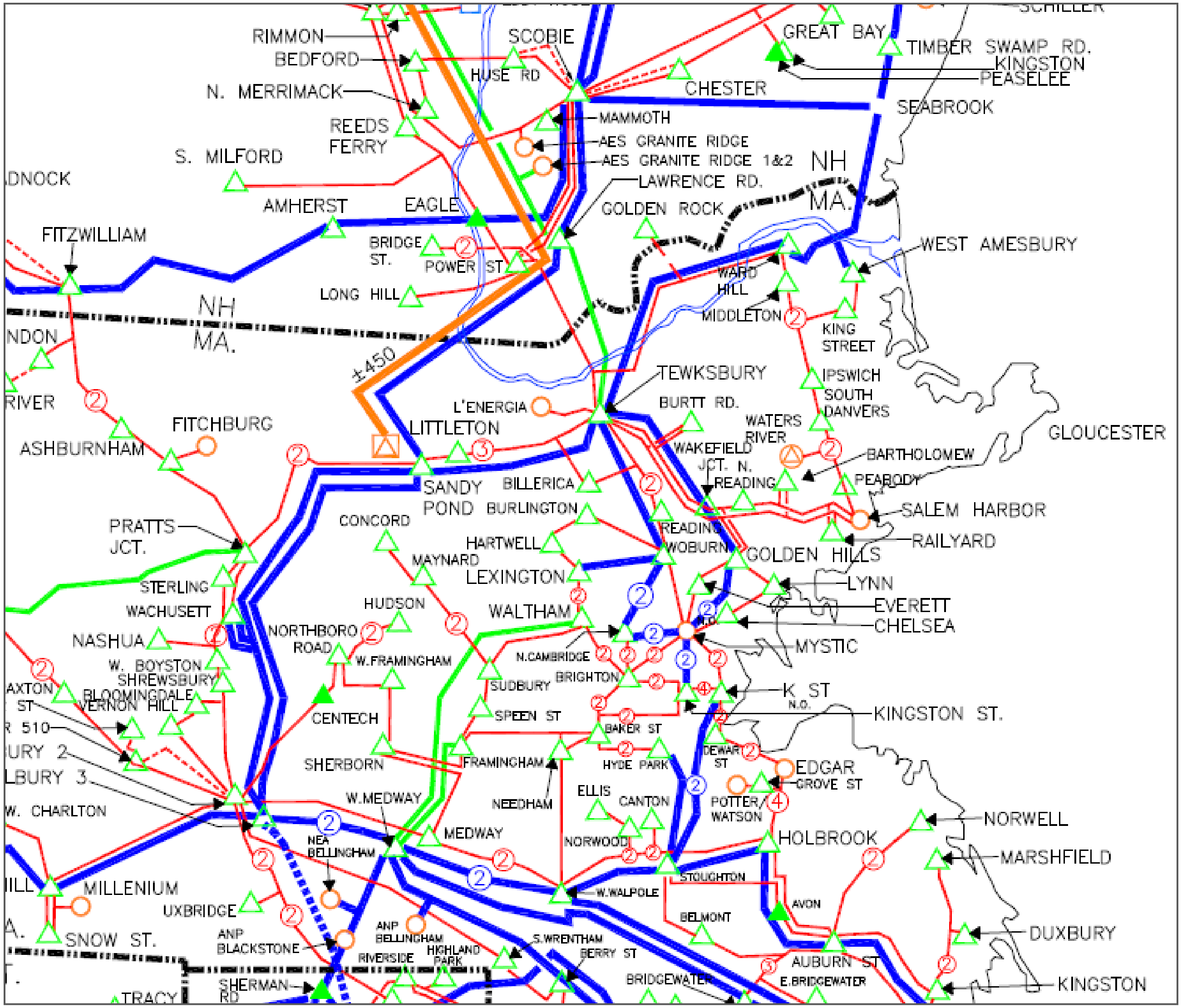
The Selection of the Preferred Solution Alternative

- Based on the factors discussed, the cost separation between the two plans is still wide even after considering other criteria
- The AC Plan is the most cost effective solution for the region and the AC Plan is the preferred solution alternative for the Greater Boston study

Questions

APPENDIX

Geographical Map of the Study Area



Study History

- First trip to the PAC was May 2008 with a presentation of the Needs Assessment Scope of Work
- Steady state needs were presented in July 2009 (N-1) and in December 2009 (N-1-1) with a Needs Assessment report issued in July 2010
  - Short-circuit needs and critical load level assessment were presented at June 2011 PAC
- Identified and advanced some of the upgrades including five 115 kV line reconductorings needed for the Salem Harbor Non-Price Retirement (NPR) in June 2011
- A complete Greater Boston AC preferred solution was presented to PAC in March 2012
  - Agreed to examine a hybrid HVDC / AC alternative conceptual proposal made by New Hampshire Transmission, LLC (NHT)
- In July 2013 a refreshed set of needs updated to the 2013 CELT, FCA 7, and the updated NSTAR cable ratings were presented to PAC (Greater Boston 2023 Needs Assessment)
- In June 2014 two plans to meet the reliability needs of the Greater Boston area were presented to PAC
  - Revised AC Plan to meet the July 2013 refreshed needs
  - An HVDC Plan based on the NHT hybrid proposal
- In November 2014 an independent consultant provided a review of the major unique components of the AC Plan and the HVDC Plan
- In December 2014 both NHT and Northeast Utilities (NU)/National Grid (NGRID) each presented their assessment of the pros and cons of the two plans

Study History

1. Needs Assessment scope presented to PAC in May 2008

   https://smd.iso-ne.com/trans/sys_studies/rsp_docs/pres/2008/a_nema_boston.pdf

2. Initial needs presented to PAC in January 2009

   https://smd.iso-ne.com/committees/comm_wkgrps/prtcpnts_comm/pac/ceii/mtrls/2009/jan212009/a_greater_boston_sow.pdf

3. Detailed preliminary needs and Notification of Solution Study discussed at PAC in July 2009

   https://smd.iso-ne.com/committees/comm_wkgrps/prtcpnts_comm/pac/ceii/mtrls/2009/jul162009/boston.pdf

4. Needs Assessment Status Update in December 2009

   http://www.iso-ne.com/static-assets/documents/committees/comm_wkgrps/prtcpnts_comm/pac/mtrls/2009/dec162009/gbwg.pdf

Study History

5. Greater Boston Study Needs Assessment/Solution Study Status Update presented at PAC in December 2010
   - Grouped transmission solution alternatives into three areas
     - North of Boston
     - South of Boston
     - Central Area
   - Identified the preliminary preferred solutions for both the north and south areas
     https://smd.iso-ne.com/committees/comm_wkgrps/prtcpnts_comm/pac/ceii/mtrls/2010/dec162010/greater_boston.pdf

Study History

6. Greater Boston Study Needs Assessment/Solution Study Status Update presented at PAC in June 2011
   - Completed the “Needs Assessment” phase by presenting short-circuit assessment and critical load level assessment for the Boston Area
   - Discussed the impact of Salem Harbor NPR

   https://smd.iso-ne.com/committees/comm_wkgrps/prtcpnts_comm/pac/ceii/mtrls/2011/jun302011/greater_boston.pdf

Study History

7. Greater Boston Study Needs Assessment/Solution Study Status Update presented at PAC in January 2012
   - Grouped transmission solution alternatives for the Central Area into the Western Suburbs and Downtown Boston sub-Areas
   - Western Suburbs
     - Presented competing transmission alternatives
     - Provided feasibility, cost, and technical assessment
     - Identified the preliminary preferred solutions
   - Downtown Boston
     - Presented competing transmission alternatives

   https://smd.iso-ne.com/committees/comm_wkgrps/prtcpnts_comm/pac/ceii/mtrls/2012/jan182012/gbwg_update.pdf

Study History

8. Greater Boston Study Needs Assessment / Solution Study Status Update in March 2012
   – Downtown Boston
     - Presented competing transmission alternatives
     - Provided feasibility, cost, and technical assessment
     - Identified the preliminary preferred solutions
   – Presented the complete Greater Boston Solution
   – Agreed to consider an HVDC alternative from Seabrook into Boston

   https://smd.iso-ne.com/committees/comm_wkgrps/prtcpnts_comm/pac/ceii/mtrls/2012/mar142012/gbwg_update.pdf

9. Greater Boston Solution Study Update in February 2013
   – Presented the impact of assumption changes
   – Presented a preliminary transfer assessment based on the set of AC upgrades described in the March 2012 PAC presentation

   https://smd.iso-ne.com/committees/comm_wkgrps/prtcpnts_comm/pac/ceii/mtrls/2013/feb122013/a5_greater_boston_solution_study_update.pdf

Study History

10. NSTAR Underground Cable Rating Update in April 2013

    https://smd.iso-ne.com/committees/comm_wkgrps/prtcpnts_comm/pac/ceii/mtrls/2013/apr242013/a10_nstar_greater_boston_cable_ratings.pdf

11. Greater Boston 2023 Needs Assessment and Solution Study Status Update in July 2013

    https://smd.iso-ne.com/committees/comm_wkgrps/prtcpnts_comm/pac/ceii/mtrls/2013/jul92013/a2_greater_boston_needs_assessment.pdf

12. Greater Boston 2023 Solutions Study Status Update in November 2013

    https://smd.iso-ne.com/committees/comm_wkgrps/prtcpnts_comm/pac/ceii/mtrls/2013/nov202013/a6_greater_boston_2023_needs_assessment_soultion_update.pdf

Study History

13. Greater Boston Solutions Study Update in June 2014

    http://www.iso-ne.com/static-assets/documents/committees/comm_wkgrps/prtcpnts_comm/pac/mtrls/2014/jun192014/a4_greater_boston_solution_study_cost_estimates.pdf

14. Greater Boston Solutions Study Update and Greater Boston Solutions Study High Level Cost Estimate by ECI in November 2014

    http://www.iso-ne.com/static-assets/documents/2014/11/a4_greater_boston_solution_study_cost_comparisons.pdf

    http://www.iso-ne.com/static-assets/documents/2014/11/a4_eci_greater_boston_solutions_presentation.pdf

Study History

15. NHT's presentation titled Greater Boston Solutions in December 2014

    http://www.iso-ne.com/static-assets/documents/2014/12/a6_nht_greater_boston_presentation.pdf

    NU/NGRID's presentation titled Comparison of the AC and HVDC Solutions Greater Boston

    http://www.iso-ne.com/static-assets/documents/2014/12/a6_nu_ngrid_greater_boston_presentation.pdf

16. Needs Assessment report posted on January 30, 2015

    https://smd.iso-ne.com/planning/ceii/reports/2010s/greater_boston_updated_needs_assessment_report_final.pdf

Upgrades Common to Both AC and HVDC Plans

Proposed Facilities	Length (Miles)	Cost (in 2017$)
North - Reconductor Y-151 Power Street– NU/NGRID border	4	$8.5 M
North - Reconductor M-139 Tewksbury – Billerica 115 kV	3	$5.3 M
North - Reconductor F-158N Golden Hills– Maplewood 115 kV	4	$5.4 M
South - West Walpole – Holbrook 115 kV – **Project is being Advanced**	14	$17.3 M
South – Sharon Switching station – **Project is being Advanced**	N/A	$12.8 M
Western - Sudbury 230/115 kV autotransformer	N/A	$28.1 M
Western - Sudbury – Hudson 115 kV – **Does not include Hudson Light & Power termination cost**	9	$46.0 M
Western - Refurbish the X-24 69 kV	15	$8.5 M
Western - Reconductor W-23W Northboro – Woodside 69 kV	6	$5.9 M
Western - Reconfigure the Waltham substation	N/A	$17.5 M
Western - Separate the X-24 / E-157W DCT	4 Structures	$3.4 M
Western - Add 36.7 MVAR capacitor at Sudbury 115 kV	N/A	$1.3 M
Western – Add a 115 kV breaker at Framingham	N/A	**Not yet provided**
Downtown - Reconfigure Kingston Substation adding four new 115 kV breaker	N/A	$14.5 M
Downtown – Add K Street tie breaker	N/A	$2.6 M
Downtown – Add 36.7 MVAR capacitor at Hartwell 115 kV	N/A	**Not yet provided**
Downtown – Add a 345 kV shunt reactor at K Street	N/A	**Not yet provided**
Downtown - Reconfigure North Cambridge 115 kV	N/A	$8.2 M
Downtown - Separate 240-510 / 110-522 DCT	4	$31.3 M
Downtown - Separate the F158 / Q169 DCT	1 Structure	$0.7 M
Downtown - Add 54 MVAR capacitor at Newton 115 kV	N/A	$1.4 M
Downtown – Add 345 kV shunt reactor at Holbrook due to minimum load analysis	N/A	**Not yet provided**
Downtown – Add 345 kV breaker at Stoughton due to minimum load analysis	N/A	$1.6 M
Downtown – Move Chelsea capacitor	N/A	$0.9 M
Transmission Owner's Cost Estimate for Common Upgrades		**$221.0 M**

One-line of Common Upgrades