2019 Economic Study Offshore Wind Transmission Interconnection Analysis

Planning Advisory Committee

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Approach to the 2019 Economic Study Offshore Wind Transmission Interconnection Analysis

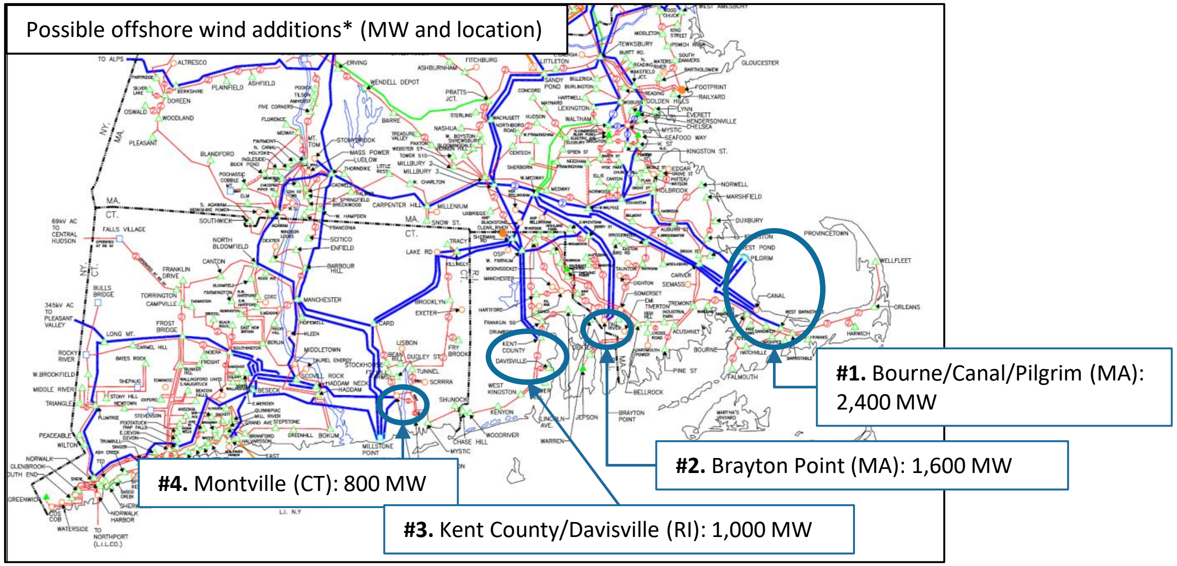
- For the NESCOE 2019 Economic Study Request*, the ISO developed future interconnection scenarios for offshore wind
- The ISO focused on the interconnection points identified by offshore wind interconnection customers with interconnection requests in the ISO queue
- The transmission assessment for the 2019 NESCOE Economic Study was not a detailed interconnection study
  - The study did not seek to identify all of the solutions that would be needed to address the identified problems
- Based on the knowledge gained through the completion of several of the interconnection studies for those requests, the ISO identified the approximate MW quantities that could interconnect without major transmission upgrades beyond these local points
- The ISO then sought to identify the upgrades that would be needed to continue to increase the interconnection levels beyond those initial amounts

*See Appendix 1 for a brief summary of the NESCOE 2019 Economic Study Request and Further background on the transmission interconnection analysis

Review: This slide was presented to the PAC Meeting May 20, 2020

Study Finding: Anticipated Injection Capabilities Without Major Transmission Reinforcements

- Interconnection customers are proposing to use AC cable connections from the wind farm lease areas to coastal 345 kV substations
- Based on the currently expected transmission system for 2030, the ISO anticipates that the depicted levels (5,800 MW) of offshore wind additions have the potential to be accomplished without major additional 345 kV reinforcements*



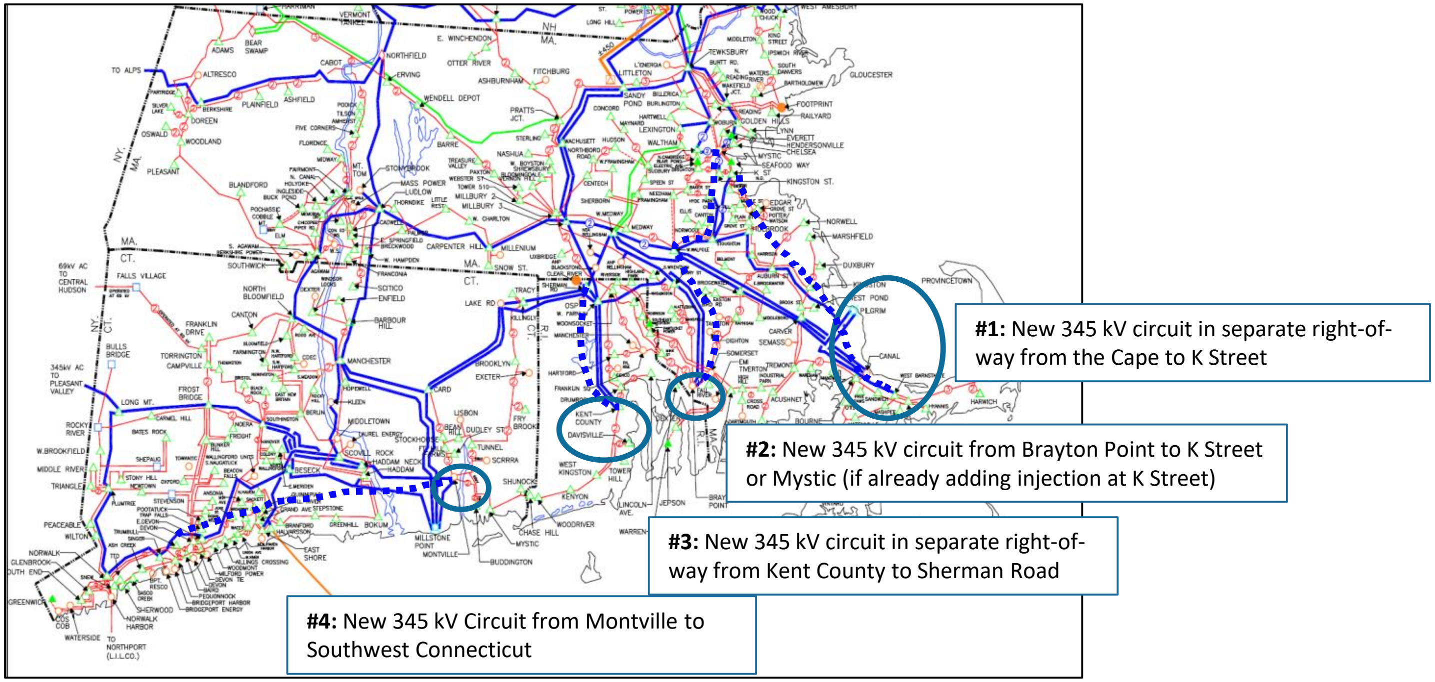
*__Some 345 kV reinforcement/expansion may still be needed for this scenario__. This anticipation is preliminary (system impact studies have not been completed for all of these MW). This anticipates minimal interconnection at nameplate levels and capacity interconnection at intermittent capacity values – does not anticipate all of the MW being able to run simultaneously at nameplate levels at all times on the system.

Note that the numbering (#) of the interconnection points has changed from earlier PAC presentations

Review: This slide was presented to the PAC Meeting May 20, 2020

Study Finding: Additional Southern Shore Injections Likely Require Significant Reinforcements

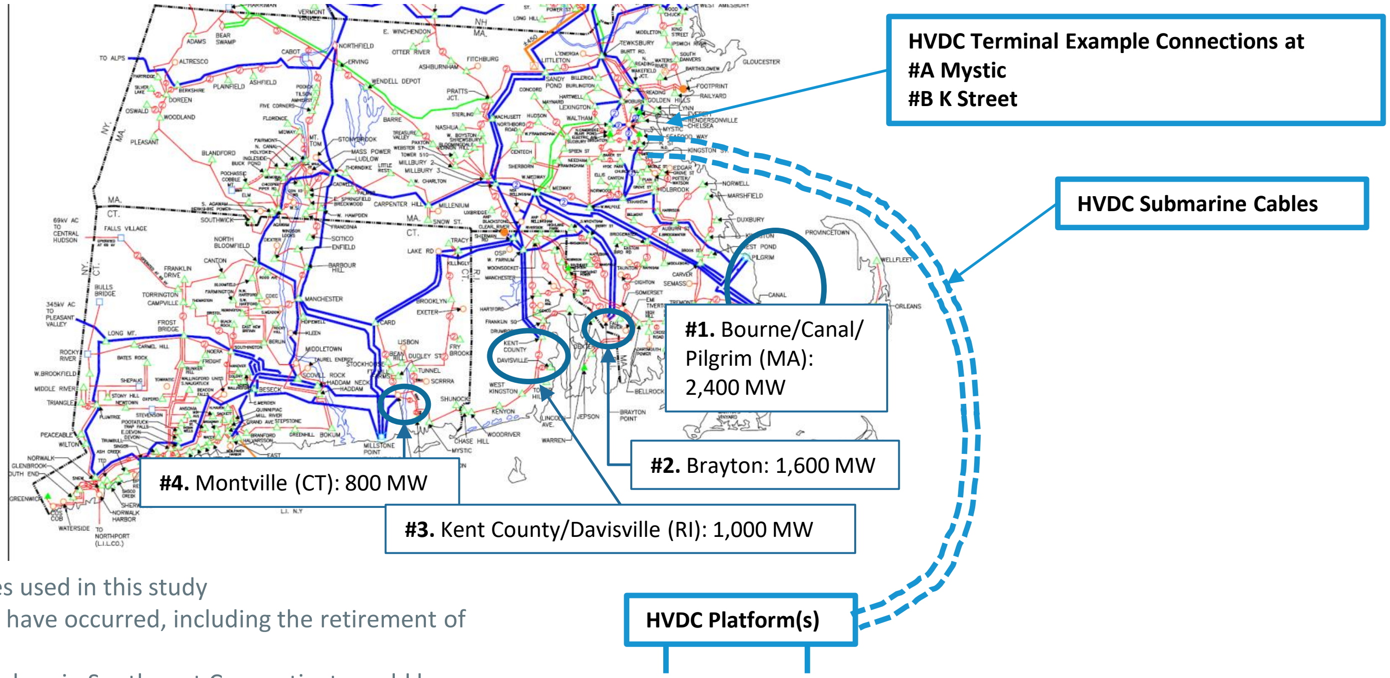
- Additional offshore wind injections at the interconnection points on the southern shore, above the levels shown on the prior slide, would require significant transmission reinforcements, as represented conceptually below



Review: This slide was presented to the PAC Meeting May 20, 2020

Study Finding: HVDC Alternatives Can Avoid Major Onshore Transmission Additions

- Alternatively, additional offshore wind could be connected while avoiding significant onshore transmission upgrades by using High Voltage Direct Current (HVDC) connections from the offshore wind farms to load center substations*



*Mystic & K Street were examples used in this study
This assumes FCA 13 retirements have occurred, including the retirement of Mystic 8 & 9
Other load center substations, such as in Southwest Connecticut, could be considered

Review: This slide was presented to the PAC Meeting May 20, 2020

Study Finding: Infrastructure Summary

MW Injection Levels by Interconnection Point(s) and Associated Transmission Infrastructure Summary

Total Offshore Wind Injection (MW)_Scenario	Offshore Wind Connected to Shore at these Points Using AC Cables				Connected at these Points Using HVDC Cables		Offshore Infrastructure		Onshore Infrastructure
	#1 Bourne/ Barnstable	#2 Brayton Point	#3 Kent Co/ Davisville	#4 Montville	#A Mystic	#B K Street	Offshore AC Cables[3]	Offshore HVDC Cables[4]	Major Onshore Additional Transmission Identified to Accommodate Interconnection Scenario[1]
2,000	800	500	700	-	-	-	5	-	None
3,000	1,500	800	700	-	-	-	8	-	None
5,000	2,400	800	1,000	800	-	-	13	-	None
5,800	2,400	1,600	1,000	800	-	-	15	-	None
7,000	2,400	1,600	1,000	800	1,200	-	15	1	None
8,000_1	2,400	1,600	1,000	800	1,200	1,000	15	2	None
8,000_2	3,400	1,600	1,000	800	1,200	-	17	1	New approximately 60 mile 345 kV line in separate right-of-way from Barnstable, MA to K Street Substation
8,000_3	2,400	2,600	1,000	800	1,200	-	17	1	New approximately 50 mile 345 kV line in separate right-of-way from Brayton Point to K Street Substation (or Mystic if injection is already added at K Street)
8,000_4	2,400	1,600	2,000	800	1,200	-	17	1	New approximately 30 mile 345 kV line[2] in separate right-of-way from Kent Co, RI to Sherman Road Substation
8,000_5	2,400	1,600	1,000	1,800	1,200	-	17	1	New approximately 60 mile 345 kV line from Montville CT to Southwest CT

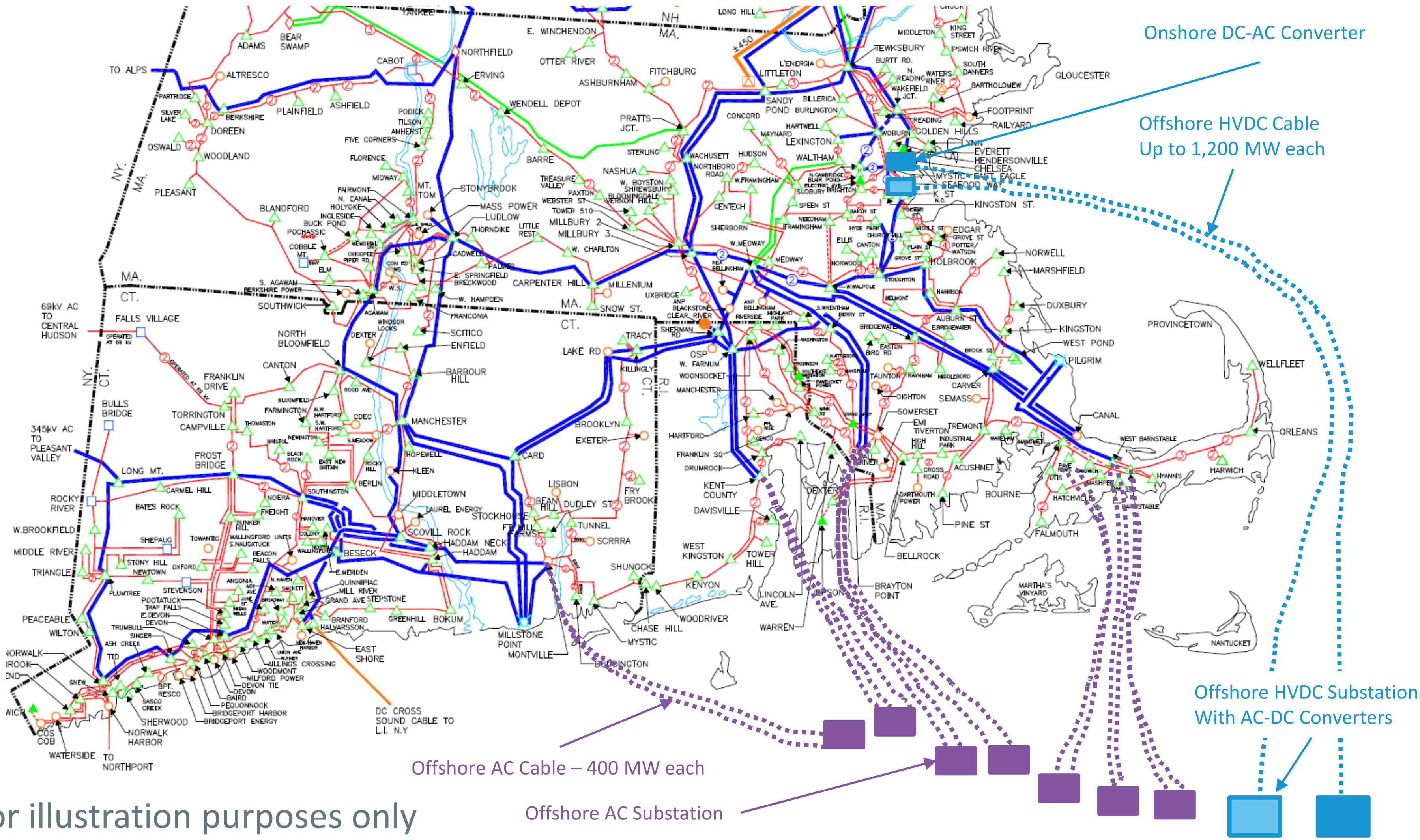
1. Note that some local 345 kV reinforcement/expansion is still likely to be needed for all interconnection scenarios
2. Note that significant congestion would be observed with this offshore wind injection and upgrade when the existing area combined cycle facilities are running
3. Each offshore three phase AC cable is assumed to be approximately 40-60 miles in length and is rated for approximately 400 MW, operating at 230-280 kV
4. Each offshore HVDC cable is assumed to be approximately 150-200 miles in length and is rated for up-to 1,200 MW

Injection Level Color Code

- (green) Injection level is below the level where major infrastructure beyond the local interconnection area would be needed
- (yellow) Injection level is at the limit above which major infrastructure beyond the local interconnection area would be needed for additional injections
- (red) Injection level is above the level where major infrastructure beyond the local interconnection area would be needed

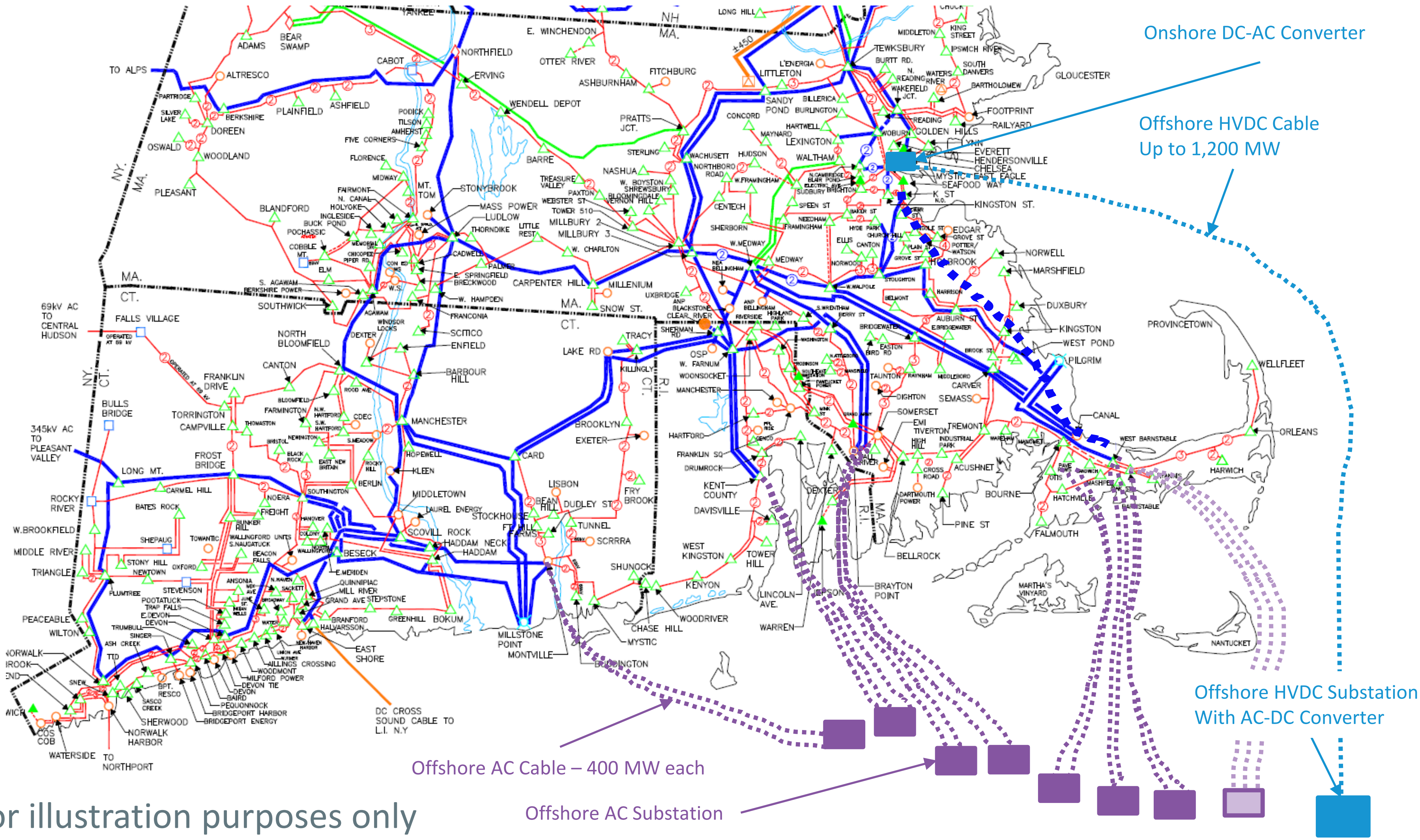
A DISCUSSION OF INTERCONNECTION ALTERNATIVES AND TRADE-OFFS

Conceptual Depiction of Offshore Interconnection: 8,000 MW Case (Scenario 8,000_1)



For illustration purposes only

Conceptual Depiction of Offshore Interconnection: 8,000 MW Case (Scenario 8,000_2)



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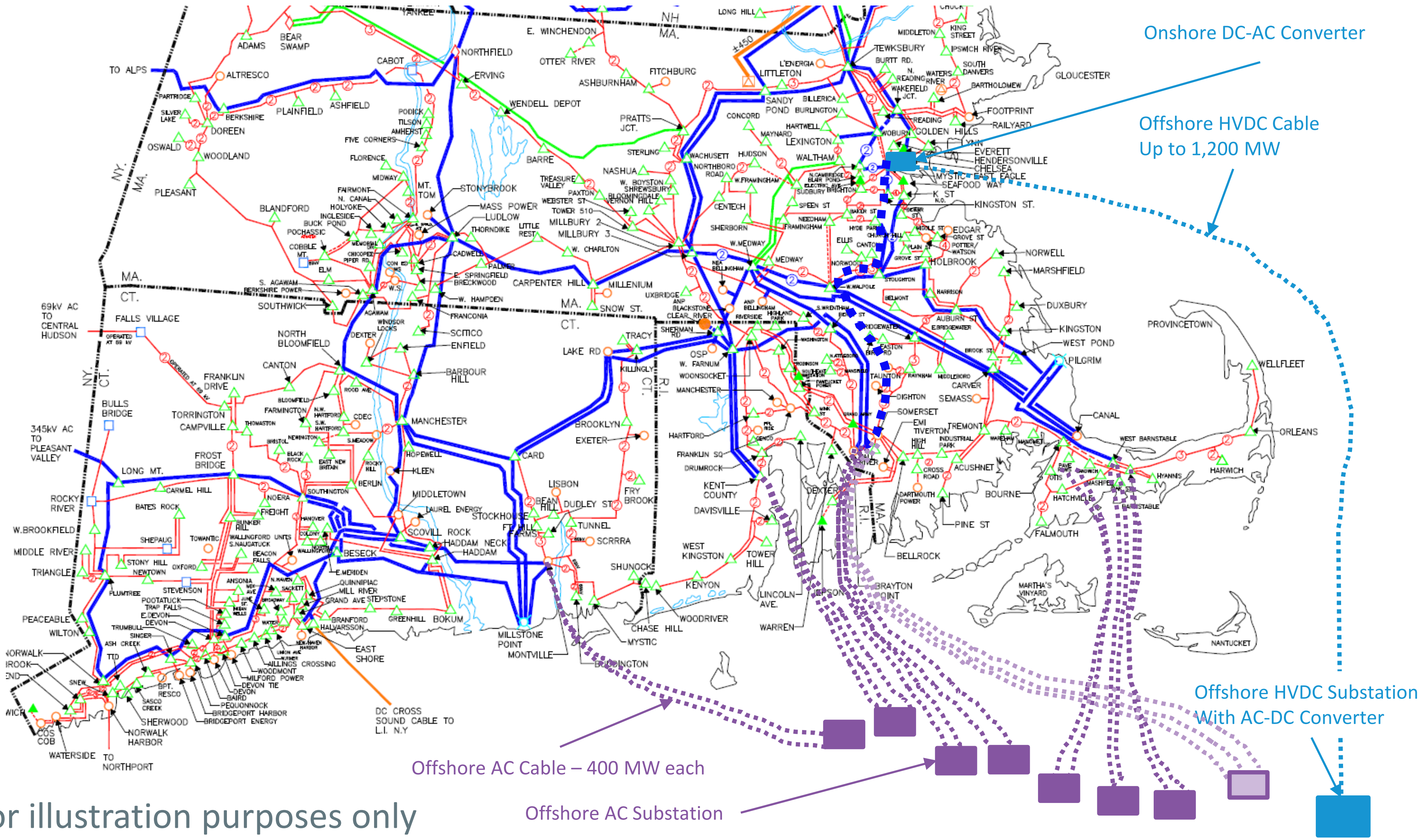
Conceptual Depiction of Offshore Interconnection: 8,000 MW Case (Scenario 8,000_3)



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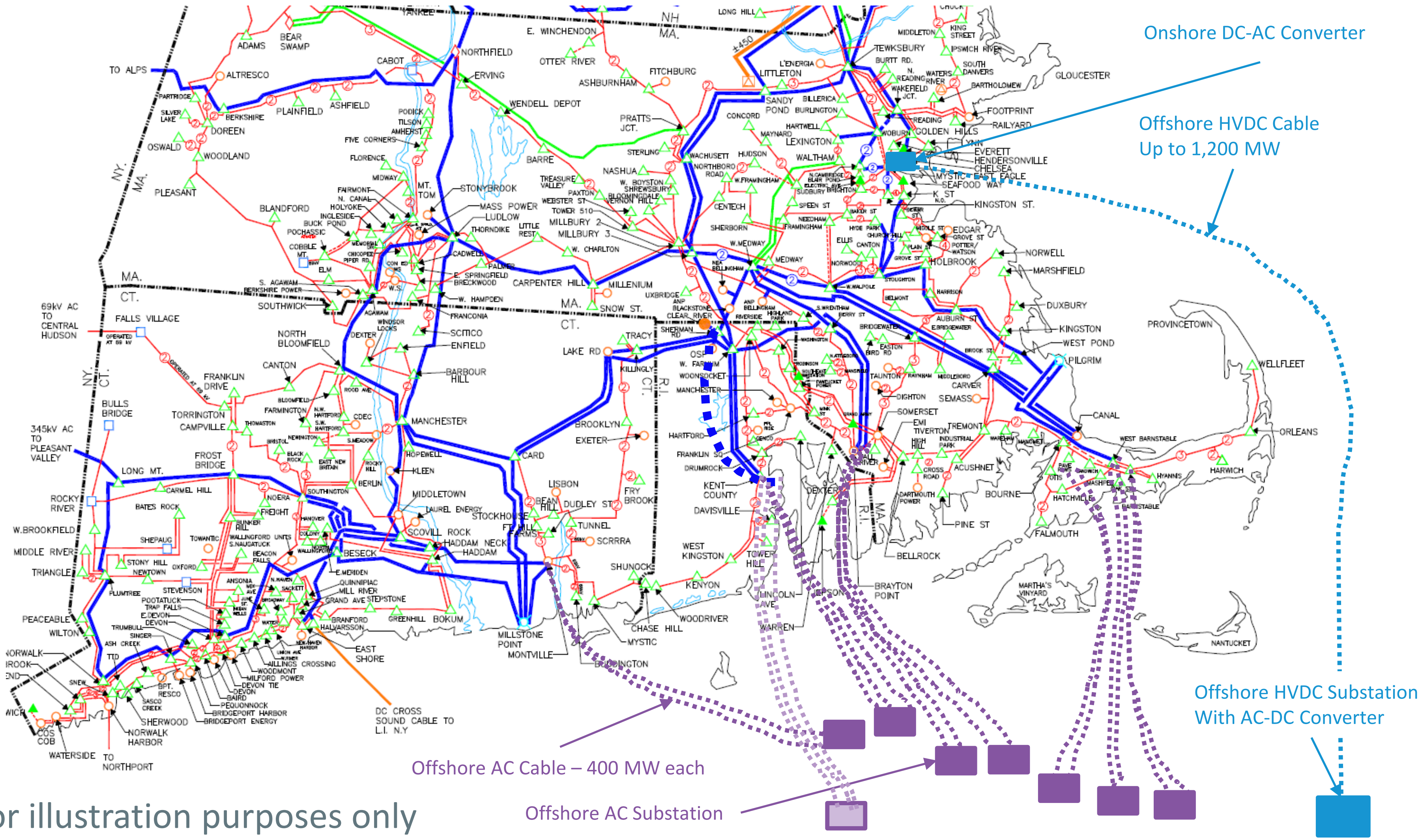
Conceptual Depiction of Offshore Interconnection: 8,000 MW Case (Scenario 8,000_4)



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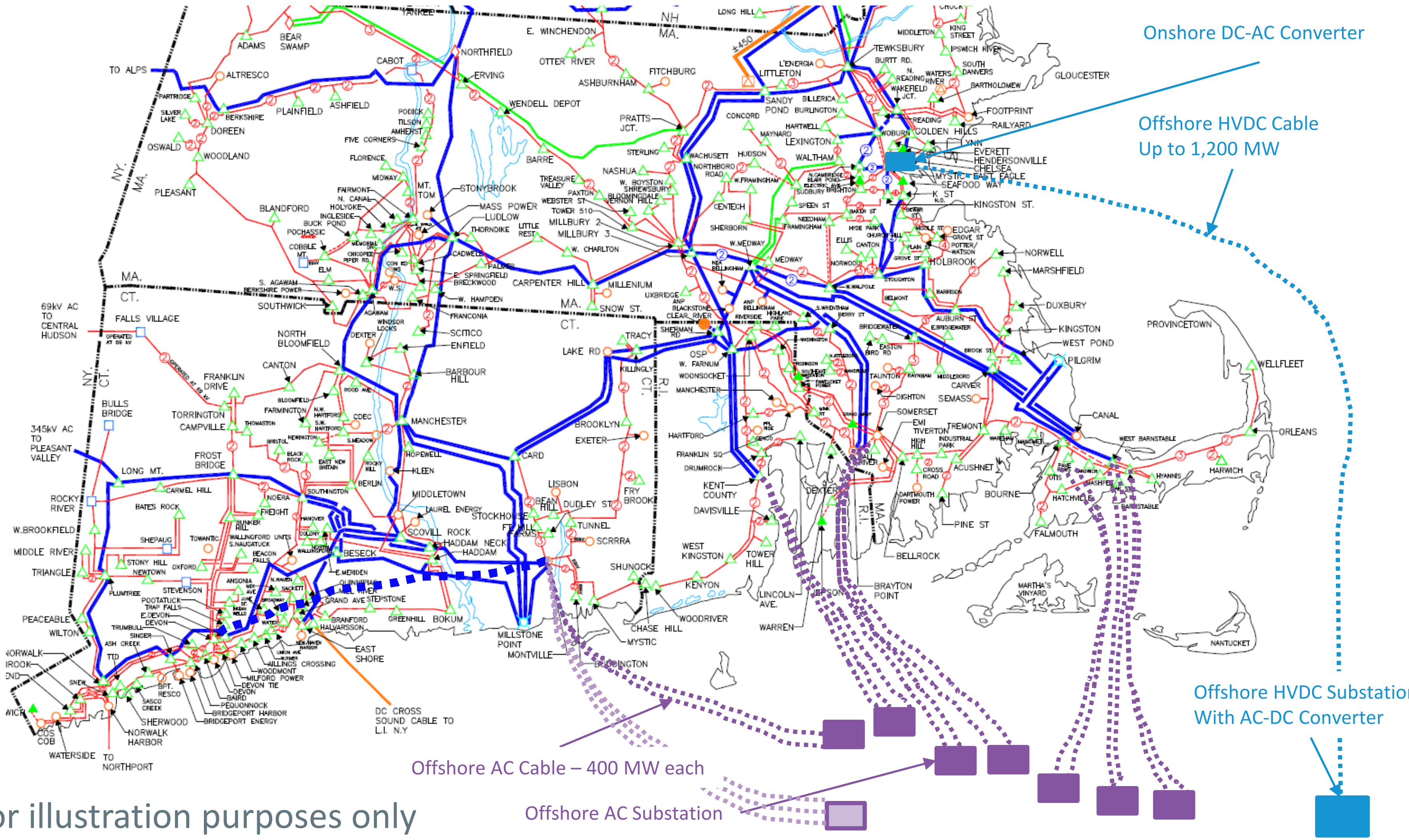
Conceptual Depiction of Offshore Interconnection: 8,000 MW Case (Scenario 8,000_5)



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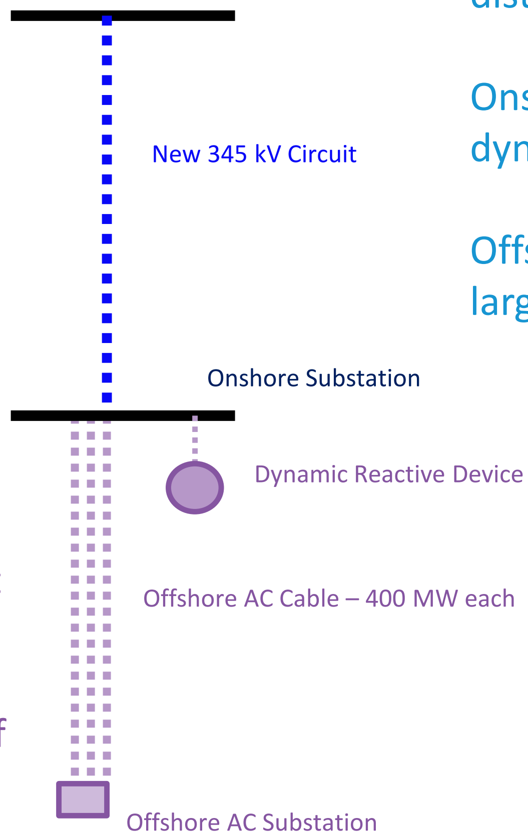
Summary Comparison of Alternatives for Additional Interconnections Beyond the Base 5,800 MW

New 345 kV circuits of significant length in new rights-of-way in congested parts of the system. Partial undergrounding may be required.

AC connections typically require a dynamic reactive device (synchronous condenser or STATCOM) at the on-shore substation.

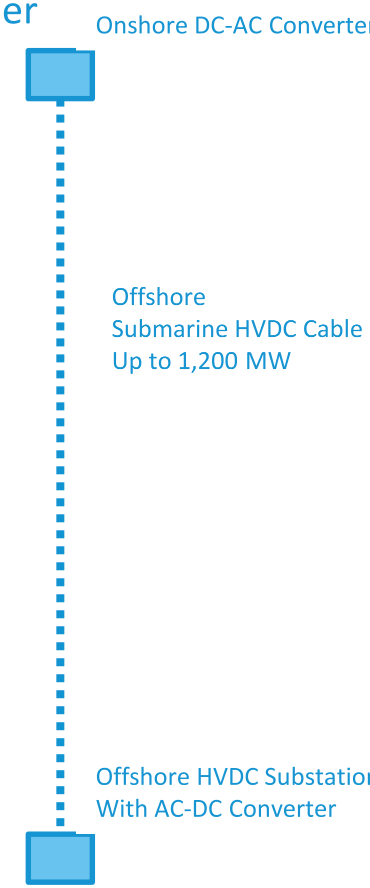
Permitting & installation of multiple cable landings



HVDC can use a single cable for 1,200 MW and can travel further distances to the load centers.

Onshore converter provides dynamic reactive capability

Offshore HVDC substation is large and expensive to install



Alternatives in the Marketplace

- The offshore wind sector is in a very dynamic phase of evolution and limited component cost data is available
  - Recent procurement announcements have signaled continued reductions in overall project costs
  - The ISO has no reliable data on current projects of this type
- This study explored two alternative approaches for continued interconnection beyond the initial 5,800 MW
  - Additional offshore AC connections with significant onshore transmission upgrades, or,
  - Offshore HVDC connections that bypass onshore grid constraints
- The overall cost of each approach could be comparable
  - Under each approach, estimates of the overall transmission component could be $1 Billion, or more, for each 1,200 MW addition
  - But, actual costs are highly dependent on the specific circumstances of each project, especially for the on-shore AC expansion, which will be location-specific
- It is appropriate to consider both alternatives for any prospective project because of the project-specific costs and the continued rapid evolution of offshore wind development costs

Conclusions

- Approximately 5,800 MW of offshore wind can be interconnected using AC cable connections to interconnection points along the southern New England coast without significant upgrades to the on-shore transmission network
  - Note that some local 345 kV reinforcement/expansion is still likely to be needed for this scenario
- Additional interconnections to these points would drive the need for significant network upgrades
- Alternatively, HVDC connections could be used to continue to travel further distances and connect additional offshore wind directly to the load centers
  - Connection of a total of 2,200 MW using HVDC was identified without major on-shore transmission upgrade
  - In addition to the 5,800 MW connected using AC cables to the southern New England coast – this gives a total of 8,000 MW of connected offshore wind
- After reaching the 5,800 MW level of injection to the southern New England coast, there appears to be a high-level of comparability in the trade-offs of continuing the use of AC connections to the points versus the use of HVDC to travel further distances to connect to load centers

Questions

APPENDIX 1

Background to the NESCOE 2019 Economic Study Request and the Transmission Interconnection Analysis

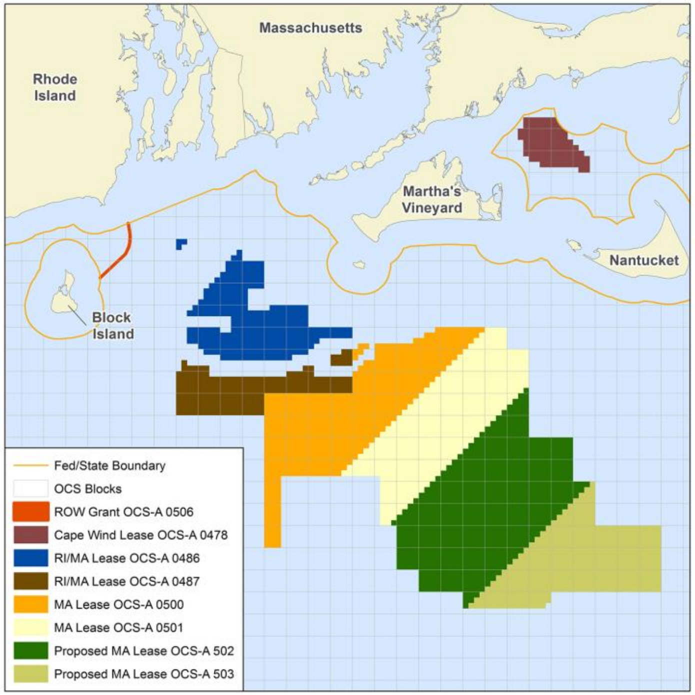
Background: Summary of the NESCOE 2019 Economic Study Request

- Scenario Analysis
  - Increasing levels of incremental offshore wind resources under anticipated 2030 New England system load conditions
  - Reference case: 0 MW
  - High case: up to 8,000 MW
- Production Impacts
  - Energy, Capacity, Ancillary Services
  - Prices and Air Emissions
  - Ancillary Services Requirements
- Transmission Interconnection Analysis
  - High-Level Conceptual Transmission Overlays
  - Transmission Upgrade Concepts
  - Various Points of Interconnection

Focus of this presentation

Scenarios Requested and Total MW Studied

MW of New Offshore Wind[1]		Total MW Studied[2]
By 2030	1,000	2,000
	2,000	3,000
	4,000	5,000
By 2035	5,000	6,000
	7,000	8,000



- Primary location of new resources: MA or RI/MA Wind Energy Areas (WEA) on the outer Continental Shelf
- Remaining amount of new offshore wind resources would be from a yet-to-be determined WEA in the Gulf of Maine

[1] Scenarios identified in NESCOE's request; Presentation to Planning Advisory Committee, April 25, 2019.
[2] Includes 1,000 MW of wind already contracted at the time of NESCOE's request.

Additional Material for the 2019 Economic Study Offshore Wind Transmission Interconnection Analysis

- At the March 18, 2020 PAC meeting, the ISO presented a summary of the results of the analysis of the identified injection levels
- Additional results were presented at the April 23, 2020 and the May 20, 2020 PAC meetings

APPENDIX 2

A Discussion of AC versus HVDC connection of offshore wind

Submarine AC Cable

- Submarine AC cable can be used to connect from an offshore collector substation to the interconnection point at the onshore substation
- Submarine AC technology can be used for distances of up to approximately 40-60 miles
- Typical applications are operated at 225-275 kV and are rated to carry approximately 400 MW for each (three phase) cable
- Very commonly, developers have proposed projects to use two AC cables for an 800 MW project

Submarine DC Cable

- Submarine DC cable can also be used to connect from an offshore collector substation to the interconnection point at the onshore substation
- Submarine DC technology can be used for very long distances (hundreds of miles)
- Converter stations are needed at both ends (one at the offshore collector substation and one at the onshore interconnection point) to convert from DC back to AC
  - Converter stations add significantly to the overall cost
- A single HVDC cable can be used to connect up-to 1,200 MW of generation