State Of New York Department of Public Service

Case 20-E-0197 - Proceeding on Motion of the Commission to Implement Transmission Planning Pursuant to the Accelerated Renewable Energy Growth and Community Benefit Act.

Initial Report on the Power Grid Study – Transmission Grid Ancillary Services

Personal Comments of
Roger Caiazza
7679 Bay Circle
Liverpool, NY 13090
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Introduction

On January 19, 2021 the New York State Department of Public Service (DPS) submitted the Initial Report on the Power Grid Study ("Power Grid Study") prepared pursuant to the Accelerated Renewable Energy Growth and Community Benefit Act (AREGCBA). The AREGCBA legislation is intended to ensure that Climate Leadership and Community Protection Act (CLCPA) renewable generation is sited in a timely and cost-effective manner. In order for an electric energy grid powered primarily by renewable energy resources to maintain the same level of reliability as the existing system, somebody, somewhere has to provide transmission grid ancillary services. However, none of the reports provided in the Power Grid Study documentation address this problem. My comment is simply this – who is responsible for this necessary work?

I am following the implementation of the Climate Leadership and Community Protection Act (Climate Act) because I believe it will affect the affordability and reliability of New York's energy. I am a retired utility meteorologist with nearly 40-years experience analyzing the effects of environmental regulations on electric and gas operations. The opinions expressed in this post do not reflect the position of any of my previous employers or any other company I have been associated with, these comments are mine alone.

Background

Staff from the Department of Public Service (Department Staff), with the support of the New York State Energy Research and Development Authority, The Brattle Group, and Pterra Consulting, prepared the Power Grid Study (PGS), three transmission system studies, and a related report entitled "The Initial Report on the New York Power Grid Study" (Initial Report). The primary purpose of the PGS is to inform planning for the bulk transmission and local transmission and distribution (T&D) investments that will be necessary to achieve the clean energy mandates established under the Climate Leadership and Community Protection Act (CLCPA). The CLCPA mandates include achievement of 70% renewable generation by 2030 (70 by 30 mandate), zero emissions from the statewide electrical demand system by 2040, and an 85% decarbonized economy by 2050. The CLCPA also requires that load serving entities procure at least 6,000 MW of distributed solar photovoltaics by 2025 and 9,000 MW of offshore wind (OSW) by 2035, and support 3,000 MW of statewide energy storage capacity by 2030. The three studies that comprise the PGS are (1) a study conducted by the Joint Utilities on local transmission and distribution needs (Utility Study); (2) a study of offshore and onshore bulk-power transmission infrastructure scenarios, and related environmental permitting considerations, to illustrate possible solutions to integrate into the transmission grid 9,000 MW of OSW generation by 2035 (OSW Study); and (3) a statewide scenario-based study to analyze transmission, generation, and storage options for achieving 70% renewable generation by 2030 and a zero emissions grid by 2040 (Zero Emissions Study).

Ancillary Grid Transmission Services

A reliable electric power system is very complex and must operate within narrow parameters while balancing loads and resources and supporting synchronism. New York's conventional rotating machinery such as oil, nuclear, and gas plants as well as hydro generation provide a lot of synchronous support to the system. This includes reactive power (vars), inertia, regulation of the system frequency and the capability to ramping up and down as the load varies. Wind and solar resources are asynchronous and cannot provide the necessary grid ancillary support.

Some, but not all of the disadvantages of solar and wind energy in this regard can be mitigated through electronic and mechanical means. When these renewable resources only make up a small percentage of the generation on the system, it is not a big deal. The system is strong enough that letting a small percentage of the resources that don't provide those services to lean on the system. But as the penetration of solar and wind energy increases the system robustness will degrade and reliability will be compromised without costly improvements. A renewable system could be coupled with extensive batteries and other storage devices, large mechanical flywheels and condensers (basically an unpowered motor/generator that can spit out or consume reactive power). These devices could approximate the behaviors of our conventional power system.

Analysis

I reviewed four reports to see if the ancillary transmission grid services necessary to keep the grid operating were considered:

- Initial Report on the New York Power Grid Study;
- Appendix C: Utility Transmission & Distribution Investment Working Group Study;
- Appendix D: Offshore Wind Integration Study; and
- Appendix E: Zero-Emissions Electric Grid in New York by 2040 Study.

I checked these reports in two ways. First, I reviewed the approaches and then I searched the documents for specific references to these services.

Attachment 1 extracts the study approaches for the Initial Report and Appendices C, D, and E. In my opinion, there is no indication that any of the approaches considered this problem. It is worrisome that the Power Grid Study responds to the guidelines established by the PSC in its May 2020 Order that do not include a charge to look at these services.

The other screening methodology was a term search of the documents. I searched documents for terms that I believe should be associated with this requirement. I used the following search terms: "Synchro", "Ancillary", "Frequency", "Inertia", "Reactive" and "Vars". The complete results are shown in Attachment 2.

Using those search terms, I found several cursory references to the ancillary services challenge. Static synchronous series compensators were mentioned because they offer the operating flexibility to avoid congestion in meshed networks and provide an effective solution to congestion that may arise from variable renewable energy. There were two references to the fact that Smart Inverters can provide ride-through capability for frequency and voltage fluctuations that would typically trip the inverters and can regulate the use of ancillary services that may be provided by solar or storage devices

When I used those search terms in the study of offshore and onshore bulk-power transmission infrastructure scenarios, the only relevant references mentioned static synchronous series compensators and smart inverters. Those were passing references to specific kinds of equipment and did not address the scope or magnitude of the services necessary to maintain reliability. I believe this indicates that this study does not adequately address this issue

I also reviewed the Utility Study in the same way and in that report found relevant references. Eight utility companies proposed plans for local transmission and distribution systems to meet the CLCPA requirements and two included projects targeted to address these ancillary services. The Long Island Power Authority (LIPA) identified a "potentially major issue on the transmission system with the significant increase of inverter-based resources (IBR) and concurrent retirement of conventional fossil power plants is the weakness of the system and the potential for adverse IBR behavior due to this weakness, as well as voltage instability." This is exactly the kind of issue that I believe needs to be addressed. The report does not quantify this risk but explains that it is very likely that "new synchronous resources will be required (or alternatively, existing resources not being retired and run uneconomically) to strengthen the system such that these new IBR as well as the overall power system can operate in a stable manner." LIPA included a proxy project for at least one synchronous condenser installation on their system. Avangrid proposed Power Flow Control Devices at several locations including three (3) different technologies (Series Reactors, Phase Angle Regulators, and Static Series Synchronous Compensator devices).

In addition, the Utility Study raised the issue in a section on potential technology solutions that included "Energy storage for T&D services". It addressed ancillary services beyond energy storage:

> Energy storage is increasingly being considered for many transmission and distribution (T&D) grid applications to potentially enhance system reliability, support grid flexibility, defer capital projects, and ease the integration of variable renewable generation. Central to the State's policies and mandates is the need to enhance power system flexibility to effectively manage renewable energy deployment and the associated increase in variability. As power systems begin to integrate higher penetrations of variable, renewable, inverter-based generation in place of conventional fossil-fuel fired synchronous generation, grid-scale energy storage could become an increasingly important device that can help maintain the load-generation balance of the system and provide the flexibility needed on the T&D system. Pumped hydro storage (PHS) and compressed air energy storage (CAES) are long-established bulk energy storage technologies.
>
> Utility-scale lithium-ion battery storage has expanded dramatically, as decreasing lithium ion battery costs make this an increasingly cost-effective solution to meet T&D non-wire, reliability,

> and ancillary service needs. Redox flow batteries, sodium sulfur batteries, thermal energy storage (both latent and sensible heat), and adiabatic compressed air energy storage are all in various stages of demonstration. This information provides a concise overview of a wide variety of existing and emerging energy storage technologies being considered for T&D systems. It describes the main technical characteristics, application considerations, readiness of the technology, and vendor landscape. It also discusses implementation and performance of different energy storage technologies. In this Report, energy storage systems greater than 10 MW and four or more hours of duration, are considered as bulk and transmission and sub-transmission-connected energy storage.

There were also several other general references to the ancillary services problem. However, the study did not quantify the risks of adverse inverter-based resource behavior or voltage instability in general and only LIPA included specific projects to address that problem. Clearly, someone has to quantify these risks.

The offshore wind integration study was analyzed similarly. Most of the references to these terms were in the context of transmission capacity not transmission support. In connection to the costs it was mentioned that the cost of each offshore wind project could be impacted by certain specific cost drivers such as required ancillary services.

I reviewed Zero Emissions Study the same way. According to the findings of the report:

> Based on the analysis carried out in the study, New York State should be able to achieve its 70 x 30 and zero-emission generation by 2040 goals under both the Initial Scenario and the High Demand Scenario using a mix of distributed energy, energy efficiency measures, energy storage, planned transmission projects, utility-scale renewables, and zero-emission resources. The most significant difference in these scenarios was the amount of renewable generation added and the scope (transmission capacity increases) of the transmission projects required to manage congestion and reduce costs.

Note that this summary described transmission capacity increases but did not mention the ancillary support services requirements. I found no references that addressed reactive power (vars), inertia, or regulation of the system frequency, but they did mention the ramping adequacy ancillary service. Given that achieving the CLCPA goals will require these ancillary services and the report did not address the problem the conclusion that New York should be able to achieve the goals is unsupportable.

Conclusion

My particular concern is that other venues of the CLCPA process have also only considered the energy storage ancillary services needed to keep the system operating when intermittent wind and solar resources are not available. The Power Grid Study was concerned about the related issue of transmission capacity and availability to support the renewable energy resources projected. Unfortunately, the other grid support requirements needed so the electric grid can transmit the power from where it is produced to where it is needed are not discussed in sufficient detail to acknowledge the problem in three of the reports included in the Power Grid Study that is supposed to inform the CLCPA implementation process. Instead, all but Appendix C: Utility Transmission & Distribution Investment Working Group Study ignore or dismiss these services. For example, the Offshore Wind Study notes: "since most ancillary service requirements can be met by power plants anywhere in NYISO, offshore wind curtailment was not significantly impacted."

The future CLCPA electric system that will be dependent upon wind and solar resources has to be coupled with other devices that can approximate the behaviors of our conventional power system in order to get the power where it is needed. This is a significant shortcoming in the CLCPA process that must be addressed. The conclusion from these reports that New York State should be able to achieve the 2040 CLCPA targets is not based on adequate analysis. The transmission grid ancillary services needed for a wind and solar powered electric system issue must be addressed to determine feasibility.

Attachment 1: Power Grid Study Component Study Approaches

This attachment extracts the study approaches for the Initial Report and Appendices C, D, and E in the Power Grid Study.

Initial Report on the New York Power Grid Study

The Utility Study responds to the following guidelines established by the PSC in its May 2020 Order:

- Evaluate the local transmission and distribution system of the individual utility service territories, to understand where capacity "headroom" exists today;
- Identify existing constraints or bottlenecks that limit energy deliverability;
- Consider synergies with traditional capital expenditure projects (i.e., aging infrastructure, reliability, resilience, market efficiency, operational flexibility, etc.);
- Identify least-cost upgrade projects to increase the capacity of the existing system;
- Identify potential new or emerging solutions that can accompany or complement traditional upgrades;
- Identify potential new projects that would increase capacity on the local transmission and distribution system to allow for interconnection of new renewable generation resources; and
- Identify the possibility of fossil generation retirements and the impacts and potential availability of those interconnection points.

Utility Local T&D Infrastructure

The Utility Study responds to the following guidelines established by the PSC in its May 2020 Order:

- Evaluate the local transmission and distribution system of the individual utility service territories, to understand where capacity "headroom" exists today;
- Identify existing constraints or bottlenecks that limit energy deliverability;
- Consider synergies with traditional capital expenditure projects (i.e., aging infrastructure, reliability, resilience, market efficiency, operational flexibility, etc.);
- Identify least-cost upgrade projects to increase the capacity of the existing system;
- Identify potential new or emerging solutions that can accompany or complement traditional upgrades;
- Identify potential new projects that would increase capacity on the local transmission and distribution system to allow for interconnection of new renewable generation resources; and
- Identify the possibility of fossil generation retirements and the impacts and potential availability of those interconnection points.

Utility Group Advanced Technologies

While the Power Grid Study did not model the implementation of advanced transmission technologies, this section offers recommendations on the need for integrating such technologies expeditiously into both local T&D and bulk transmission investment plans because of the substantial potential for cost-effective un-bottling of renewable generation that is offered by these technologies.

In Part 3 of Utility Study as filed in Case 20-E-0197.27 the Advanced Technologies Working Group (ATWG) explored the capability of advanced transmission technologies to: (a) alleviate transmission system bottlenecks to allow for better deliverability of renewable energy throughout the State, (b) unbottle constrained resources to allow more hydro and/or wind imports and the ability to reduce system congestion, (c) optimize the utilization of existing transmission capacity and right of ways, and (d) increase circuit load factor through dynamic ratings. The group then evaluated seven groups of advanced technologies:

- Dynamic line ratings and improved transmission utilization;
- Power flow control devices (both distributed and centralized);
- Energy storage for transmission and distribution services;
- Tools for improving operator situational awareness;
- Transformer monitoring;
- Advanced high-temperature, low-sag (HTLS) conductors; and
- Compact tower design.

Offshore Wind Study Findings and Recommendations

The Offshore Wind Integration Study conducted by DNV-GL, PowerGem, and WSP addresses four questions:

- At which onshore substations are there good opportunities to inject 9,000 MW of OSW into the bulk power grid of New York City and Long Island in a feasible, reliable, and least-cost manner?
- What are the environmental/permitting challenges associated with bringing OSW to existing onshore substations?
- Considering (a) the 1,825 MW of OSW that have recently been procured, (b) the onshore substations with identified capacity to interconnect future OSW, and (c) the environmental/permitting constraints, what are plausible planned transmission strategies for collecting and delivering the remaining 7,175 MW?
- How does a networked offshore transmission solution compare to a reference case "business as usual" scenario that utilizes only radial connections?

Zero Emissions Electric Grid by 2040

Study Findings and Recommendations

The Zero Emissions Electric Grid by 2040 study (Zero Emissions Study) is a resource planning study prepared by Siemens to analyze transmission, generation, and storage scenarios for meeting New York's goals of zero-emission electricity by 2040 and achieving interim targets of 70% renewable generation by 2030.

The study approach is organized into six steps, with the two initial steps followed by four iterative steps:

1. Define Objectives and Assumptions: Key objectives include reaching 70% renewable energy by 2030, reaching zero emissions by 2040, preserving the “1 in 10 years” loss of load event (LOLE) resource adequacy standard, supplying sufficient flexible resources to manage ramping needs, minimizing costs, curtailment, new transmission, and imports.
2. Define load and Distributed Energy Resource (DER) forecasts: The Study drew upon the New York Decarbonization Pathways Study[70] and utilities’ forecasts as input to develop the base and alternative scenarios for the load and DER forecasts (distributed behind the meter solar). The Study developed two scenarios: an “Initial Scenario” and a “High Demand Scenario.”
3. Simulate Optimal Capacity Expansion for 2030 and 2040: Optimal capacity expansion simulations were performed using the AURORA simulation tool with zonal resolution.
4. Transmission Reliability Assessment: The TARA reliability study tool was used to analyze thermal and voltage violations for pre-contingency and local and design criteria contingency conditions.
5. Congestion Assessment: Nodal analysis was performed using the PROMOD production cost simulation tool to identify congestion and renewable curtailments.
6. Define Transmission Solutions: Transmission expansions to address reliability or congestion challenges found in prior steps were identified and their likely cost-effectiveness assessed in terms of benefit to cost (B/C) ratios.

Attachment 2: Power Grid Study Component Ancillary Services Search Results

Given the importance of the transmission grid ancillary services needed to keep the lights on I assumed that these services would be addressed in the Power Grid Study documents. In order to determine if that was the case, I searched documents for terms that I believe should be associated with this requirement using the following search terms: “Synchro”, “Ancillary”, “Frequency”, “Inertia”, “Reactive” and “Vars”.

Initial Report on the New York Power Grid Study

Search terms:

Synchro

- Static synchronous series compensators
    - FACTS Devices. Fast, real-time control of flow on specific transmission paths can be achieved through Flexible AC Transmission devices such as thyristor-controlled phase angle regulators (TCPAR) and static synchronous series compensators (SSSC). These devices offer the operating flexibility to avoid congestion in meshed networks and provide an effective solution to congestion that may arise from VRE

Ancillary

Frequency (only reference in context of electric system)

- Smart Inverters. One side of the smart grid paradigm are devices that have the capability to make grid-impacting decisions on a local basis. This is especially important as Advanced Monitoring and Control technology are still in process of development and implementation that puts DER devices and lower voltage systems beyond reach. Smart inverters address some of the concerns and challenges associated with high VRE integration into the electric grid via sophisticated monitoring and communication of the grid status, and the capability to make autonomous decisions to maintain grid stability and reliability. Many existing and proposed DER already have this capability but need the overall monitoring and control infrastructure to enable their use. In addition to system benefits, these types of inverters can also:
    - Provide ride-through capability for frequency and voltage fluctuations that would typically trip the inverters
    - Regulate the use of ancillary services that may be provided by solar or storage devices.

Inertia

- No references

Reactive

- No references

Vars

- No references

Appendix C: Utility Transmission & Distribution Investment Working Group Study

Search terms:

Synchro

- Figure 57: LIPA "Phase 2" Transmission projects Summary
  - New Synchronous Condenser Installation(s) $200 million
  - A potentially major issue on the transmission system with the significant increase of inverter-based resources (IBR) and concurrent retirement of conventional fossil power plants is the weakness of the system and the potential for adverse IBR behavior due to this weakness, as well as voltage instability. This Report does not attempt to quantify this risk. It is very likely that new synchronous resources will be required (or alternatively, existing resources not being retired and run uneconomically) to strengthen the system such that these new IBR as well as the overall power system can operate in a stable manner. Therefore, we believe that it is reasonable to include a proxy project for at least one synchronous condenser installation on the LIPA system
- Figure 85: Avangrid Solution Summary Table
  - Genesee Valley Area Phase 2 Upgrades
    - Build a new 115 kV station, bring in a new source, and add a new transformer at multiple substations. Add Power Flow Control Device - Static Series Synchronous Compensator
  - Geneva Area Phase 1 Upgrades
    - Install 115 kV Power Flow Control Device - Static Series Synchronous Compensator
  - Oneonta Area Phase 1 Reinforcement
    - Reconductor 115 kV line, upgrade terminal equipment at multiple 115 kV substations. Install 115 kV Power Flow Control Device - Static Series Synchronous Compensator technology
  - Power Flow Control Devices: This technology was proposed at several locations including three (3) different technologies (Series Reactors, Phase Angle Regulators, and Static Series Synchronous Compensator devices). Series Reactors were found to have the lowest cost but also provide the least amount of real time operational flexibility as they are static or fixed flow control devices. PAR's tended to be the most expensive but also provided maximum flexibility in responding to varying system power flow conditions. Static Series Synchronous Compensator devices are a newer technology that may offer a balanced solution between cost and flexibility although there is limited industry experience with these and they are not widely available across multiple vendors. Although this study made preliminary recommendations in some cases, further study will be necessary to make a final determination
- IV. POTENTIAL TECHNOLOGY SOLUTIONS
  - C. Energy storage for T&D services:
    - Energy storage is increasingly being considered for many transmission and distribution (T&D) grid applications to potentially enhance system reliability, support grid flexibility, defer capital projects, and ease the integration of variable renewable generation. Central to the State's policies and mandates is the need to enhance power system flexibility to effectively manage renewable

energy deployment and the associated increase in variability. As power systems begin to integrate higher penetrations of variable, renewable, inverter-based generation in place of conventional fossil-fuel fired synchronous generation, grid-scale energy storage could become an increasingly important device that can help maintain the load-generation balance of the system and provide the flexibility needed on the T&D system. Pumped hydro storage (PHS) and compressed air energy storage (CAES) are long-established bulk energy storage technologies.

- Utility-scale lithium ion battery storage has expanded dramatically, as decreasing lithium ion battery costs make this an increasingly cost-effective solution to meet T&D non-wire, reliability, and ancillary service needs. Redox flow batteries, sodium sulfur batteries, thermal energy storage (both latent and sensible heat), and adiabatic compressed air energy storage are all in various stages of demonstration. This information provides a concise overview of a wide variety of existing and emerging energy storage technologies being considered for T&D systems. It describes the main technical characteristics, application considerations, readiness of the technology, and vendor landscape. It also discusses implementation and performance of different energy storage technologies. In this Report, energy storage systems greater than 10 MW and four or more hours of duration, are considered as bulk and transmission and sub- transmission-connected energy storage.

Ancillary

- IV. POTENTIAL TECHNOLOGY SOLUTIONS
  - C. Energy storage for T&D services:
    - Utility-scale lithium ion battery storage has expanded dramatically, as decreasing lithium ion battery costs make this an increasingly cost-effective solution to meet T&D non-wire, reliability, and ancillary service needs.
- APPENDIX A: TRADITIONAL PLANNING CRITERIA
  - A. Production Cost Modeling
    - Production cost modeling is a tool for simulating and studying the electric market in a defined area. Typical uses include day-ahead market simulation, long-term market impact studies, future year production cost, planning and market efficiency simulation, multi-day resource and ancillary services optimization, and congestion and outage analyses. For production cost modeling many available tools are available to utilize. For example, a Linear Programming- based Security Constrained Economic Dispatch (SCED) and/or Security Constrained Unit Commitment (SCUC) can be used to perform both short- and long-term market simulation.
- ii) Proposed Regulatory Frameworks for Equitable Cost Recovery of CLCPA Projects
  - 4. Renewable Generator Sponsorship

        - Unlike the other three options, this approach would result in the cost burden of projects being directly assigned to unbottled generators. Cost allocation would still be regional, to the extent that generators recover the transmission investment costs they incur to utilities through the REC or OREC payments or NYISO market revenues (energy, capacity, and ancillary services, as applicable) they receive. However, this approach could raise free ridership concerns, as a generator may benefit from a project funded by another generator, and, unlike other ISOs such as PJM Interconnection Inc., the NYISO does not administer any firm transmission rights to guarantee delivery.
- Part 2: Technical Analysis Working
    - vi) Other Key Assumptions
        - The DSIP analysis focused on typical 1-in-2 impacts for which a market driven battery storage charge / discharge profile was used. The key objective of the CLCPA 70x30 analysis is to identify grid constraints under minimum net load and maximum net load conditions so the nameplate capacity was applied to reflect a scenario where battery storage is not managed by the utility, but managed by developers and customers. It is possible that battery storage could be operated under conditions which align with local need, thereby increasing headroom. However, for planning purposes battery storage is assumed to be operated by the battery owner or developer. In effect, because battery storage is not operated by the utility it could be managed to align with other needs such as ancillary services which may be misaligned with local needs.

Reactive

- 4. LIPA Phase 2 projects
    - c) Protection Projects
    - The "Phase 2" Protection projects which have been included are based on following assumptions:
        - Install 48 line regulators and/or capacitors on DER feeders to maintain to provide reactive compensation for DER inverters and associated voltage control.

Vars

- No references

Frequency

- No relevant references

Inertia

- No references

Appendix D: Offshore Wind Integration Study

Search terms:

Synchro

- No references

Ancillary

- Table 3-7. Sensitivity Conditions - Scenario 1

Sensitivity	Description	Analysis*	Study Years
Ancillary services	Co-optimize Energy & AS (enforce NYISO AS requirements)	PCM	2035

- 3.4.4.2 Production Cost Modeling / Economic Analysis Results
    - The additional sensitivities shown in Table 3-7 did not reveal significant OSW curtailment or transmission system weaknesses; in nearly all cases curtailment remained zero or negligible:
        - The scenario enforcing NYISO ancillary services requirements showed 2,421 MWh of curtailment. It was considered that enforcing ancillary services might force more thermal generation online and therefore increase offshore wind curtailment. However, since most ancillary service requirements can be met by power plants anywhere in NYISO, offshore wind curtailment was not significantly impacted.
- 8.2 Offshore Costs
    - 8.2.1 General Assumptions
    - Market fluctuations and location-specific cost drivers are excluded from the offshore cost estimation. The cost estimation for 2020 is based on historical cost data from year 2017. The cost of each OSW project could be impacted by certain specific cost drivers such as required ancillary services, redundancy level, the scope of service contract, ambient temperatures, water depth, and cable routing. Except for offshore platforms, those specific drivers will not be considered at each OSW project level, instead they were considered on an average basis.

Reactive

- 3.2.3 Modeling Assumptions
    - Phase Angle Regulators (PARs), switched shunts, and load-tap-changing (LTC) transformers were allowed to regulate in pre-contingency conditions; they were locked (non-regulating) in post-contingency conditions. Static var compensator and Flexible AC transmission system devices in NYCA were set to zero reactive power output pre-contingency but were allowed to regulate up to their full output post- contingency.

- 5.1.1 HVAC Technology
    - HVAC illustrates the Radial connection approach used by the offshore wind industry to date with more operating experience and industrially mature technology. This technology requires reactive compensation schemes at cable terminals and midpoints in case of transmission distances beyond 70 miles. Long HVAC cable systems (> 70 miles) have also been observed to result in challenges related to harmonics, control interactions, operational configuration management and voltage regulation

- Table 8-6. The Comparison of Combined CAPEX of the Three Variants

Reactive Compensation	47	8	115	20	175	30

- 8.2.4 Levelized Transmission Cost of Energy (LTCOE)
  - The baseline uncertainty in the onshore and offshore cost estimates of ±30% combined with the ±9.5% uncertainty due to the technology learning curve applied to model reduction in costs over time, directly translates into the LTCOE uncertainty, presented in the second column of Table 8-8. The Meshed design has all the components from the Radial design plus added cables and reactive compensation. This means there is no situation where the Meshed design would have a lower LTCOE than the Radial design due to uncertainty span in the estimates.

Vars

- No references

Frequency

- 5.1.2 HVDC Technology
  - HVDC converters can be divided in two main technologies: Line Commutated Converters and insulated bipolar transistor based Voltage Source Converters (VSC). Since line commutated converters need to be connected to a relatively strong AC network, which is rare in coastal urban regions, VSC technologies are the superior and technically feasible HVDC option for OSW connections. VSC technologies can also be controlled to provide voltage and frequency support to the onshore grid and have black-start capabilities. For the purpose of this Study, 320 kV symmetric monopole and 525 kV symmetric bi-pole HVDC technologies were considered.

Inertia

- No references

Appendix E: Zero-Emissions Electric Grid in New York by 2040 Study

Search terms:

Synchro

- No references

Ancillary

- Ramping Adequacy and Flexibility Ramping Adequacy
    - Flexibility reserve (Flex) is a relatively new type of ancillary service product that has been implemented in CAISO (California) and MISO energy markets to address the increasing need for resources that can rapidly ramp up or down to respond to the changes in the intra-hour production of renewable resources. The study estimated the Flex adequacy requirements in supply portfolios based on the estimated sub-hourly variation in renewable energy production and load.

Reactive

- No references

Vars

- No references

Frequency

- No relevant references

Inertia

- No references