De-Carbonization / DER Report for NYSRC Executive Committee Meeting 4/8/2022

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The April 2022 edition of the De-Carbonization / Distributed Energy Resources (DER) Report includes the following items:

- EPRI Report: Increasing Transmission Line Capacity Through Ratings
- Energy Systems Integration Group (ESIG) Reports:
    a. Grid Forming Technology and Integration
    b. Design Requirements for a U.S. Macrogrid
- NYISO Blog: How the Installed Reserve Margin Supports Reliability, How Reliability Happens (Video)
- Snapshot of the NYISO Interconnection Queue: Storage / Solar / Wind / Co-located Storage

EPRI Report: Increasing Transmission Line Capacity Through Ratings

On December 16th, 2021, FERC issued Order 881, which establishes a new policy for the determination and use of transmission line ratings (Additional info: News Release and Staff Presentation). This Final rule requires transmission providers to implement Ambient-Adjusted Ratings (AAR) to measure the maximum transfer capability of their transmission lines for near-term transmission service. FERC determined that use of static ratings can cause transmission providers either to understate near-term transfer capability (leading to increased curtailments, interruptions, and congestion charges), or overstate transfer capability (leading to reliability problems).

The Rule also requires regional Transmission Owners (TOs) and Independent System Operators to establish systems and procedures that allow transmission owners to electronically update their transmission line ratings at least hourly and to accommodate even more accurate ratings, such as Dynamic Line Ratings (DLR), if TOs wish to implement them. Transmission providers are also required to use "uniquely" determined emergency ratings for operational contingency analyses and post-contingency simulations of constraints.

This White Paper (Publicly Available Download Link) describes and compares potentially low-cost methods to add capacity to overhead transmission lines, and includes material on the concepts of AAR and DLR, along with other options.

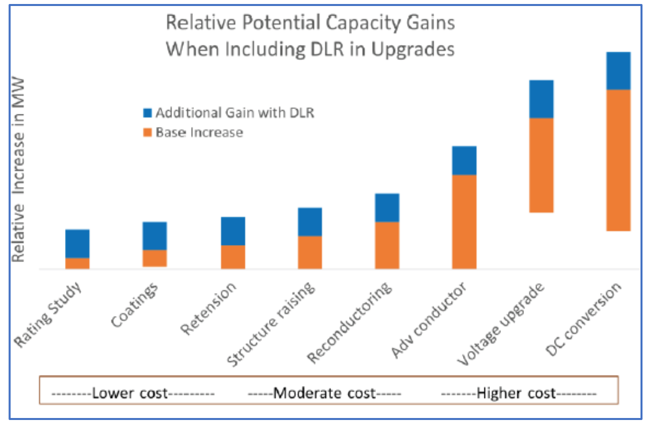
The major conditions impacting overhead feeder ratings are:

- Air Temperature
- Wind Speed and Conductor Emissivity (Cooling in the absence of wind)
- Sun Intensity and Conductor Absorptivity (Rate of heating by the sun)

Other factors that may limit the maximum allowable temperature of a conductor system include:

- Loss of strength due to annealing at higher temperatures. If a conductor loses strength, it may fail during wind or ice events. Often the maximum allowable temperature is 93°C.
- Reduced ground clearances at elevated temperatures. As conductors heat, they expand and consequently sag. Temperature limits ensure conductors do not sag enough to violate safety and legal requirements for physical clearances of other objects, such as vegetation. If clearance limits are exceeded, a line may flash over, which can reduce reliability, create hazards to the public, or contribute to wildfires.
- Increased risk of connector and hardware failure. Connectors, splices, and dead-end connectors, as well as hardware, are rated for specific conductor temperatures (often 93°C). If these temperatures are exceeded, the risk of failure increases.

The figure at right compares the potential increased capacity from various advanced rating methods compared to a traditional year-round static rating (100%). When evaluating advanced methods, a utility must compare them to more traditional approaches with known risks, such as conductor re-tensioning, addition of more conductors, or structure modification. When considering deploying the instrumentation needed for AAR or DLR, utilities need to consider:



- Field data and analysis needed either to determine the location and number of weather stations or to use data from other sources
- The selection and proper installation of weather stations and sensors to ensure accurate measurements
- The costs and benefits of implementing advanced ratings; these are not always well known
- O&M costs to maintain the instrumentation and ensure high quality, reliable data
- Tools to visualize the data in operations and send new ratings to the energy management system (EMS).

The different aspects of AAR and DLR methods are:

- AAR adjusts the forecasted and present ratings based on ambient air temperature.
- DLR adjusts line ratings based on measured wind speed, solar radiation, and ambient air temperature

To implement AAR, a utility must either measure air temperatures at many locations in its service area or have very accurate weather models for air temperatures. These air temperatures can be transmitted to an operations center, where they are used to calculate ratings for the impacted lines. AAR are relatively cost-effective since air temperature does not change dramatically over time or distance. Therefore, the models or sensors used to collect data can be less expensive than those for DLR

Utilities using AAR often use look-up tables, with ratings for different ranges of air temperatures (for example, 70–80°F) on tables provided to both operations and market monitors. This is beneficial for operations teams as the rating will not change by the minute or hour. For example, the line rating only changes when the temperature goes below 70°F or above 80°F.

DLR improves the ability to understand the real-time conditions to optimize power flow, relieve congestion, and minimize curtailments. DLR does not allow forecasted ratings since the prediction of wind speed is uncertain. AAR has a greater potential to aid in forecasted ratings since ambient temperature prediction is more reliable. Seasonal ratings cannot be replaced by AAR or DLR as they are needed for long-term planning and design.

In practice, lower capacity gains are realized as measures are implemented to reduce the frequency of rating changes in the control room. Typical capacity gains are closer to 3–7% for AAR and 20–40% for DLR.

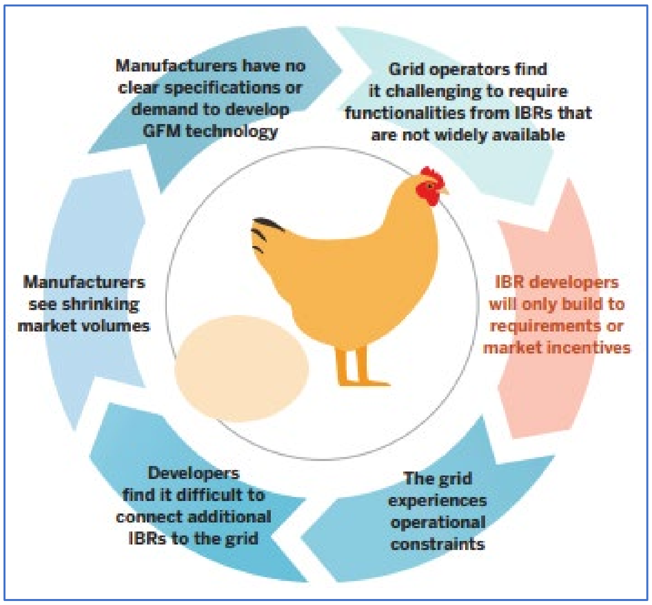
A potential downside is that AAR can increase risks to utilities. A utility may increase a rating on a cool day. However, if the wind speed is below the assumed minimum value (e.g., 2 ft/sec), a line can easily operate >30°C hotter than was assumed. This can accelerate damage due to annealing and cause clearances to be violated.

The cost of weather stations is small compared to the costs of field crew time for installation and engineering for integration, and ongoing maintenance. Once the initial data integration challenges are overcome, the process for additional lines becomes routine, reducing cost and time to implementation. Utilities should be aware that, as with any type of increased-capacity project, attention needs to be paid to relay settings, transient recovery voltages, circuit hardware, and EMS settings that may be affected by sending more power down the lines.

Energy Systems Integration Group: Report on Grid Forming Technology and Integration

The Energy Systems Integration Group (ESIG) has released a new 80-page report entitled *Grid-Forming Technology in Energy Systems Integration*, providing a comprehensive view of advanced inverter controls needed to run stable power systems with high shares of renewable energy. Additional links include a News Release, Fact Sheet, and Summary Sheet.

As rising numbers of solar, wind, and battery resources are deployed in power systems around the world, their role on the grid continues to evolve. To maintain grid stability and reliability, these resources need to begin providing some of the grid services traditionally provided by conventional power plants. Although solar, wind, and batteries are already required to have the ability to deliver some grid services, more advanced controls will be needed by a portion of these resources so that they can provide the full range of necessary grid services in a high-renewables grid.



Nearly all IBRs deployed today are "grid-following"; they rely on a strong and stable voltage and frequency signal from the grid to which they can synchronize. But as levels of grid-following resources rise, and they eventually come to provide the majority of electricity, new advanced inverter controls—termed grid-forming (GFM)—will be needed to maintain system stability.

Battery storage combined with GFMs are particularly suited for grid support at all levels. This commercially available technology has several key characteristics for playing a GFM role: it has dedicated energy storage (by definition), has no moving parts, and it can potentially be operated at a lower rating (leaving some "space" in the inverter to deliver extra current during disturbances) without foregoing energy, as wind or solar would have to do.

With clear requirements and market incentives, a significant proportion of battery storage resources in interconnection queues could be equipped with GFM functionality today, helping power systems avoid the costs of installing much larger additional grid-supporting devices or additional grid reinforcements in the future.

The report identifies the following functional areas where GFM's should be evaluated and incorporated for their support of the grid:

- Stability and Synchronization — Remaining synchronized through grid disturbances
- Frequency Regulation — Response to sudden generation / load imbalances
- Voltage Regulation — Maintaining nominal voltage and recovery from adverse events
- Damping — Provide positive damping for oscillatory modes
- Protection — Safe and timely detection and isolation of faults
- Restoration — Contribute to restoration of partial or system wide outages
- Energy and Capacity — Sufficient energy at all times to support demand and reserve

Energy Systems Integration Group: Report on Grid Forming Technology and Integration (Continued)

The table below compares attributes for Grid-Following vs. Grid-Forming Inverter Controls:

Inverter Attribute	Grid-Following Control	Grid-Forming Control
Reliance on grid voltage	Relies on well-defined grid voltage, which the control assumes to be tightly regulated by other generators (including GFM inverters and synchronous machines)	Actively maintains internal voltage magnitude and phase angle
Dynamic behavior	Controls current injected into the grid (appears to the grid as a constant current source in the transient time frame)	Sets voltage magnitude and frequency/phase (appears to the grid as a constant voltage source in the transient time frame)
Reliance on PLL for synchronization	Needs phase-locked loop (PLL) or equivalent fast control for synchronization	Does not need PLL for tight synchronization of current controls, but may use a PLL or other mechanism to synchronize overall plant response with the grid.*
Ability to provide black start	Not usually possible	Can self-start in the absence of network voltage. When designed with sufficient energy buffer and over-current capability, it can also restart the power system under blackout conditions. (Only a limited number of generators on a system need to be black start–capable.)
Ability to operate in low grid strength conditions	Stable operation range can be enhanced with advanced controls, but is still limited to a minimum level of system strength	Stable operation range can be achieved without a minimum system strength requirement, including operation in an electrical island. (GFM IBRs will not, however, help to resolve steady-state voltage stability for long-distance high-power transfer.)
Field deployment and standards	Has been widely used commercially. Existing standards and standards under development define its behavior and required functional-ities well.	Has been deployed in combination with battery storage primarily for isolated applications. Very limited experience exists in inter-connected power systems. Existing standards do not yet define its behavior and required functionalities well.

* A GFM inverter also needs a synchronization mechanism when it has reached its current or energy buffer limits. If it reaches these limits, it will temporarily fall back to grid-following operation and will need to track the grid voltage phasor.

Source: Energy Systems Integration Group.

The report recommends an optimal approach cycle for adopting system needs

1. Define the target system
2. Define Resilience Parameters
3. Perform studies to determine system needs
4. Formulate technical requirements for system services
5. Quantify system services
6. Determine the economically optimal form of service provision
7. Define technical benchmarking
8. Implement services
9. Monitor Performance

As power systems proceed through the nine steps above to define and deploy new system services to be provided by solar, wind, batteries, and other technologies, advances are needed in modeling tools, simulation tools, and economic studies used by system planners to study grid stability in a high-renewables future. Some of these will model system stability under conditions of rising levels of IBRs, while others will characterize IBR capabilities to serve various system needs. Stability studies will also need to be more closely tied to other analytical and economic assessments, to ensure that study assumptions are realistic, consistent throughout, and capture stability scenarios under all relevant grid conditions

Energy Systems Integration Group (ESIG): Report on Design Requirements for a U.S. Macrogrid

The convergence of the national push for very high levels of clean electricity and the advances in HVDC transmission technology of the last decade have created a unique opportunity for a detailed exploration of an alternative to the conventional transmission expansion process to address identified challenges for the U.S. electric power system. With that in mind, ESIG has published this report that highlights recommendations for the next stage of proactive transmission planning of a national-scale HVDC Macrogrid, which could be built over and interconnected into the existing AC grid. Here are links for the News Release, Report, and Presentation.

The report draws from several comprehensive studies of a clean energy future for the United States, including:

- ESIG - Transmission Planning for 100% Clean Electricity - White Paper and Summary Page
- NREL - Interconnection Seam Study
- MIT - Value of Inter-Regional Coordination and Transmission in Decarbonizing the US Electric System
- MISO - Renewable Integration Impact Assessment
- VCE - Transmission Insights from Zero by Fifty
- ESIG - ESIG Resource Library

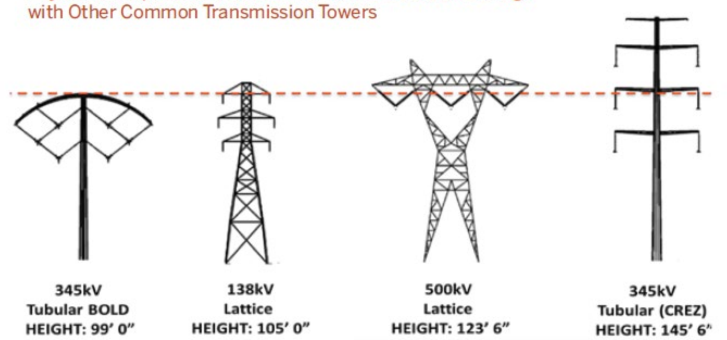
The report devotes a chapter to each of five major components in the next steps of Macrogrid design. First, the initial design studies will need to include technology selection (with a recommendation for networked, multi-terminal HVDC based on voltage source converter (VSC) technology), Macrogrid topology, circuit capacities, and performance evaluation. Following these are a reliability assessment (including stability analysis), a resilience analysis, an assessment of economics and feasibility, and an operations analysis.

The benefits of a national Macrogrid include increased reliability, as Macrogrid technologies would tie regions together in ways that facilitate better and more efficient overall grid performance, with energy, capacity, and ancillary services being deliverable among all regions of the country. A Macrogrid would also reduce the bulk power system's susceptibility to failure and allow faster recovery from outages. It would bring resilience benefits, as the interconnectivity provided by a Macrogrid spanning the country would help to ensure the resilience of the electricity infrastructure on which residents and the economy depend.

The Macrogrid concept proposed here consists of a backbone of long-distance lines composed of networked, multi-terminal HVDC based on VSC technology. It would incorporate important transmission planning principles, including the "rule of three" (transmission paths) for transmission expansion. The HVDC transmission paths form a true DC network and are composed of triple bi-pole circuits operating at +/- 800 kV DC.

A transmission tower design by American Electric Power (AEP), known as the "Bold" concept, could be utilized for these high-capacity Macrogrid transmission line segments. Currently in use as a double-circuit high surge impedance loading (HSIL) line, the structure is more material-efficient, compact, and aesthetic than alternatives. With some adaptation it could be used to carry three bi-pole circuits of six conductors total rather than two three-phase AC circuits of six conductors.

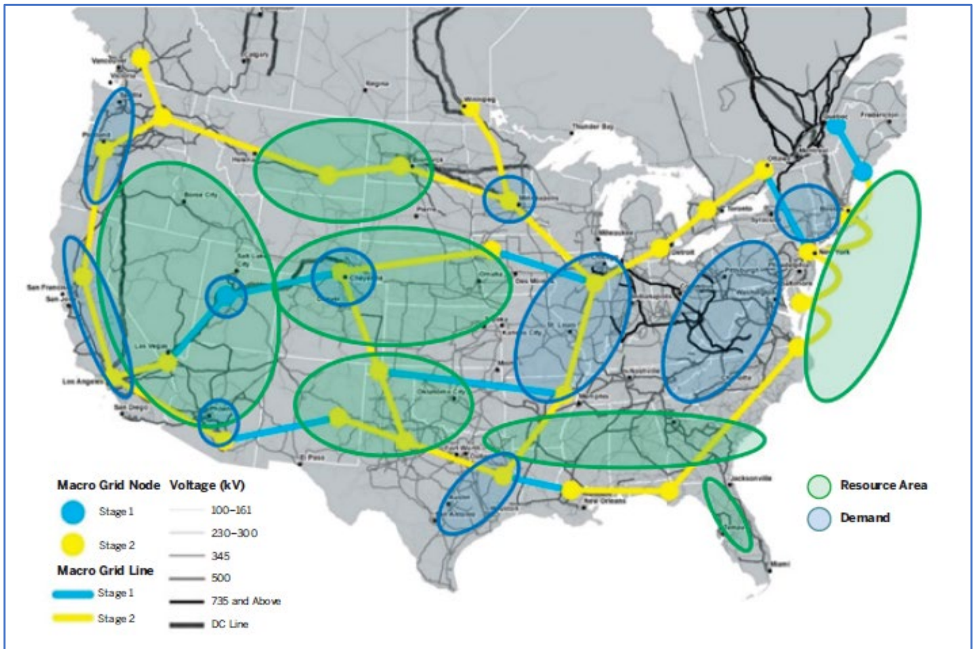
Physical Comparison of Structures for AEP Bold Line Design with Other Common Transmission Towers



Source: American Electric Power.

Energy Systems Integration Group (ESIG): Report on Design Requirements for a U.S. Macrogrid (Continued)

The figure below illustrates the Macrogrid concept with overlaid clean energy resource areas and locations of major electricity demand.



Source: Energy Systems Integration Group.

The benefits of an HVDC overlying Macrogrid include:

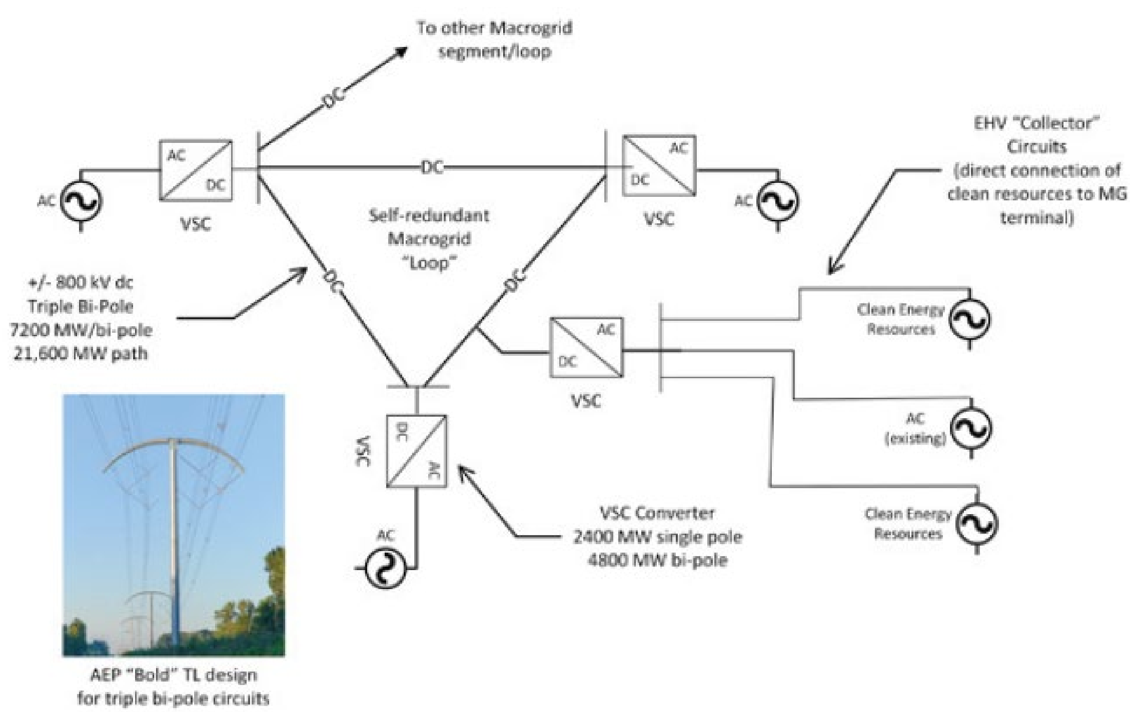
- There is no minimum capacity required for stable interconnection
- A Macrogrid using DC transmission offloads the underlying AC system, allowing increased AC interconnection of renewables
- It improves AC system performance in terms of voltage, frequency, transient, and oscillatory stability through converter control
- The power density (MW per right-of-way area required) is greater than AC
- The cost per MW-mile for long-distance transmission is lower than for AC
- HVDC losses are less than HVAC losses for the same transfer capacity

Other benefits would be economic: a Macrogrid would substantially reduce the overall cost for a clean energy future, saving as much as one trillion dollars. It could facilitate the use of the most economically attractive resources, which can be dispatched to cover energy demand across four time zones to serve all regions and customers. And HVDC transmission has lower costs when transmitting electricity over hundreds of miles. And it would provide operability benefits, with the Macrogrid adding an overarching layer on the existing grid management structure, enabling the coordination of national and regional energy flows.

The existing interconnections in the United States are managed through a multi-party and multi-layer control structure that includes embedded competitive wholesale energy markets. The Macrogrid would add an overarching layer on this existing grid management scheme, necessitating the coordination of national and regional energy flows, and requiring the creation of an entity to ensure the Macrogrid is operated in such a way as to meet reliability and resilience needs and facilitate economic operation of the U.S. electricity infrastructure.

Energy Systems Integration Group (ESIG): Report on Design Requirements for a U.S. Macrogrid (Continued)

It has long been recognized that the ability to add a third terminal to a point-to-point HVDC line would be a significant advantage for applications requiring Improved flexibility and faster control. A few such systems are in commercial service globally and are technically feasible with either conventional or VSC terminals



Sources: Energy Systems Integration Group (graphic); American Electric Power (photograph).

One disadvantage of the "tapped" arrangement is that all converters must be shut down instantaneously or as quickly as possible in the event of a short circuit on the DC lines. For example, a short circuit on a short tap line would require that all three converters be blocked (shut down) to allow the DC fault current to be extinguished. The protection complications as well as other technical control challenges have been an impediment to significant adoption of multi-terminal HVDC systems.

A major challenge for a true HVDC network is the protection of the DC links themselves. Interruption of HVDC currents in the event of a short circuit is difficult, since there are no natural instants where the fault current goes to zero as in AC systems. There are some relatively recent developments, however, that point to the availability of commercial HVDC circuit breakers in the not-too-distant future.

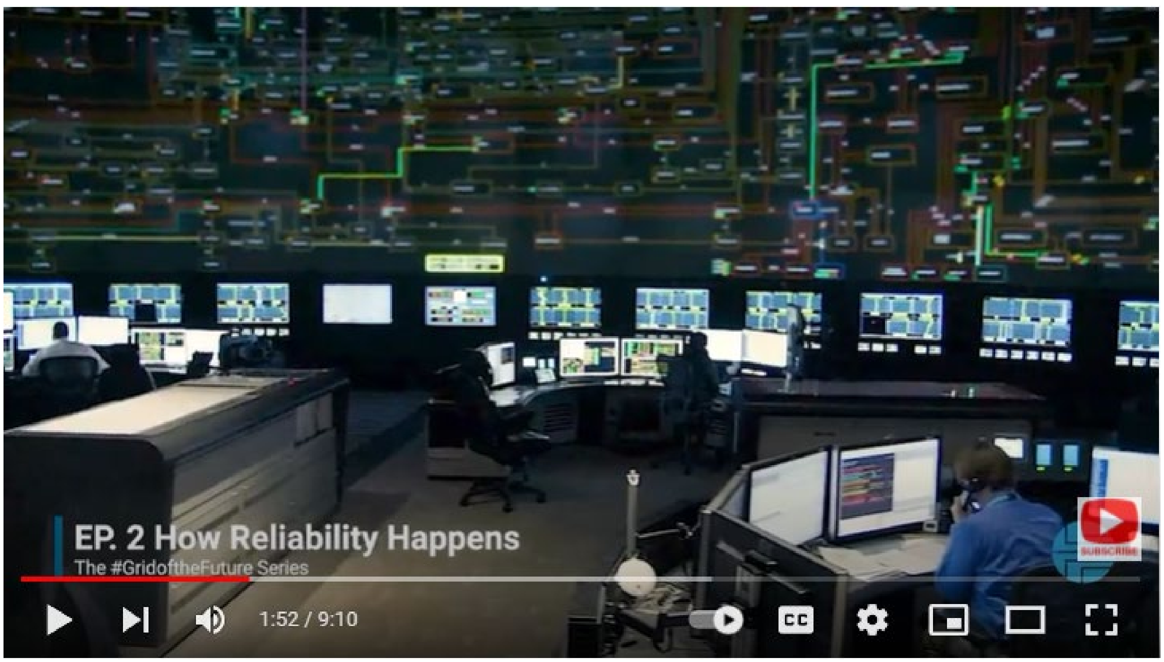
An advanced hybrid grid concept such as described above is key for the massive transmission expansion required to support very high levels of clean electricity for the United States. Some major features of the Macrogrid concept are the principle of looped circuits and the interspersed converter stations to either collect clean electricity or deliver it to demand centers

VSC converter stations are now available with ratings up to 3000 A. This equates to a 2400 MW rating at 800 kV for a single pole and double that—4800 MW—for a bi-pole configuration. Other needed technologies, such as HVDC breakers, are entering commercialization and can be assumed to be available by the time any procurements would commence. The Macrogrid vision consists of a backbone of long-distance lines composed of networked, multi-terminal HVDC based on VSC technology.

NYISO: Announcements on the Blog Page of the NYISO Website:
Features from the Blog Page of the NYISO Website are as follows:

Posting: How the Installed Reserve Margin Supports Reliability in New York
The posting seeks to explain the basic concepts for determining the process for determining the Installed Reserve Margin (IRM), along with an introduction to the calculations involved and the impact of the results. The posting underscores the concerns for the future impacts on the IRM as the state transitions to greater amounts of intermittent renewable energy and storage.

Video: How Reliability Happens
In this second episode in the series from the Grid of the Future Focus Area, the NYISO presents insights from former FERC Commissioner Colette Honorable and New York State Reliability Council's Roger Clayton. In addition, NYISO Chief Operating Officer Rick Gonzales and Vice President of System & Resource Planning Zach Smith explain the job of making sure the energy we need is available while adhering to the strictest reliability requirements in the nation.



IEEE 2800-2022 Update:
Standard for Interconnection and Interoperability of Inverter-Based Resources Interconnecting with Associated Transmission Systems Webinar

May 3, 2022 | 12:00–1:30 p.m. Eastern

Click here to: [Join Meeting]
Dial-in: 1-415-655-0002 (US Toll) 1-855-797-9485 (US Toll free) | **Access code:** 2423 759 3546.
Password: IEEE_2800_Update | **Event number:** 2423 759 3546

This joint webinar will provide an update on the IEEE 2800-2022 – Standard for Interconnection and Interoperability of Inverter-Based Resources (IBRs) Interconnecting with Associated Transmission and Sub-Transmission Electric Power Systems. The technical minimum requirements specified in IEEE 2800-2022 for the interconnection of large-scale transmission and sub-transmission connected IBRs are essential elements to maintain the reliability of the bulk power system with increasing amounts of IBRs, including those radially connected via High Voltage Direct Current (HVDC) - voltage source converters (VSC) facilities to the grid. The IEEE Sustainability Accounting Standards Board has recently approved the balloted draft of IEEE 2800, which is now going through the final publication review process with publication anticipated by mid-to-late April 2022. This webinar aims to review the purpose and scope of the standard along with selected requirements, followed by time for Q&A. More information on IEEE 2800-2022 is available on the IEEE Standards Association site.[1]

Agenda

- **Introduction and Opening Remarks from EPRI, NERC, NATF, and NAGF**
- **Purpose, Scope, and Applicability of IEEE 2800-2022**
- **High-Level Review of Selected Requirements:**
  - Reactive Capability
  - Reactive Power – Voltage Control
  - Active Power – Frequency Control
  - Low Short-Circuit Power
  - Power Quality
  - Ride-Through Capability & Performance
  - IBR Protection
  - Modeling & Validation, Measurement Data, and Performance Monitoring
  - Tests and Verification

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1 https://sagroups.ieee.org/2800/

- **Adoption of IEEE 2800-2022 in North America**
  - Potential Adoption Frameworks
  - Benefits of Adoption to both Transmission & Generation Entities
- **Q&A**

Stakeholder Focus

- Transmission Owners, Transmission Operators, Reliability Coordinators, Balancing Authorities, ISO/RTOs, Transmission Planners, Planning Coordinators, Generator Owners, Generator Operators

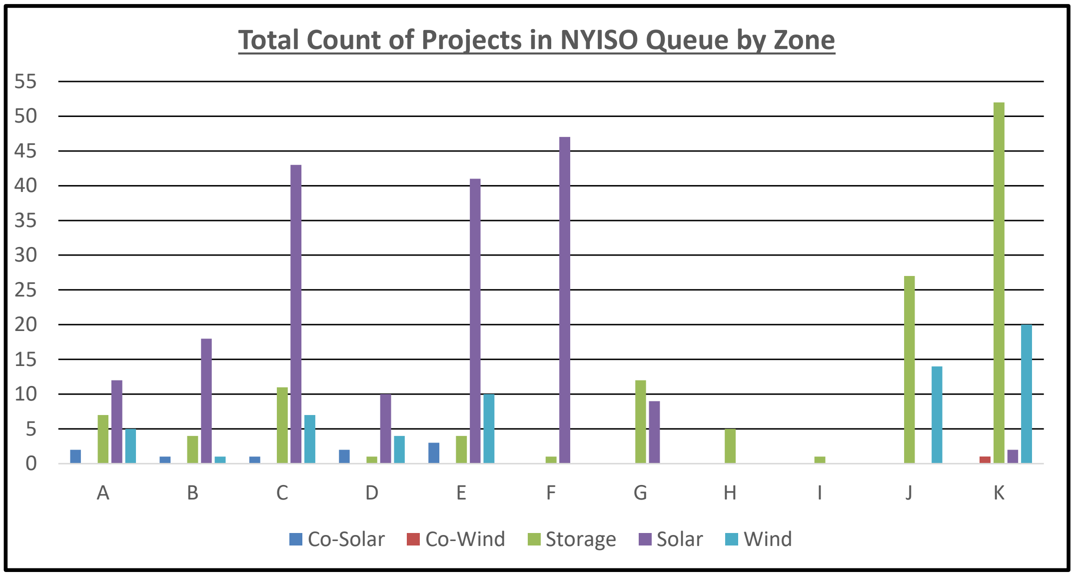
Interconnection Queue: Monthly Snapshot – Storage / Solar / Wind / CSRs (Co-located Storage)

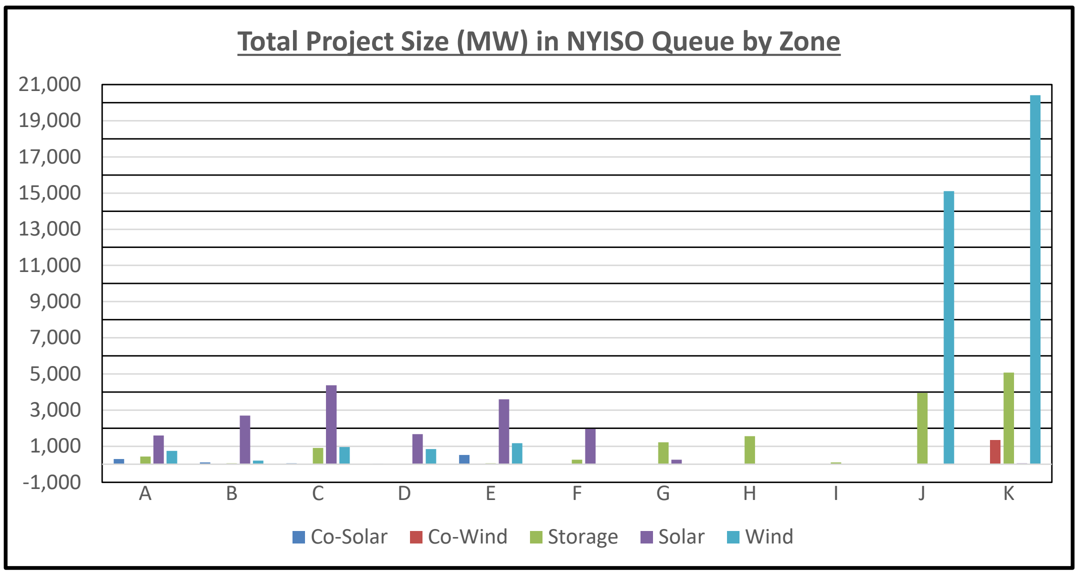
The intent is to track the growth of Energy Storage, Wind, Solar and Co-Located Storage (Solar and Wind now in separate categories) projects in the NYISO Interconnection Queue, looking to identify trends and patterns by zone and in total for the state. The information was obtained from the [NYISO Interconnection Website](), based on information published on March 21st, and representing the Queue as of February 28th. Note that 13 projects were added, and 3 were withdrawn during the month of February. Results are tabulated below and shown graphically on the next page.

Total Count of Projects in NYISO Queue by Zone					
Zone	**Co-Solar**	**Co-Wind**	**Storage**	**Solar**	**Wind**
A	2		7	12	5
B	1		4	18	1
C	1		11	43	7
D	2		1	10	4
E	3		4	41	10
F			1	47	
G			12	9	
H			5		
I			1		
J			27		14
K		1	52	2	20
State	9	1	125	182	61

Total Project Size (MW) in NYISO Queue by Zone					
Zone	**Co-Solar**	**Co-Wind**	**Storage**	**Solar**	**Wind**
A	290		430	1,590	741
B	100		61	2,695	200
C	50		908	4,369	959
D	40		20	1,674	847
E	513		52	3,599	1,167
F			250	1,957	
G			1,223	250	
H			1,560		
I			100		
J			3,941		15,112
K		1,356	5,071	59	20,418
State	993	1,356	13,616	16,192	39,445

Average Size (MW) of Projects in NYISO Queue by Zone					
Zone	**Co-Solar**	**Co-Wind**	**Storage**	**Solar**	**Wind**
A	145		61	132	148
B	100		15	150	200
C	50		83	102	137
D	20		20	167	212
E	171		13	88	117
F			250	42	
G			102	28	
H			312		
I			100		
J			146		1,079
K		1,356	98	29	1,021
State	110	1,356	109	89	647


Total Count of Projects in NYISO Queue by Zone
55
50
45
40
35
30
25
20
15
10
5
0
A
B
C
D
E
F
G
H
I
J
K
Co-Solar
Co-Wind
Storage
Solar
Wind


Total Project Size (MW) in NYISO Queue by Zone
21,000
19,000
17,000
15,000
13,000
11,000
9,000
7,000
5,000
3,000
1,000
-1,000
A
B
C
D
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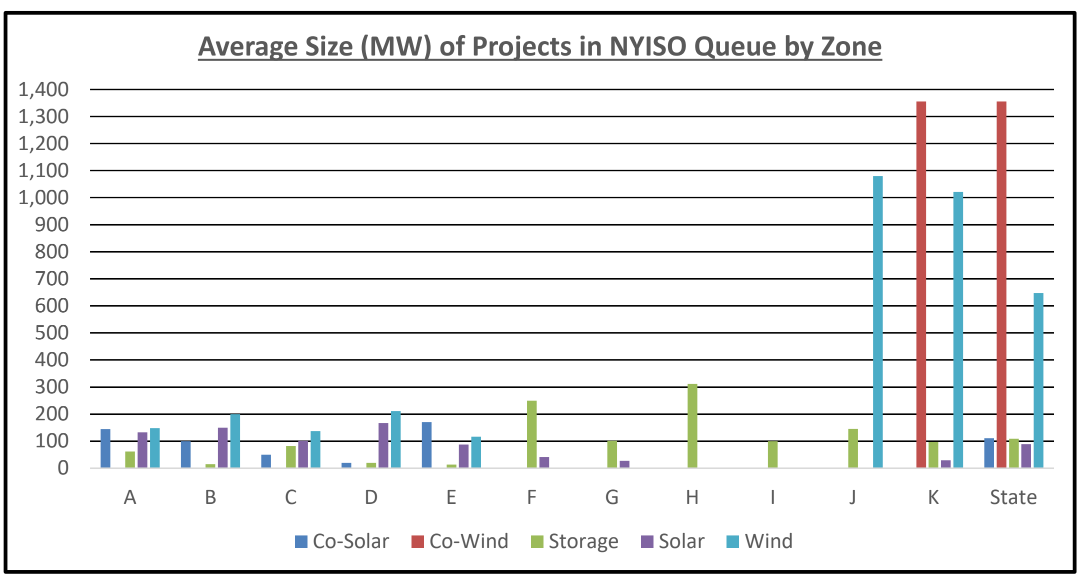
F
G
H
I
J
K
Co-Solar
Co-Wind
Storage
Solar
Wind


Average Size (MW) of Projects in NYISO Queue by Zone
1,400
1,300
1,200
1,100
1,000
900
800
700
600
500
400
300
200
100
0
A
B
C
D
E
F
G
H
I
J
K
State
Co-Solar
Co-Wind
Storage
Solar
Wind