21, rue d'Artois, F-75008 PARIS
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Hurdles in Renewable Integration – Some Practical Considerations

G. WANG[1], H. CHAO[1], F. WANG[2]
Quanta Technology[1], NextEra Energy Resources[2]
USA

SUMMARY

This paper focuses on preparing the grid to accommodate what is expected to be a high renewable future with both utility scale and distributed energy resources. The proliferation of renewable integration has posed real challenges to the electric power grid in three ways: (1) the limitation of grid delivery capability; (2) the impact on grid flexibility under changing resource mix; and (3) demand and supply balancing in seasonal and real time grid operations. This paper uses New York Independent System Operator (NYISO) system as an example to address the above challenges and discuss practical approaches to achieve optimal siting and interconnection of renewable projects and to lead to optimal grid capacity expansions.

KEYWORDS

Flexibility, Interconnection, Renewable Procurement, Reserve Requirements, Reliability, and Resiliency

swang@quanta-technology.com

1. Introduction

The rapid introduction of renewable technologies provides significant opportunities and risks to the North American electric power systems and electric power markets. In order to produce the needed amount of renewable energy required by public policies to curb the climate change, over build in renewable capacity is inevitable. There are two potential outcomes of the over-build situation: (1) Wholesale market energy prices will be lower, challenging economic viability of fossil generation to stay in operations; (2) Renewable projects are subject to high production curtailment due to resource intermittency and lack of grid deliverability capability. Extreme care must be taken so that the adoption of renewable technologies and the lack of fossil generation in the source mix do not undermine the reliability and resilience of the electric power grid, and the developed renewable projects are indeed integrated without significant curtailment of their energy productions.

To make things even more complicated, in many regions in the country, existing renewable generation is currently curtailed while state and local government agencies continue procuring renewables without full information of grid energy deliverability. Current grid planning processes do not provide the government agencies and regulators a complete picture of where the energy deliverability bottlenecks are and what are the cost-effective mitigation solutions.

Obviously, the common concern in renewables integration change is partly due to the lack of transparent data, common planning model, publicly available detailed engineering analysis of renewable systems at the state and regional scale. The engineering challenges, costs, and benefits of renewables vary as a function of the renewable share in the total resource mix. Robust high penetration renewable solutions must start with an optimal use of the existing power system assets.

Some RTOs have begun investigating the impact of current practices and modeling assumptions on the level of renewable penetration [1]. Obviously, there is a need of more thorough and systematical review of the current analytical practices, grid modeling, data collection method and categorization. It is rather urgent to look ahead, to anticipate the needs for analytical models, methods, and data for the electric power industry.

Within this framework, the paper first discussed the necessity of transparent grid data and models, including low voltage and high voltage transmission system at both state and federal jurisdictions. Then, the paper analyzed some practical issues and approaches to achieving renewables goals by addressing three major hurdles: 1) grid delivery capability; 2) grid flexibility in operation; and 3) balance of supply and demand to maintain grid reliability, resilience, efficiency, and economics.

2. Shortfalls and Improvement in Grid Planning Practices

ISO/RTOs usually prepare the data for their system information, such as load, capacity, and transmission upgrade, for current and future years for the public and market participants [2-3]. Those data are important for decision makers to invest on additional renewable projects, and coordinate on system operation strategy. However, current grid planning practices have the following shortfalls:

- A piecemeal approach in addressing local transmission and distribution (byway) congestion may lead to uneconomic, inefficient, and ineffective outcomes. What can be worse is when the byway constraints (e.g., 115 kV and below transmission) are fixed, highways (e.g., 230 kV and above transmission) may become congested, resulting in ineffective transmission expansion.
- Robust and cost-effective renewable development should be developed on optimal use existing power system. Lack of a common model and separations of byways from and highways have prevented renewable developers and renewable energy contracting counterparties form effectively evaluating and executing renewable energy procurement programs.

- There is no comprehensive grid level operating needs assessment on an on-going basis. Grid flexibility needs are critical in setting proper planning and operating reserve requirements. Transmission transfer capability, grid voltage and stability performance, and grid black-start capability are the deciding factors in planning for the installed reserve margin in the world of changing demand and resource mixes.

Regions and states need a process to look at how the challenges of incorporating renewables change with increasing penetration. This process would enable a consistent, continuing, and detailed engineering and economic analysis of renewable systems at the state level for policy-making and regulation. Taking the case of New York state as an example, the Climate Leadership and Community Protection Act (CLCPA) mandates that New York consumers be served by 70% renewable energy by 2030 ("70x30"). NYISO's economic planning study (CARIS) report [4] defines the 70x30 scenario's demand and renewable generation as Table I.

TABLE I - NEW YORK RENEWABLE ENERGY GOALS

Year	Gross Load (GWhs)*	Renewable Energy (GWhs)	Renewable Energy (%)
2030	162,378	113,665	70

* After energy efficiency and demand side management

In 2019, renewable energy generation was 37,294 GWh, 28% of total NYCA generation. including hydro, wind, solar and biomass as shown in Table II.

TABLE II - NEW YORK FUEL MIX IN 2019

Generator Type	GWhs	Percentage (%)
Fossil	51,870.9	38.5%
Pump Storage	583.1	0.4%
Hydro	30,140.9	22.4%
Nuclear	44,787.9	33.3%
Methane	660.9	0.5%
Solar	52.1	0.04%
Solid Waste	1,986.9	1.5%
Wind	4,453.6	3.3%
Total:	134,536.3	100%

Hence a tripling of energy from renewable resources will be required to reach the 70x30 goal of 113,665 GWH. Large scale installation of variable renewable resources including wind and solar PV require special attention when considering installed capacity reserves to meet generation system reliability criteria. The concept of effective load carrying capability (ELCC) [5] is used to measure how effective a resource can produce energy when the grid is most likely to experience electricity shortfalls under a certain resource mix condition. A variable resource such as solar or wind has ELCC at 30-40% when the grid has large amount of fuel certain generation resources (e.g., pondage hydro and fossil generation is above 50% of the resource mix). This ELCC drops to single digit in percentage point if the fuel certain generation is decreased to less than 20% in the total resource mix, meaning the renewable solar or wind alone will be extremely ineffective in carrying the demand.

The common analysis models would enable the federal and state agencies to coordinate and incorporate the various inputs and changing variables in the planning process to bridge the jurisdiction gaps. The commonly available model and data would ensure the later-procured renewable projects will not cause production curtailments to the renewable projects, existing or previously procured/contracted, due to increased grid congestion if no new transmission is properly and timely built.

We performed energy deliverability and curtailment studies for the projects that passed NYISO Class Year reports [6] or contracted under NYSERDA Tier 1 REC or RPS [7] for 2025 and 2030. The following table illustrates curtailment performance for 10 projects assuming that all transmission facilities are in service. The 2030 case included additional renewable projects to meet the 70x30 goal consistent with the resource mix defined in [4]. Obviously, even with the optimistic assumption that all circuits are in-services, there will be curtailments in 2025, and the curtailment increases from 2025 and 2030.

TABLE III - NEW YORK RENEWABLE CURTAILMENT IN 2025 AND 2030

NYSERDA REC Projects	MW Capacity	2025 curtailment	2030 curtailment
Project 1	100.0	2.4%	6.5%
Project 2	50.0	0.7%	12.1%
Project 3	90.0	9.1%	13.2%
Project 4	50.0	0.0%	0.0%
Project 5	180.0	0.7%	0.1%
Project 7	80.0	0.0%	0.9%
Project 8	280.0	0.0%	0.0%
Project 9	200.0	0.0%	0.4%

It is desirable for the common model to embrace the byway models, considerations, and inputs in the bulk power transmission planning process to address byway concerns to achieve overall transmission efficiency to accommodate renewable development and integration. In other words, fixing the byway issues after the highway project is selected in the regional process can increase the cost of the highway project and reduce the economic efficiency and effectiveness of the transmission expansion for renewable energy deliverability.

3. Grid Flexibility

High penetration of variable renewable resources may hinder reliable grid operation in 2030 or even sooner. The fix could be very expensive if renewable procurement programs do not require an appropriate amount of dispatchable resources within the total resource mix in the renewable contracting process.

Although the above planned scenario of variable renewable resources (Solar, Behind-the-Meter Solar, onshore and offshore wind, etc.) can allow the New York state to reach the 70x30 goal, the hourly power penetration of these variable resources can reach over 100% of the demand. Figure I shows in simulation results of year 2030, the instantaneous over-generation percentile of variable renewable penetration (VRE) against NYISO demand. Figure II shows the highest VRE production against load ratio for year 2020, 2025 and 2030, compared with each year’s renewable penetration level. It can be observed that in 2030 when renewable penetration reached 70%, VRE can exceed 100% of New York load over 950 hours, if not mitigated, leading to an excess of renewable generation as high as 13 GW. Even after accounting for the planned storage of 3 GW per the CLCPA requirement and the existing pumped hydro of 1.4 GW together with exchanges with external power pools, the excess variable generation will be difficult or impossible to manage with emission-free dispatchable resources unless curtailed, which will inhibit achieving the 70x30 goal. Reaching the 70x30 CLCPA goal will require both the existing resources and the development of newer, dispatchable, carbon-free technologies to mitigate the risk to ratepayers and shift it to investors.

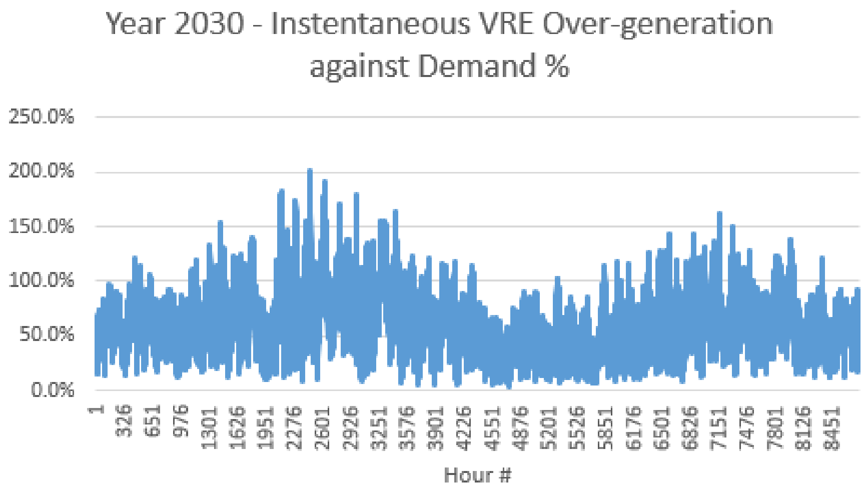

FIGURE I - NEW YORK YEARLY RENEWABLE PENETRATION VS LOAD IN 2030

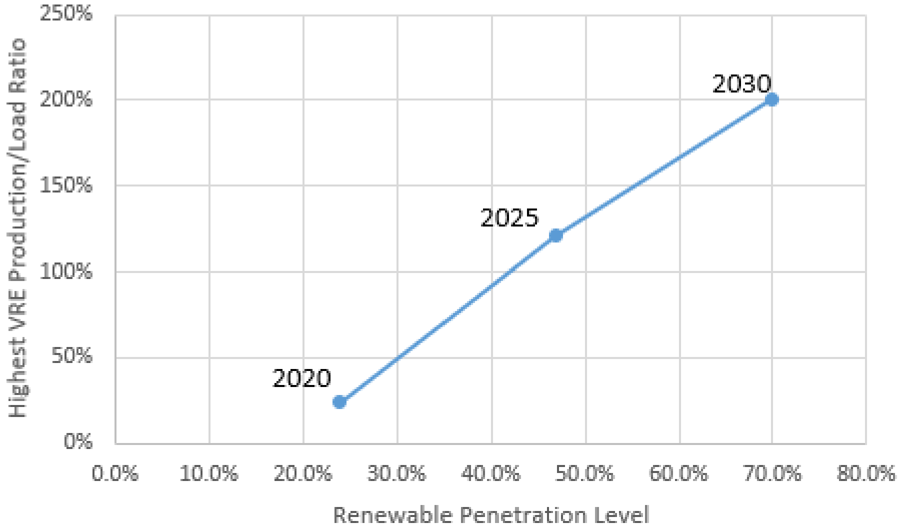

FIGURE II – HIGHEST VRE PRODUCTION/LOAD RATIO IN 2020 AND 2030

This gap is expected to be much larger when considering the following factors:

- Need to observe minimum-run limits on remaining fossil resources
- Unavailability and non-perfect alignment of solar, wind, and offshore wind resources can increase the instantaneous over-generation, complicating the grid operation
- Transmission congestion prevents the effective use of grid regulating generation capacity.

Another question is what changes in operations will be required with the large-scale installation of generation based on variable, renewable resources especially considering the new goal of defined annual production from renewable resources. What changes in procedures will be required for setting short term, day-ahead schedules including unit commitment, operating and spinning reserves, regulation and ancillary services. Without asking these questions in the planning modeling and studies, a reliable system operation in the future would be at risk.

Today, in operating the NYISO grid, the grid operators rely on sufficient generation capacity with flexibility locally for resource adequacy and require generation to mix fuel burn (i.e., natural gas plus oil) for loss of fuel contingencies. If the resources do not have the flexibility and certainty in sustained energy production, it will be a daunting task for the grid operator to manage high-risk periods, such as when solar output is at or near zero or when there is no wind, too high wind, or frozen turbines. Reliability risks—such as new stability concerns, shifting periods of grid stress, energy shortage, and inadequate resource capacity—must be identified and fully understood while we are achieving the 70x30 goals.

Reaching the 70x30 CLCPA goal, including the electrification of the economy by just over-building the number of variable resources, over and above the capacity of all existing fossil resources that will be replaced, is a risk to reliability. Again, grid operators would need more dispatchable and long-duration energy resources to manage the substantially different systems to maintain reliability in 2030.

The lack of flexibility and electric demand is predicted through the analysis of the load and renewable profiles and is shown in Figure I and II. Table IV illustrates inevitable renewable curtailment at different levels of renewable penetration.

TABLE IV - NEW YORK RENEWABLE CURTAILMENT IN 2030

Max VRE Penetration Limit %	Renewable Curtailment %	Renewable Curtailment after 4.4GW Storage
100%	5.1%	1.6%
90%	7.9%	2.7%
80%	11.7%	4.3%
70%	16.8%	6.8%
60%	23.4%	**10.3%**

Increasing grid data transparency can inform optimal siting and operations of aggregated dispatchable resources, including behind-the-meter DERs. Similarly, it will also be useful when procuring/contracting renewable and storage capacity to specify grid modernization technologies such as advanced “smart” inverters, DER management systems (DERMS), and Synchro-phasor measurements that can support grid flexibility needs.

4. Grid Operation and Resilience

The planned resource portfolio to reach 70x30 as utilized by NYISO in its 2020 RNA study [8] showed the need for additional resources consisting of 350 MW in Zone J to address resource adequacy and 1,390 MW to address transmission security and system stability. The RNA models were modest on electrification. Thus, after utilizing the CLCPA forecasts [2], additional resource requirements to address resource adequacy alone will rise from 350 MW to 2,650 MW. An investigation is required to regularly quantify the required additional resources to address transmission security, system stability, power ramping, inertial response, primary and secondary frequency response, and short circuit strength. These gaps will require additional resource investments beyond what is planned by utilities, policy makers, and renewable development.

Analysis of the hourly profiles of load, solar, wind, and offshore wind of the 2030 scenario shows that increasing levels of uncontrolled power ramps will occur as more renewables are installed. These sustained power ramps will reach 30 GW over a period from 8am to 6pm and will experience a maximum hourly ramp of 13 GW midday. These high-power ramps will require the provision of ramping resources to maintain system frequency.

Also, the reduction in short circuit currents driven by the prevalence of inverter-based resources (IBRs) will have two serious risks that should be investigated:

a. The first relates to the short circuit ratio (SCR) limits and the ability of the NY grid to integrate the required MWs of IBRs without destabilizing the inverter controls,

b. The second relates to the ability of the protection system to detect faults.

The short circuit impact can limit the number of renewable interconnections, require a serious investigation to set a minimum level of SCR for the IBR projects, or pose a safety risk due to the need to upgrade the protection system.

A report [9] issued by the New York Independent System Operator in response to the Clean Energy Standard discusses steps being undertaken to respond to the planning and operational issues being raised. For example, the report notes that large scale distributed renewable energy resources behind-the-meter and the advent of micro-grids will require amendment of load forecasting procedures and acceleration of smart grid technologies to monitor and control these distributed energy resources. In addition, as discussed above the use of battery energy storage and hydro storage to complement the variable aspect of generation is an important requirement in the grid operations as well as being the flexible generation in load following, interchange and frequency regulation by automatic generation control and generation dispatch. It is apparent that large scale introduction of generation based upon renewable, variable resources will require coordination with installation of energy storage facilities with controllability capability for dispatch and regulation.

5. Conclusions

This paper discussed major issues and challenges for the grid with high variable renewable integration, and the needs for transparent planning practices to address those issues. First of all, detailed common grid models are necessary for grid and market participants to coordinate and incorporate the various inputs and changing variables in the planning process to increase overall renewable utilization and effective integration. Secondly, regular and transparent planning studies based on the common models provide the critical information for the renewable development and renewable energy procurement. The common data model should be kept updated and the planning studies should be frequently performed to continuously monitor the grid performance and the economic development of the renewable resources.

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