Some Operational Implications of High SPV Penetration for New York

Arvind Jaggi
Senior Economist
New York Independent System Operator

DOE/SunShot Solar Forecasting Workshop
August 3, 2016
Washington, DC

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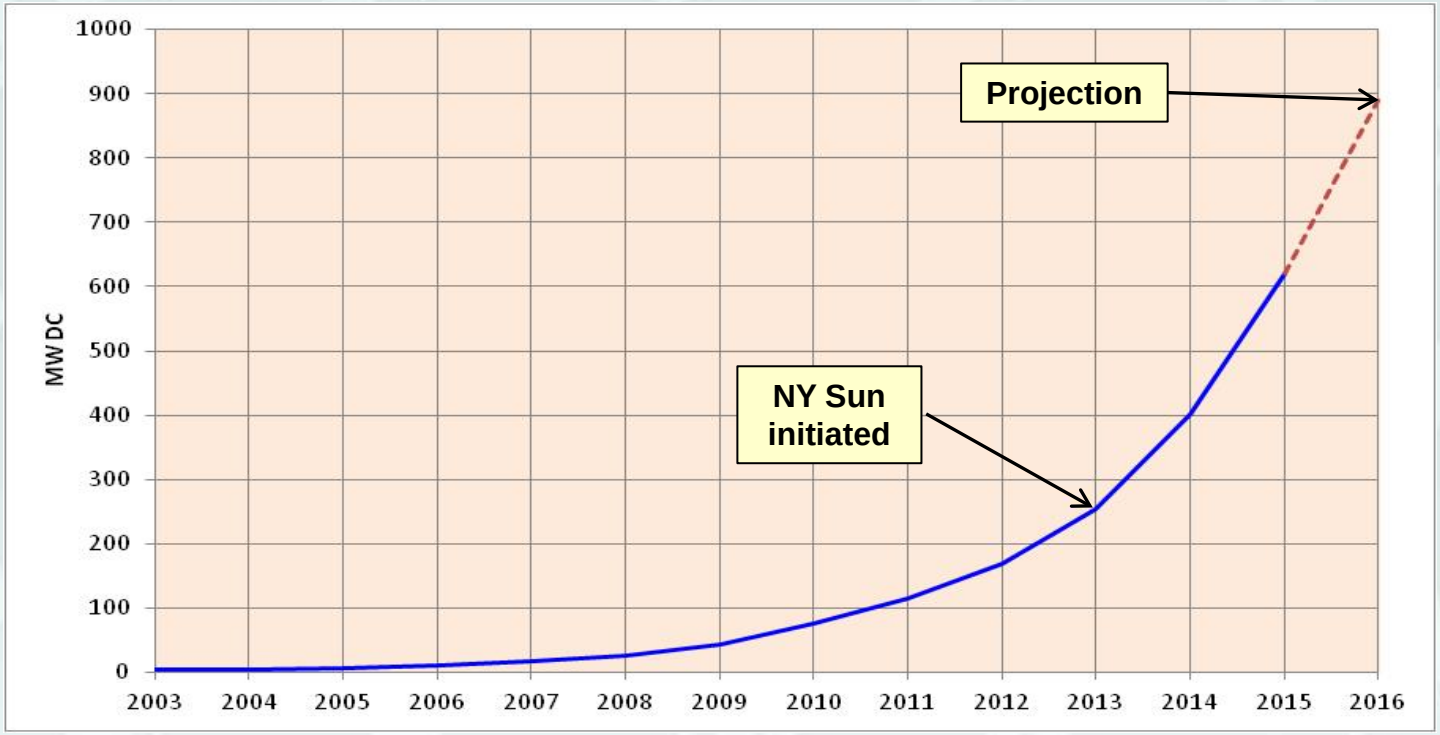
Background of Solar in New York

- ***Growth of behind-the-meter (BTM) Solar Photovoltaic (SPV) capacity* in New York is strongly influenced by public policy initiatives, including those in the State Energy Plan.***

- ***NY Sun committed $1b in 2014 to enable over 3,000 MW of BTM capacity by 2023 with capacity goals apportioned across the state's regions and across sectors.***

***This presentation pertains to BTM installations but does not address the NYISO's Behind-The-Meter Net Generation (BTM:NG) program. *See* FERC Docket No. ER16-1213. All SPV capacity is in MW DC terms.**

SPV Capacity in New York: History



As of 6/30/2016, there were about 720 MW of BTM capacity installed and almost 900 MW of approved projects in the pipeline.

NYISO Solar Study

- ***On Jun. 30, 2016, the NYISO released its study "Solar Impact on Grid Operations - An Initial Assessment."****

- ***Among other issues, the study investigated the impact of various penetration levels of SPV and wind on NYCA's Regulation Requirements used in grid operations to balance the system and maintain frequency.***

****http://www.nyiso.com/public/webdocs/markets_operations/services/planning/Documents_and_Resources/Special_Studies/Special_Studies_Documents/Solar%20Integration%20Study%20Report%20Final%20063016.pdf***

Implications for Regulation

- ***Due to lack of visibility of BTM SPV to system operators and intermittency of SPV and wind, patterns of their combined generation resemble load more than conventional generation.***

- ***System Regulation allows for a response to the variability of Net Load that may occur over a 5-minute dispatch interval to maintain the simultaneous balance of resources and load in operations.***

Regulation Analysis Details

Methodology for calculating Net Load variability*

$$\text{Net Load}_t = \text{Base Load}_t - \text{Wind Gen}_t - \text{SPV Gen}_t$$

$$\text{Net Load}_{t-5} = \text{Base Load}_{t-5} - \text{Wind Gen}_{t-10} - \text{SPV Gen}_{t-10}$$

$$\text{Net Load Delta}_t = \text{Net Load}_t - \text{Net Load}_{t-5}$$

- ***The standard deviation (sigma) of the Net Load Delta is then analyzed to assess the variability from interval to interval.***
- ***The resulting 3-sigma value represents the amount of Regulation resources required to manage Net Load variability.***

*** Renewable variability is based on a 10-min delta (as opposed to a 5-min delta for load) using a persistence assumption for forecasting the next interval's output.**

NYISO Solar Study Details

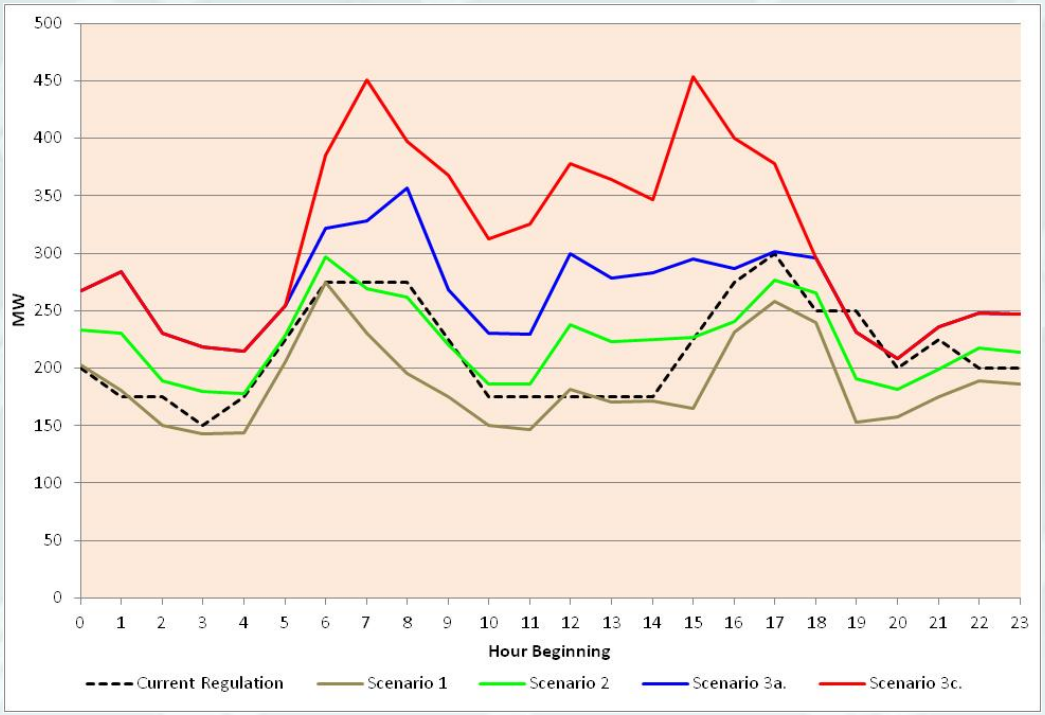
Solar Study Scenarios

	Wind	SPV
Scenario 1	2500 MW	1500 MW DC
Scenario 2	3500 MW	3000 MW DC
Scenario 3a	4500 MW	4500 MW DC
Scenario 3c	4500 MW	9000 MW DC

Season Definitions

Winter	Nov. - Mar.
Summer	Jun. - Aug.
Spring	Apr. - May
Fall	Sep. - Oct.

Regulation Requirement Impacts: Winter

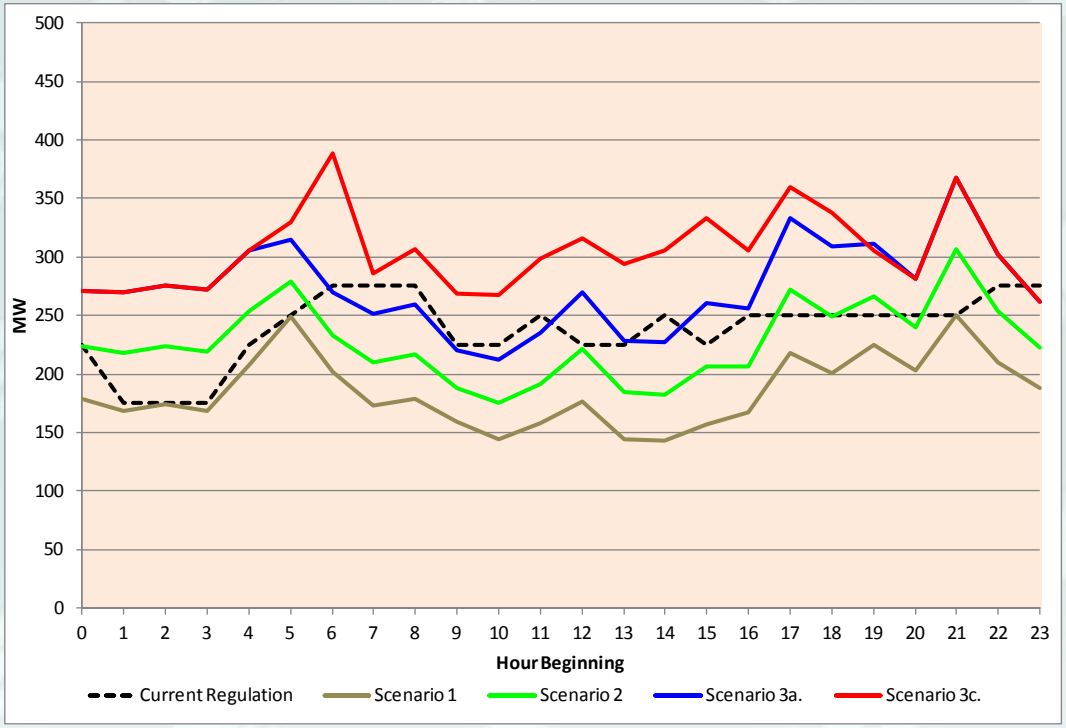


Wind capacity factors are highest during Winter months

- ***High SPV penetration scenarios warrant increase in Regulation –in part due to Wind and interaction between Wind and SPV***
- ***Morning and mid- to late-afternoon see spikes***

The data displayed is from the NYISO's *Solar Impact on Grid Operations - An Initial Assessment* study.

Regulation Requirement Impacts: Summer



NYCA is Summer peaking with the highest loads during July to August period.

- ***Modest requirement changes during Summer months in high SPV penetration scenarios***
- ***Pre-dawn and post-dusk hours shaped by Wind variability***

The data displayed is from the NYISO's *Solar Impact on Grid Operations - An Initial Assessment* study.

Projected Regulation Changes: Example

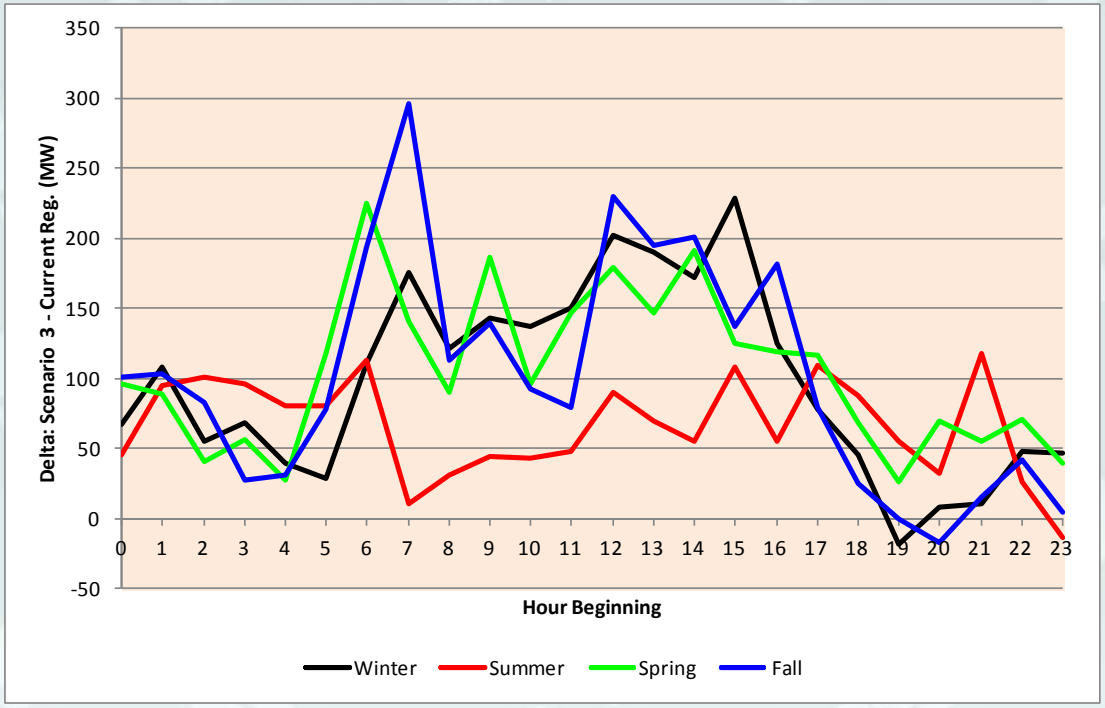
Scenario 2: 3,000 MW of SPV & 3,500 MW of Wind

	Winter		Summer		Spring		Fall	
Hour Beginning	Current	Projected	Current	Projected	Current	Projected	Current	Projected
0	200	200	225	225	175	175	175	175
1	175	175	175	175	175	175	175	175
2	175	175	175	175	175	175	150	150
3	150	150	175	175	175	175	175	175
4	175	175	225	225	225	225	225	225
5	225	225	250	250	225	225	275	275
6	275	275	275	275	225	225	275	300
7	275	275	275	275	200	225	250	275
8	275	275	275	275	200	200	225	225
9	225	225	225	225	175	200	200	225
10	175	200	225	200	200	200	175	225
11	175	200	250	200	200	225	200	225
12	175	250	225	225	175	225	200	275
13	175	225	225	200	175	200	200	250
14	175	250	250	200	175	225	175	225
15	225	250	225	225	175	200	175	225
16	275	275	250	250	175	225	200	200
17	300	300	250	275	200	225	250	250
18	250	275	250	250	225	250	275	275
29	250	250	250	250	250	275	250	250
20	200	200	250	250	200	250	250	250
21	225	225	250	250	200	200	250	250
22	200	200	275	275	200	200	200	200
23	200	200	275	275	200	200	225	225

- ***Most projected increases are during midday hours in non-Summer months.***
- ***With longer days, Spring sees increases well into the late evening hours.***
- ***Summer sees decreases due to SPV (except for HB17 when sun angle dips) and relatively low wind capacity factors.***

The data displayed is from the NYISO's *Solar Impact on Grid Operations - An Initial Assessment* study.

Regulation Requirement Comparison



This shows the delta between the High SPV scenario levels and the current Regulation requirements

- ***Wind Capacity Factors are highest in Winter, followed by Fall and Spring; lowest in Summer***
- ***Winter, Spring, and Fall exhibit comparably high levels of Regulation Requirement increases***

The data displayed is from the NYISO's *Solar Impact on Grid Operations - An Initial Assessment* study.

Impact of SPV on Regulation

- ***The above analysis was extended to simulate two new sets of scenarios – one that excluded Wind additions (i.e. Wind = 0) and varied SPV levels, and the other that kept Wind constant at 3,500 MW and varied the SPV levels across the 4 scenarios.***

- ***The difference in impacts between these two additional sets of scenarios was analyzed to assess the marginal impact of SPV alone on Regulation Requirements.***

Regulation Implications of SPV

- ***Preliminary analysis failed to show any projected changes to Regulation Requirements at the 1,500 MW and 3,000 MW.***

- ***Preliminary analysis reveals that only at very high penetration levels (i.e. 9,000 MW) does the Regulation Requirement become sensitive to SPV; changes to Regulation at low to moderate levels of SPV (1,500 MW – 4,500 MW) are ostensibly due to variability of wind generation.***

Theoretical Sensitivity of Regulation*

Additional Regulation: Winter

HB	Current Level	4500PV	4500PV& 3500Wind	4500PV& 4500Wind	9000PV	9000PV& 3500Wind	9000PV& 4500Wind
6	275	0	30	46	62	94	110
7	275	9	29	53	164	167	176
8	275	59	72	82	93	110	122
9	225	0	25	43	104	129	143
10	175	0	33	55	98	121	138
11	175	8	35	55	129	139	150
12	175	12	83	124	122	171	203
13	175	13	71	103	126	166	190
14	175	0	69	108	120	152	172
15	225	0	43	70	180	212	229
16	275	0	0	12	71	108	126
17	300	0	0	0	29	53	78
18	250	0	22	46	0	22	46

Additional Regulation: Summer

HB	Current Level	4500PV	4500PV& 3500Wind	4500PV& 4500Wind	9000PV	9000PV& 3500Wind	9000PV& 4500Wind
6	275	0	0	0	102	107	113
7	275	0	0	0	0	0	11
8	275	0	0	0	0	6	31
9	225	0	0	0	0	26	44
10	225	0	0	0	10	31	43
11	250	0	0	0	10	30	48
12	225	0	8	45	37	73	90
13	225	0	0	0	57	56	69
14	250	0	0	0	27	38	56
15	225	0	0	36	17	80	108
16	250	0	0	6	0	26	55
17	250	0	31	83	0	59	109
18	250	0	0	59	0	39	87

- ***With wind resource levels and variability considerably higher, Winter months see expected increases across most hours.***
- ***SPV's relative impact becomes significant only at high penetration levels.***
- ***Even in the high SPV +Wind penetration scenario, incremental needs seem reasonable.***

*** These figures are merely notional and indicative of directionality and relative magnitude.**

Ramping Implications of SPV

- ***Also of concern to system operators is the implication of high SPV penetration for load profiles, specifically the morning build-up of SPV generation and the need for ramping of conventional generation as the sun angle dips in the afternoon.***

- ***While New York's geographic location and climatic conditions do not quite present a 'Duck Curve' like scenario, nonetheless potential ramping needs are a critical issue.***

Ramping Analysis Details

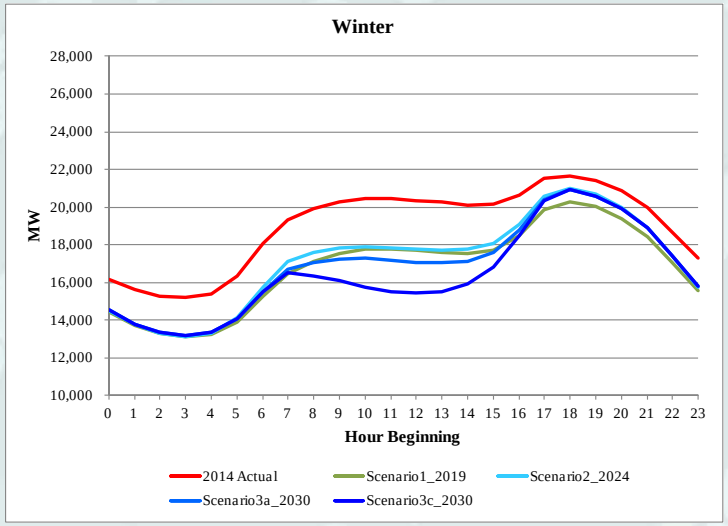
- ***NYISO analyzed hourly performance data from over 200 large C&I SPV installations (almost 100 MW) over multiple years to assess intra-day generation variability across seasons and the state's regions.***
- ***Note: This analysis generalizes results based on the available data for C&I systems with unknown tilt. Including Residential systems can introduce greater spatial and temporal differences in capacity factors and peak performance.***

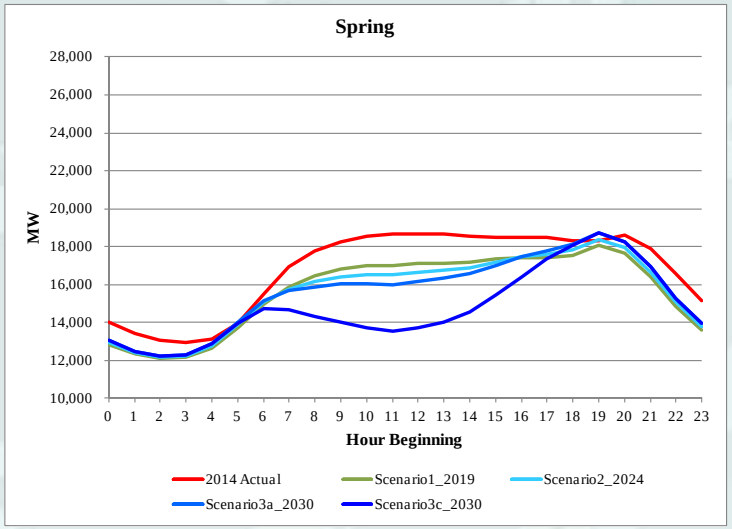
Ramping Analysis Assumptions & Details

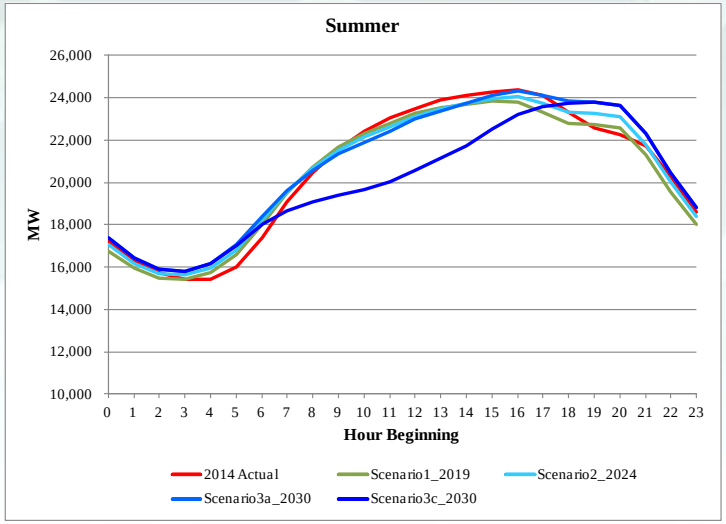
- ***3 regions analyzed: Upstate (Zones A–E), Hudson Valley (Zones F & G), & Con Edison Area (Zones H-J).***
- ***For each region, hourly MW output for 2014 & 2015 was normalized for DC capacity and then averaged to yield typical daily profiles by season.***
- ***<u>Morning buildup</u>: Rise in per-MW average output between 7 am and 10 am.***

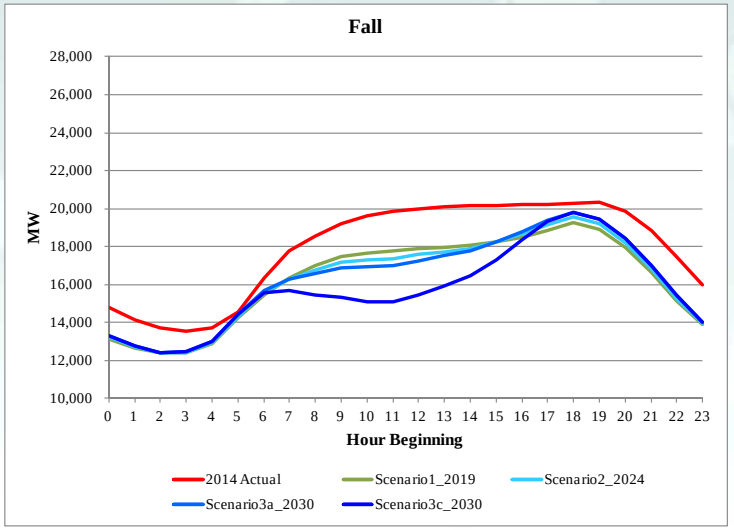
  <u>Afternoon decline</u>: Fall in per-MW average output between 2 pm and 5 pm.

Typical Seasonal Load Shapes: NYCA

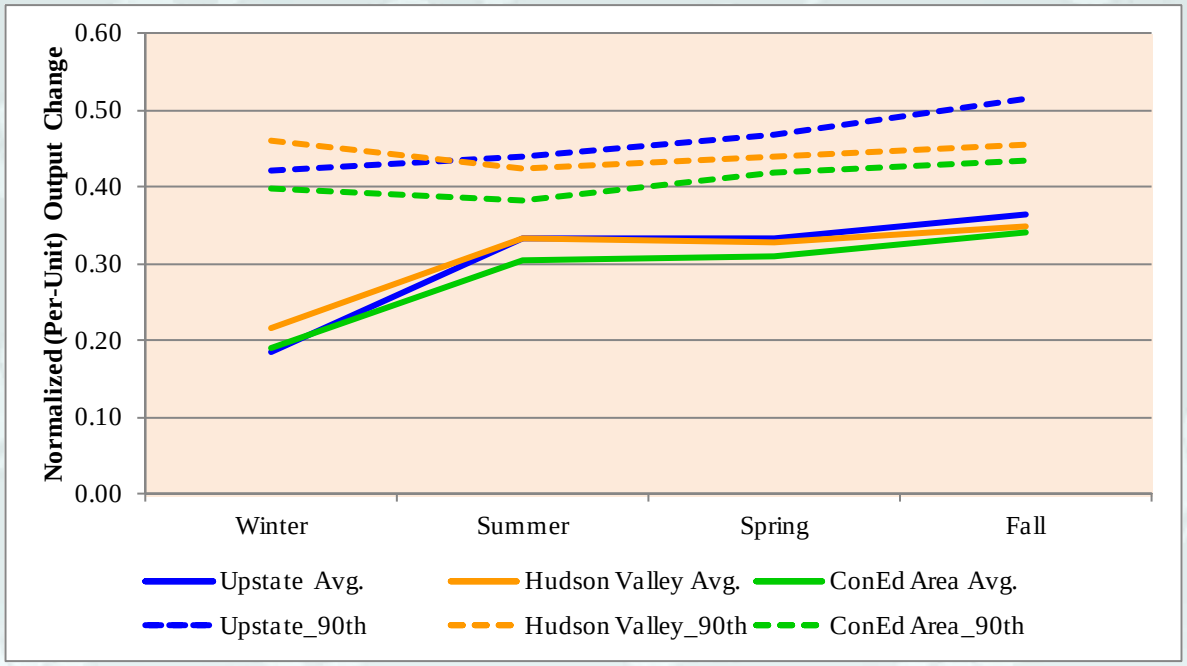








Ramping Analysis: Morning 7 am to 10 am

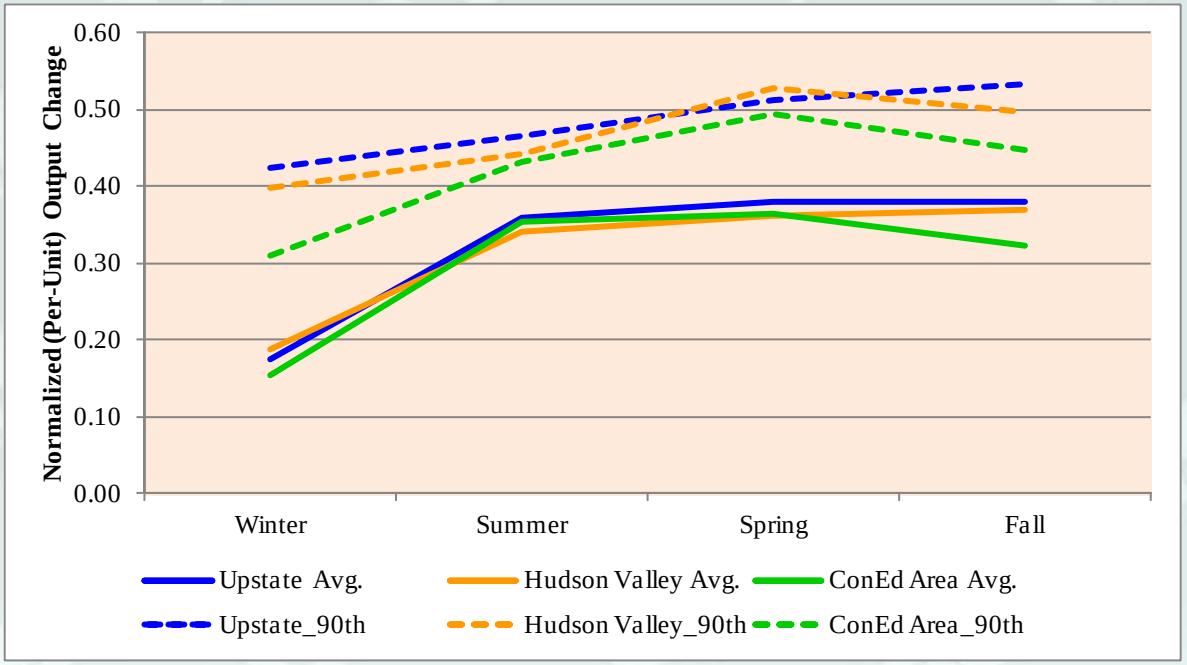


- ***A 0.3 level implies SPV output increases by 3 MW per I0 MW of capacity during the morning period.***

- ***Cloudiness/fog explain low Winter rates.***

- ***Similarity in typical regional system performance***
- ***Disparity at the high-end might suggest variability in SPV output on relatively clear mornings across both regions and seasons***

Ramping Analysis: Afternoon 2 pm to 5 pm



- ***Afternoon output decays are relatively higher except in Winter***
- ***Greater regional disparity during Fall & Winter***

- ***2000 MW system-wide implies need for around 600 MW+ (equivalent to a Combined Cycle plant) of ramping generation during Spring through Fall***
- ***The ramping needs appear fairly predictable***

Solar Forecasting at NYISO

- ***NYISO is working on implementing a Solar Forecasting system by 2017 to provide real-time MW forecasts to Operations.***

- ***The primary business justification is to mitigate the risks of over- and under-forecasts of load in day-ahead and real-time by delivering more efficient market outcomes for unit dispatch and unit commitment due to the increase in deployment of SPV systems – both BTM and utility-scale BTM:NG.***

Forecasts & Regulation

- ***Regulation is not directly affected by Wind (and SPV) forecasts. These forecasts become helpful in predicting large changes in variable generation over the 5-15 minute horizon.***

- ***NYISO Operations' main tool to accommodate such changes is the market software that responds by deploying offline fast-start units or alters interchanges with other Control Areas. Other tools are reserve pickups and curtailment of interchanges with other Control Areas, depending on the direction of the shifts in variable generation.***

Conclusions

- ***Even at high penetration levels of SPV (and wind), projected increases in Regulation Requirements are relatively modest and can likely be accommodated within the current market rules, transmission system operations, and generation resource mix. This overall finding is contingent upon the current resource mix and its capability to provide Regulation services.***
- ***Extension of NYISO's Solar study analysis suggests that only at very high penetration levels does SPV exert significant impact on Regulation.***
- ***In the studied scenarios, Ramping needs are fairly predictable and amount to around 650 MW per 2,000 MW (approximately) of SPV.***

The mission of the New York Independent System Operator, in collaboration with its stakeholders, is to serve the public interest and provide benefit to consumers by:

- ***Maintaining and enhancing regional reliability***
- ***Operating open, fair and competitive wholesale electricity markets***
- ***Planning the power system for the future***
- ***Providing factual information to policy makers, stakeholders and investors in the power system***

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