

## Wind Integration Event Frequency Study

Analysis, for various reserve amount scenarios,  
of the frequency of the following events:

- 1) limiting wind
- 2) curtailing schedules (tags)

### Overview

In order to maintain the reliability of the transmission system with increasing amounts of variable (non-dispatchable) generation, increasing with-hour reserve amounts are required. The amount of reserves needed for the projected amounts of installed wind generation by the end of FY2011 is reaching the limits of what the FCRPS can provide, and the cost of providing the reserves are felt to be excessive by the wind community. To maintain reliability, system operators take actions under certain conditions to ensure the reserves needed to maintain load and resource balance are not depleted. The wind generators have proposed that a smaller amount of reserves be maintained than is required by the current studies, which would cause the system operators to take these reliability actions more frequently, as the reserves would be depleted sooner. This study looks at the frequency of these reliability actions under different scenarios of reserve levels, with the same 21-month data set used to determine the requirement for the reserve levels.

In addition, the total reserves required by the study are allocated for rate purposes between load and wind. This study also considers how often the total wind error or total load error exceeds the allocation set aside for (and paid for) by the wind generators or load serving entities respectively, under different scenarios of reserve levels. Scenario L corresponds to the initial proposal for the 2010 Rate Case.

### Limiting Wind Generator Output

Wind generation will be limited when the total decremental (dec) reserves  $R_{dt}$  are depleted to a 90% level. For the purposes of this study, it is assumed that when the signal is given to limit wind the wind generation output is immediately limited to the dec reserves allocated to wind  $R_{dw}$ . It is also assumed that no action is taken to limit the load. If the movement of the load fully depletes the reserves after the wind has been limited to  $R_{dw}$ , it is assumed that the wind will be further limited by any reserve amount required beyond  $R_{dt}$ . The measurements identified are the average MWh per month that would be limited due to reaching the 90% depletion level, and the average MWh per month including the additional amount wind would be limited due to depletion moving beyond  $R_{dt}$ .

*Limiting Wind Generation, Scenario A through D*

- Reserves are held at a level required by a **30-minute persistence** wind estimate accuracy
- Actual wind estimates are based on
  - A – 30-minute persistence
  - B – 45-minute persistence
  - C – 60-minute persistence
  - D – 2-hour average persistence

<b>Installed Wind</b>	<b>R<sub>dt</sub> (MW)</b>	<b>R<sub>dw</sub> (MW)</b>	<b>Wind Accuracy</b>	<b>Average Hours/mo</b>	<b>90% MWh/Mo</b>	<b>Average MWh/mo</b>
<i>Scenario A</i>						
2,105	-1,287.9	-296.7	30-min	1.38	79.4	127.0
3,155	-1,472.6	-547.2	30-min	1.90	310.0	340.8
4,330	-1,754.5	-790.3	30-min	1.48	368.9	377.1
5,570	-1,971.7	-1,061.4	30-min	2.19	552.5	553.0
<i>Scenario B</i>						
2,105	-1,287.9	-296.7	45-min	1.71	181.4	229.2
3,155	-1,472.6	-547.2	45-min	2.90	725.8	756.8
4,330	-1,754.5	-790.3	45-min	3.10	982.5	990.3
5,570	-1,971.7	-1,061.4	45-min	4.10	1,429.5	1,430.8
<i>Scenario C</i>						
2,105	-1,287.9	-296.7	60-min	1.95	346.3	394.1
3,155	-1,472.6	-547.2	60-min	4.38	1,439.0	1,469.8
4,330	-1,754.5	-790.3	60-min	4.95	1,988.3	1,996.1
5,570	-1,971.7	-1,061.4	60-min	5.95	2,683.3	2,684.6
<i>Scenario D</i>						
2,105	-1,287.9	-296.7	2-hour	2.95	767.8	820.1
3,155	-1,472.6	-547.2	2-hour	8.29	3,830.2	3,867.5
4,330	-1,754.5	-790.3	2-hour	9.81	5,211.4	5,222.4
5,570	-1,971.7	-1,061.4	2-hour	12.62	7,465.3	7,466.6

*Limiting Wind Generation, Scenario E through H*

- Reserves are held at a level required by a **45-minute persistence** wind estimate accuracy
- Actual wind estimates are based on
  - *E* – 30-minute persistence
  - *F* – 45-minute persistence
  - *G* – 60-minute persistence
  - *H* – 2-hour average persistence

<b>Installed Wind</b>	<b>R<sub>dt</sub> (MW)</b>	<b>R<sub>dw</sub> (MW)</b>	<b>Wind Accuracy</b>	<b>Average Hours/mo</b>	<b>90% MWh/Mo</b>	<b>Average MWh/mo</b>
<i>Scenario E</i>						
2,105	-1,308.3	-366.0	30-min	1.19	51.3	96.2
3,155	-1,691.5	-743.1	30-min	0.86	84.5	94.5
4,330	-1,953.6	-1,013.2	30-min	0.95	160.5	161.0
5,570	-2,273.4	-1,369.1	30-min	0.71	184.6	184.8
<i>Scenario F</i>						
2,105	-1,308.3	-366.0	45-min	1.57	133.0	178.1
3,155	-1,691.5	-743.1	45-min	1.33	293.1	303.5
4,330	-1,953.6	-1,013.2	45-min	1.48	464.3	465.2
5,570	-2,273.4	-1,369.1	45-min	1.67	579.8	580.5
<i>Scenario G</i>						
2,105	-1,308.3	-366.0	60-min	1.76	246.6	291.6
3,155	-1,691.5	-743.1	60-min	2.19	604.2	614.4
4,330	-1,953.6	-1,013.2	60-min	2.67	957.7	958.6
5,570	-2,273.4	-1,369.1	60-min	3.05	1,216.7	1,217.6
<i>Scenario H</i>						
2,105	-1,308.3	-366.0	2-hour	2.57	589.2	639.6
3,155	-1,691.5	-743.1	2-hour	4.43	1,752.9	1,764.5
4,330	-1,953.6	-1,013.2	2-hour	5.76	2,838.1	2,839.1
5,570	-2,273.4	-1,369.1	2-hour	7.14	3,711.3	3,712.3

*Limiting Wind Generation, Scenario I through L*

- Reserves are held at a level required by a **2-hour average persistence** wind estimate accuracy
- Actual wind estimates are based on
  - *I* – 30-minute persistence
  - *J* – 45-minute persistence
  - *K* – 60-minute persistence
  - *L* – 2-hour average persistence

<b>Installed Wind</b>	<b>R<sub>dt</sub> (MW)</b>	<b>R<sub>dw</sub> (MW)</b>	<b>Wind Accuracy</b>	<b>Average Hours/mo</b>	<b>90% MWh/Mo</b>	<b>Average MWh/mo</b>
<i>Scenario I</i>						
2,105	-1,569.6	-641.7	30-min	0.43	0.0	17.3
3,155	-2,164.7	-1,285.7	30-min	0.10	0.0	0.1
4,330	-2,528.9	-1,687.7	30-min	0.10	1.9	1.9
5,570	-3,047.6	-2,291.3	30-min	0.05	0.7	0.7
<i>Scenario J</i>						
2,105	-1,569.6	-641.7	45-min	0.43	1.4	19.0
3,155	-2,164.7	-1,285.7	45-min	0.19	3.9	3.9
4,330	-2,528.9	-1,687.7	45-min	0.24	11.8	11.8
5,570	-3,047.6	-2,291.3	45-min	0.14	13.2	13.2
<i>Scenario K</i>						
2,105	-1,569.6	-641.7	60-min	0.57	14.8	32.3
3,155	-2,164.7	-1,285.7	60-min	0.33	26.5	27.2
4,330	-2,528.9	-1,687.7	60-min	0.52	66.6	66.8
5,570	-3,047.6	-2,291.3	60-min	0.62	74.3	74.3
<i>Scenario L</i>						
2,105	-1,569.6	-641.7	2-hour	0.86	96.5	114.3
3,155	-2,164.7	-1,285.7	2-hour	0.71	145.9	146.8
4,330	-2,528.9	-1,687.7	2-hour	1.29	364.4	365.5
5,570	-3,047.6	-2,291.3	2-hour	1.48	415.4	416.0

### **Curtailing Schedules from Wind Generators**

Schedules from Wind generators will be curtailed when the total incremental (inc) reserves  $R_{it}$  are depleted to a 90% level. For the purposes of this study, it is assumed the schedules are curtailed immediately upon reaching the 90% depletion level. The new schedule will be the actual wind output at the time of the curtailment. The change in ramp rate is assumed to be negligible for purposes of this study. If the reserves are again depleted to a 90% level after a curtailment, an additional curtailment will be performed. For study purposes, additional curtailments are limited to once every 5 minutes. The wind allocation of the reserves  $R_{iw}$  is identified but not utilized in the calculations.

*Curtailing Schedules from Wind Generation, Scenario A through D*

- Reserves are held at a level required by a **30-minute persistence** wind estimate accuracy
- Actual wind estimates are based on
  - A – 30-minute persistence
  - B – 45-minute persistence
  - C – 60-minute persistence
  - D – 2-hour average persistence

Installed Wind	R <sub>it</sub> (MW)	R <sub>iw</sub> (MW)	Wind Accuracy	Average Hours/mo	90% MWh/Mo	Average MWh/mo
<i>Scenario A</i>						
2,105	1,019.3	231.8	30-min	1.76	296.9	297.4
3,155	1,210.9	438.7	30-min	2.38	754.9	755.2
4,330	1,396.8	645.2	30-min	2.38	925.3	925.5
5,570	1,581.2	845.5	30-min	2.38	1,159.6	1,159.7
<i>Scenario B</i>						
2,105	1,019.3	231.8	45-min	2.62	511.5	512.0
3,155	1,210.9	438.7	45-min	3.43	1,378.1	1,378.5
4,330	1,396.8	645.2	45-min	4.00	2,078.4	2,078.7
5,570	1,581.2	845.5	45-min	4.48	2,865.1	2,865.2
<i>Scenario C</i>						
2,105	1,019.3	231.8	60-min	3.24	865.4	865.9
3,155	1,210.9	438.7	60-min	5.24	2,628.3	2,628.7
4,330	1,396.8	645.2	60-min	5.81	3,883.0	3,883.2
5,570	1,581.2	845.5	60-min	7.05	5,690.0	5,690.1
<i>Scenario D</i>						
2,105	1,019.3	231.8	2-hour	4.81	1,491.0	1,491.5
3,155	1,210.9	438.7	2-hour	9.00	5,414.5	5,418.8
4,330	1,396.8	645.2	2-hour	11.14	8,422.4	8,422.6
5,570	1,581.2	845.5	2-hour	13.52	13,315.8	13,315.9

*Curtailing Schedules from Wind Generation, Scenario E through H*

- Reserves are held at a level required by a **45-minute persistence** wind estimate accuracy
- Actual wind estimates are based on
  - *E* – 30-minute persistence
  - *F* – 45-minute persistence
  - *G* – 60-minute persistence
  - *H* – 2-hour average persistence

<b>Installed Wind</b>	<b>R<sub>it</sub> (MW)</b>	<b>R<sub>iw</sub> (MW)</b>	<b>Wind Accuracy</b>	<b>Average Hours/mo</b>	<b>90% MWh/Mo</b>	<b>Average MWh/mo</b>
<i>Scenario E</i>						
2,105	1,086.0	300.1	30-min	0.86	156.0	156.5
3,155	1,334.3	532.1	30-min	0.95	331.3	331.5
4,330	1,585.8	817.2	30-min	0.95	375.0	375.1
5,570	1,841.3	1,143.3	30-min	0.81	431.1	431.1
<i>Scenario F</i>						
2,105	1,086.0	300.1	45-min	1.38	326.3	326.7
3,155	1,334.3	532.1	45-min	2.00	878.1	878.4
4,330	1,585.8	817.2	45-min	1.81	1,100.5	1,100.5
5,570	1,841.3	1,143.3	45-min	1.81	1,362.1	1,362.1
<i>Scenario G</i>						
2,105	1,086.0	300.1	60-min	2.48	689.2	689.6
3,155	1,334.3	532.1	60-min	2.90	1,518.6	1,518.9
4,330	1,585.8	817.2	60-min	3.10	2,139.6	2,139.7
5,570	1,841.3	1,143.3	60-min	2.95	2,551.2	2,551.2
<i>Scenario H</i>						
2,105	1,086.0	300.1	2-hour	3.38	1,159.2	1,159.7
3,155	1,334.3	532.1	2-hour	5.81	3,543.2	3,543.4
4,330	1,585.8	817.2	2-hour	5.90	4,746.1	4,746.2
5,570	1,841.3	1,143.3	2-hour	6.67	6,749.6	6,749.6

*Curtailing Schedules from Wind Generation, Scenario I through L*

- Reserves are held at a level required by a **2-hour average persistence** wind estimate accuracy
- Actual wind estimates are based on
  - *I* – 30-minute persistence
  - *J* – 45-minute persistence
  - *K* – 60-minute persistence
  - *L* – 2-hour average persistence

<b>Installed Wind</b>	<b>R<sub>it</sub> (MW)</b>	<b>R<sub>iw</sub> (MW)</b>	<b>Wind Accuracy</b>	<b>Average Hours/mo</b>	<b>90% MWh/Mo</b>	<b>Average MWh/mo</b>
<i>Scenario I</i>						
2,105	1,256.9	492.6	30-min	0.10	16.6	16.9
3,155	1,618.0	855.2	30-min	0.14	86.3	86.3
4,330	1,938.7	1,228.4	30-min	0.14	101.0	101.0
5,570	2,386.1	1,749.2	30-min	0.05	31.3	31.3
<i>Scenario J</i>						
2,105	1,256.9	492.6	45-min	0.38	56.8	57.1
3,155	1,618.0	855.2	45-min	0.57	284.3	284.3
4,330	1,938.7	1,228.4	45-min	0.43	250.7	250.7
5,570	2,386.1	1,749.2	45-min	0.24	125.6	125.6
<i>Scenario K</i>						
2,105	1,256.9	492.6	60-min	0.71	216.3	216.6
3,155	1,618.0	855.2	60-min	0.76	450.9	450.9
4,330	1,938.7	1,228.4	60-min	0.71	584.0	584.0
5,570	2,386.1	1,749.2	60-min	0.67	594.0	594.0
<i>Scenario L</i>						
2,105	1,256.9	492.6	2-hour	0.95	402.3	402.6
3,155	1,618.0	855.2	2-hour	1.33	979.2	979.2
4,330	1,938.7	1,228.4	2-hour	1.57	1,475.7	1,475.7
5,570	2,386.1	1,749.2	2-hour	1.29	1,639.3	1,639.3