Wind Integration: ERCOT Experience

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ERCOT System Planning

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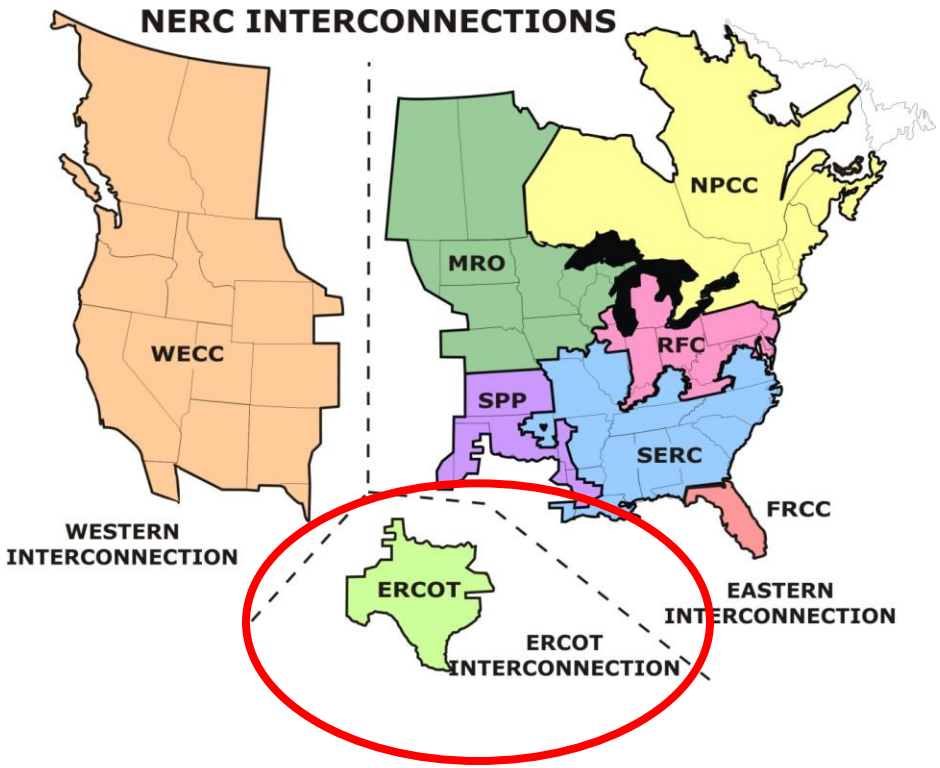
Outlines

- **ERCOT Quick Facts**
- **Competitive Renewable Energy Zone (CREZ) project**
- **Wind Generation Resource (WGR) Protocol Requirement:**
  - Voltage, Frequency
- **Tools**
  - Wind Day-Ahead Forecast and Ramp Forecast Tool
  - ERCOT Reliability Assessment Tool
  - Market Analysis Interface Tool
  - Inertial Frequency Response Estimator Tool
- **Challenges**
  - Weak Grid
  - Sub-synchronous Control Interaction

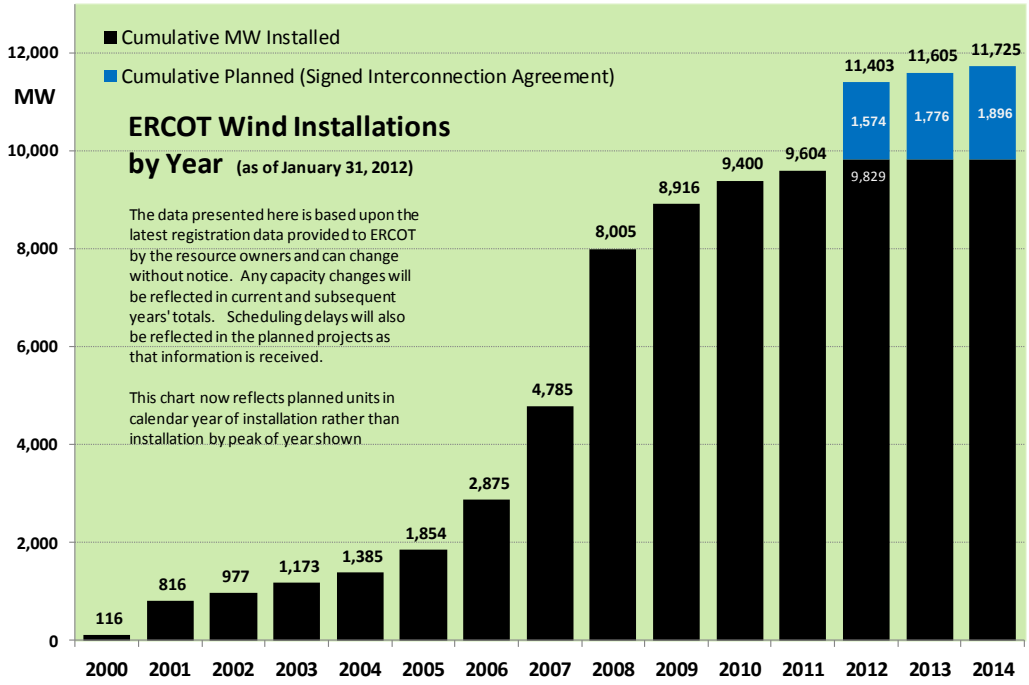
Quick Facts

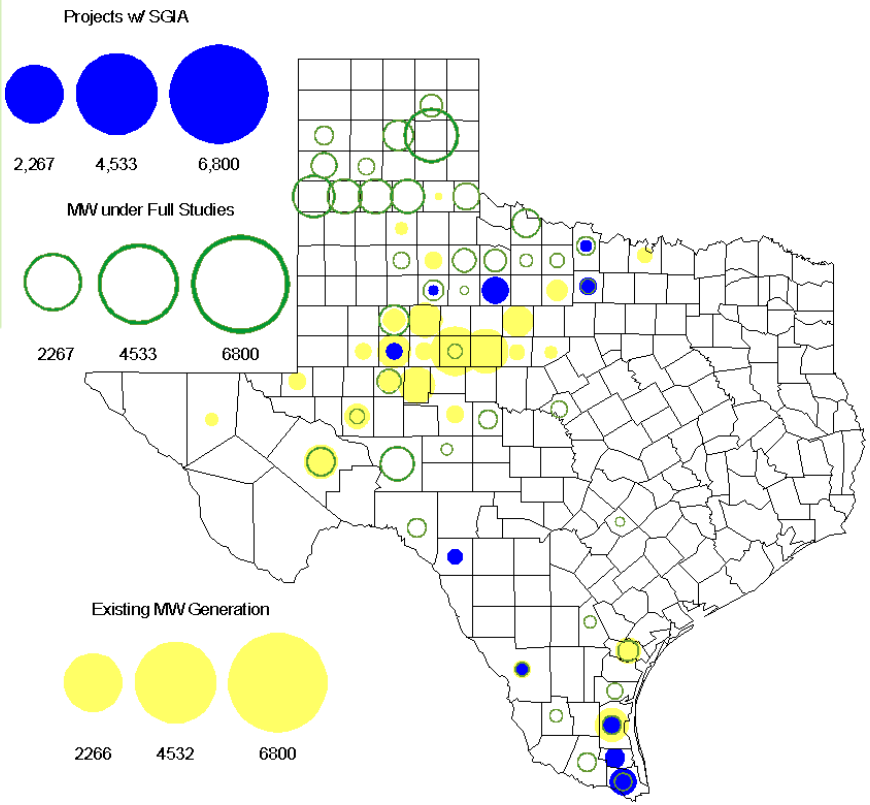


ERCOT connections to other grids are limited to direct current (DC) ties, which allow control over flow of electricity

- **Electric Reliability Council of Texas – the ERCOT grid:**
  - Covers 75% of Texas land
  - Serves 85% of Texas load
  - >40,000 miles of transmission lines
  - >550 generation units
  - Peak Load: 68,379 MW (Aug 3, 2011)
- **Wind Integration**
  - Wind capacity: ~9,800 MW
  - Most in the nation and fifth highest in the world
  - Includes about 2,000 MW in coastal area
  - Wind generation record: 7,400 MW (Oct. 7, 2011),15.2 percent of load at the time

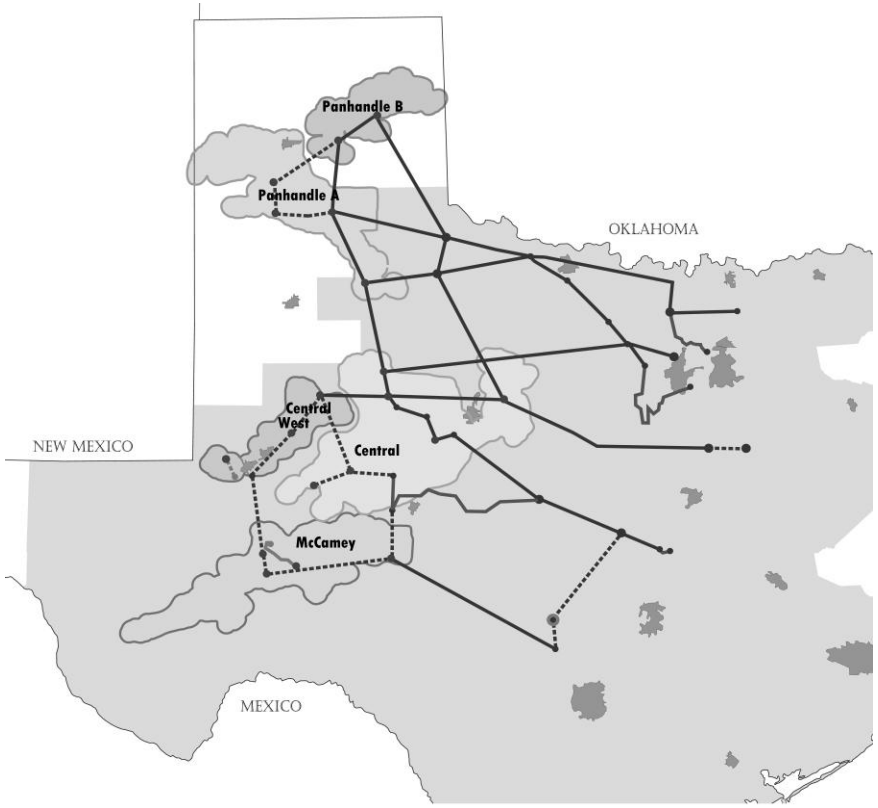
Wind Capacity Installed by Year and Locations





CREZ System Characteristics

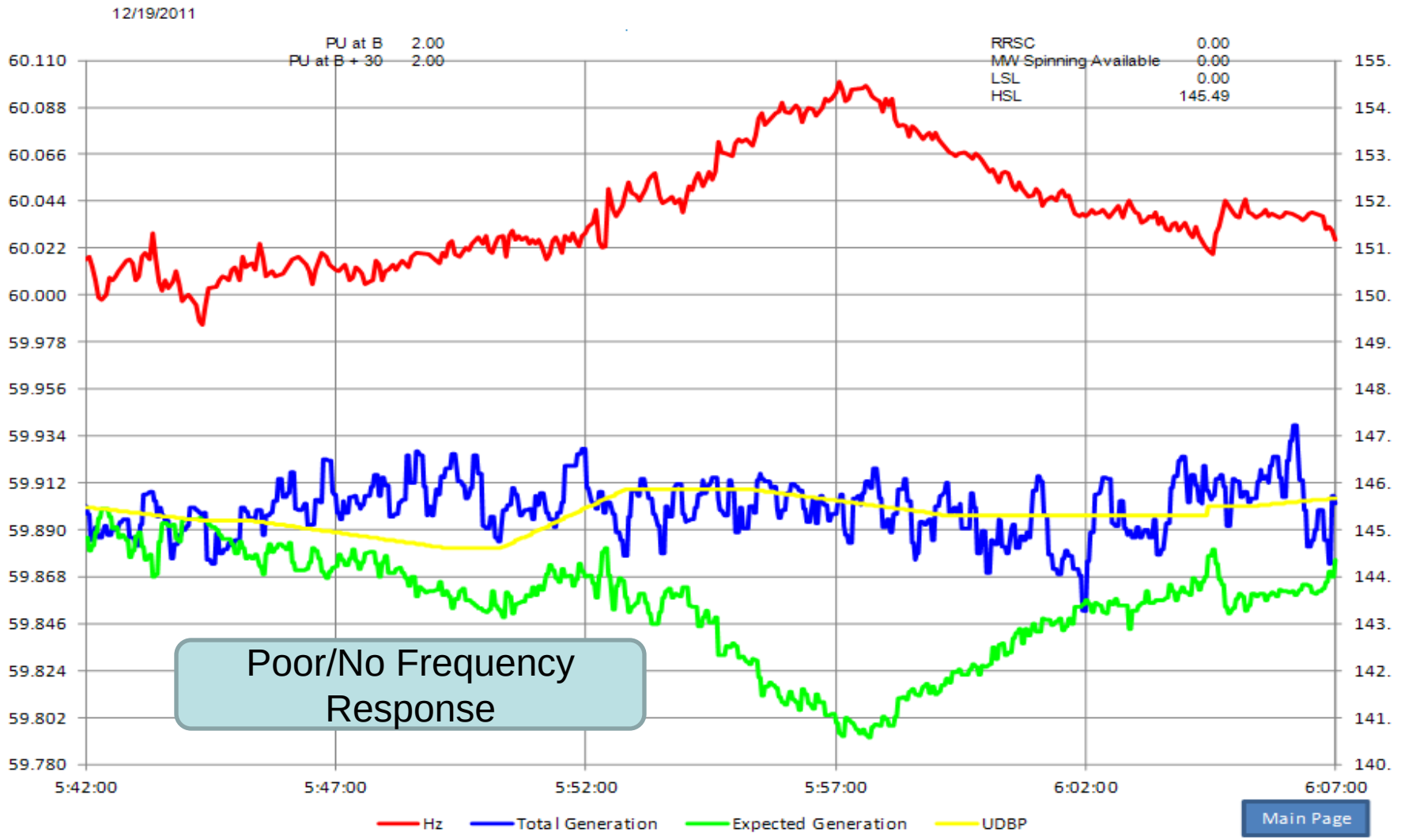
- **To accommodate additional 10GW wind generation in the near future.**
- **Deliver wind power from remote region to the load centers through long extra high voltage transmission lines.**
- **Located at remote region, far away from synchronized generators and load.**
- **Significant power electronic devices to provide system support.**
- **Weak Grid**
  - Low short circuit ratio (SCR)
  - Voltage will not be stiff, challenge for voltage control (steady state and dynamic)
  - System performance is dominated by high wind/low wind, not summer peak/winter off-peak



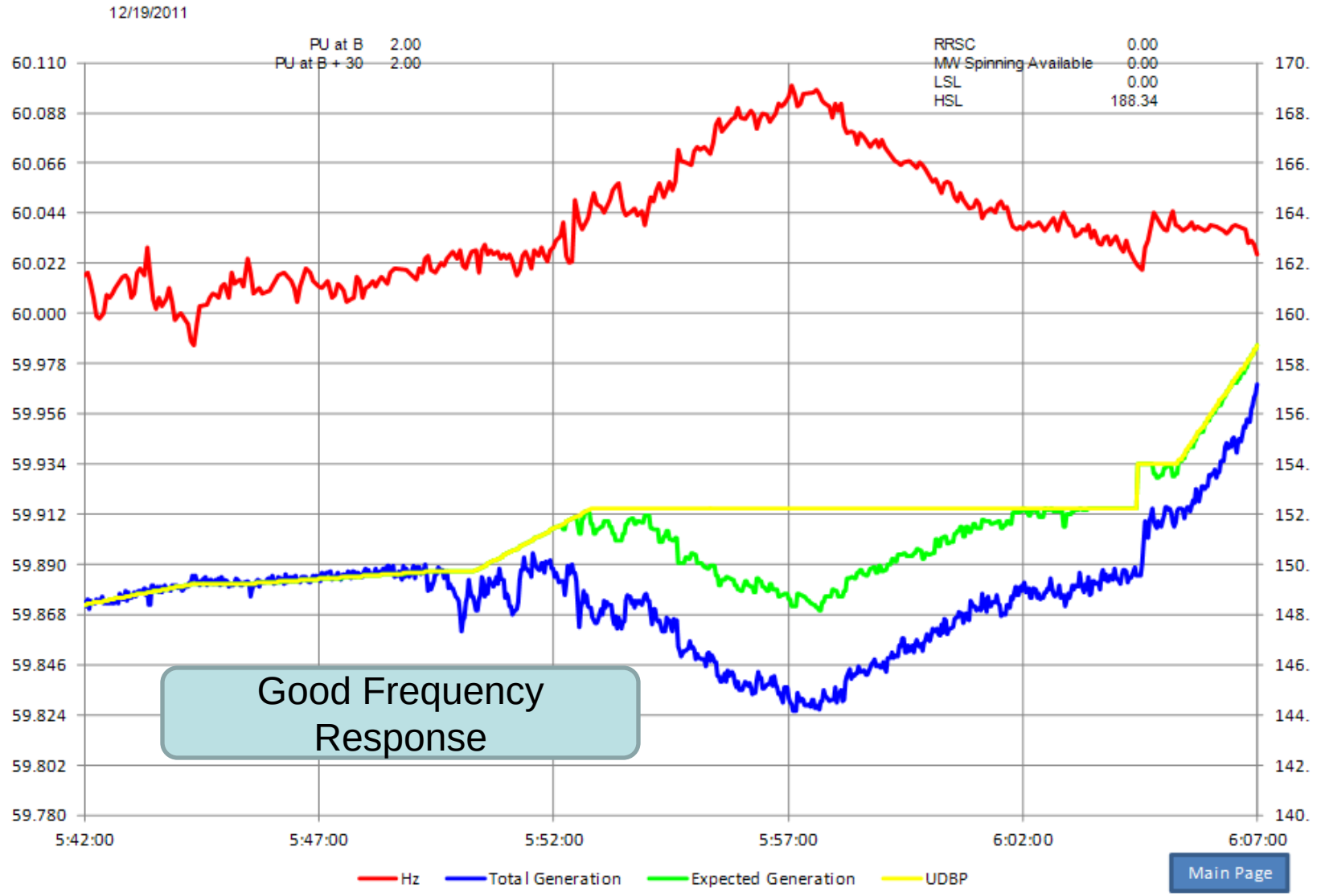
Voltage and Frequency Requirement

- **Wind Generation Resources (WGRs) are required to provide +/- 0.95 pf reactive support to the system at Point of Interconnection (POI).**
- **Voltage control at weak grid (areas without conventional units) can result in unstable response.**
- **Multiple WGRs connected to the same POI may also result in unstable response (hunting).**
- **Increasing WGRs can replace the conventional units and results in less frequency support (governor and inertia support).**
- **WGRs are required to provide primary frequency response.**

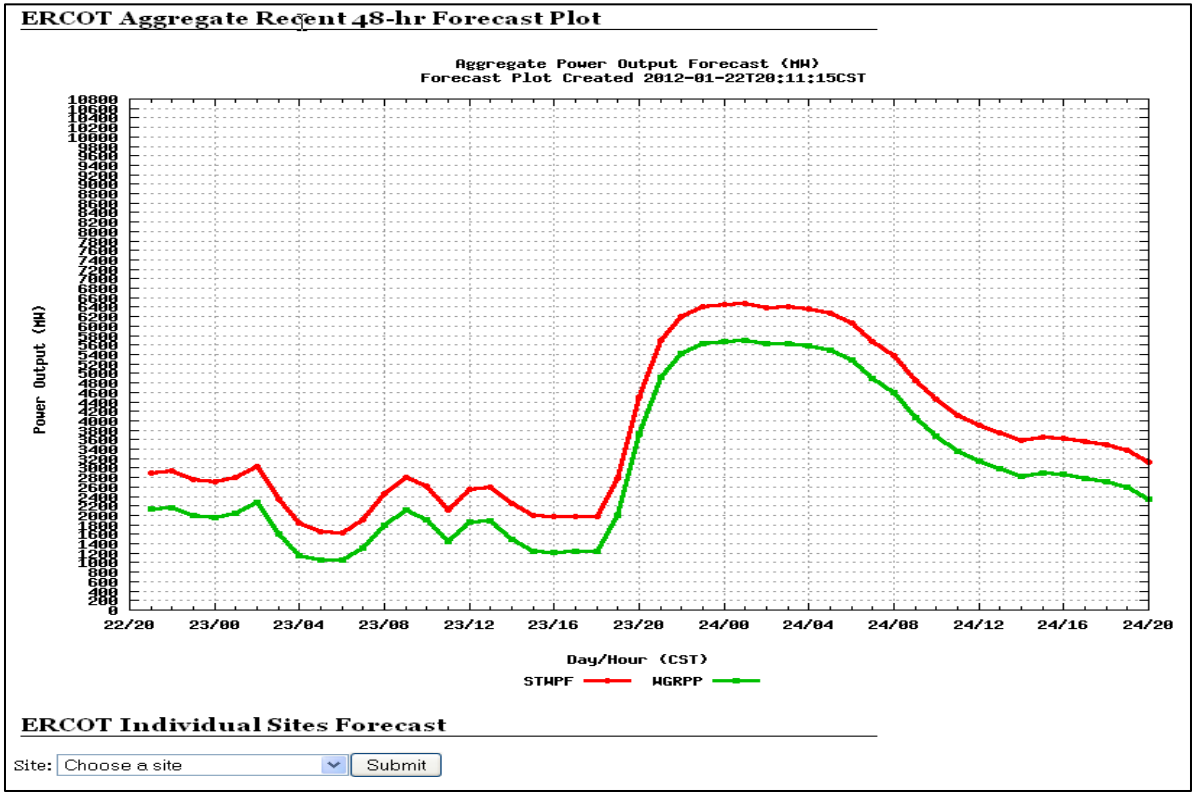
WGR Primary Frequency Response: actual measurement



WGR Primary Frequency Response: actual measurement

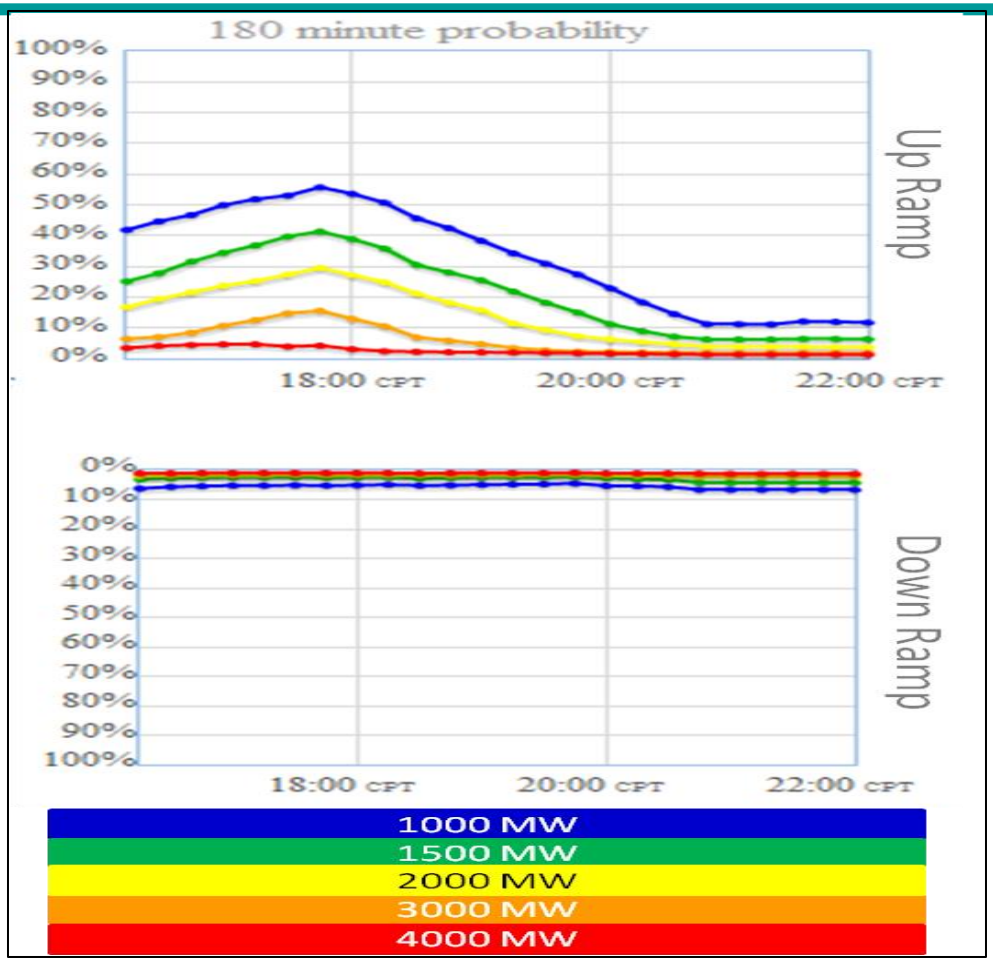


Wind Forecast



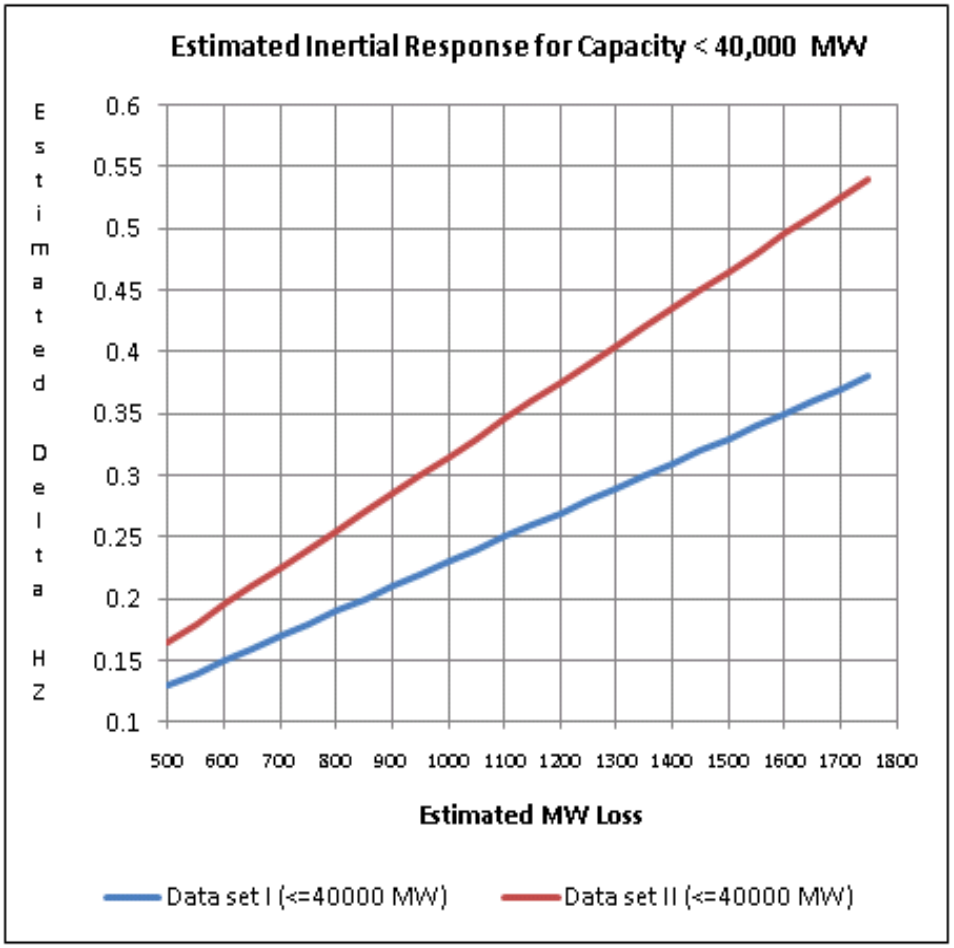
Web-based application available to System Operators to visualize, on a system-wide or an individual resource basis, the Short Term Wind Power Forecast (STWPF; 50% probability of exceedance) and the Wind Generation Resource Power Potential (WGRPP; 80% probability of exceedance)

Wind Ramp Forecast



Probabilities of system-wide 180-min ramp events. Example, there is a 30% chance of a 2000-MW Up ramp occurring over 180-minutes and starting at 17:45.

Inertia response decline and tool to estimate real time inertia response

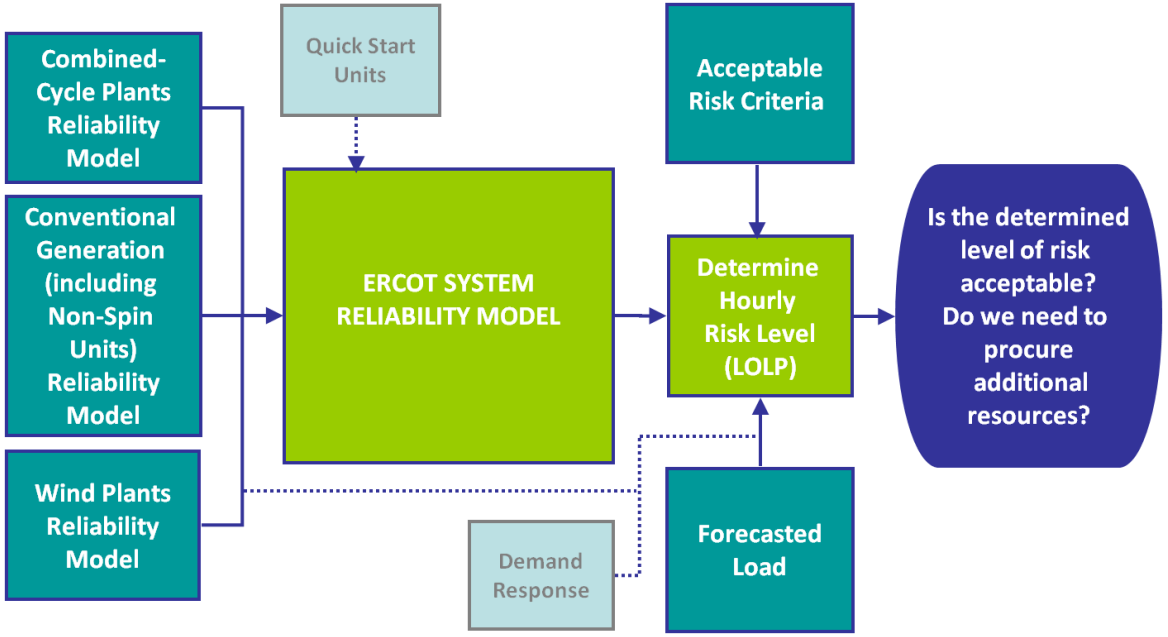


Inertial Frequency Response Estimator

11/22/2011 17:22:32	MW	ERCOT Current Frequency		
Spinning Reserve	6779.06	59.9740		
Total Wind Generation	456.10			
ERCOT Total Gen	33543.03			
ERCOT Conv Generation	33086.93			
ERCOT CONV CAPACITY	39865.99			
System IR (MW/0.1 HZ)	403.49			
System Bias STDEV	27.51			
	Maximum Freq Deviation	Lowest Freq Deviation	Approximate Actual Frequency (Low	Approximate Actual Frequency
NUKE1 (1375 MW)	0.3408	0.3190	59.6592	59.6810
NUKE1 STATION (2750)	0.6816	0.6381	59.3184	59.3619
NUKE2 STATION (2500 MW)	0.6196	0.5800	59.3804	59.4200
CCY STATION (1800 MW)	0.4461	0.4176	59.5539	59.5824
Approx 800 MW Trip	0.1983	0.1856	59.8017	59.8144

Data set I: event before 2008 (less wind installed capacity)
Date set II: events after 2008 (more wind installed capacity)

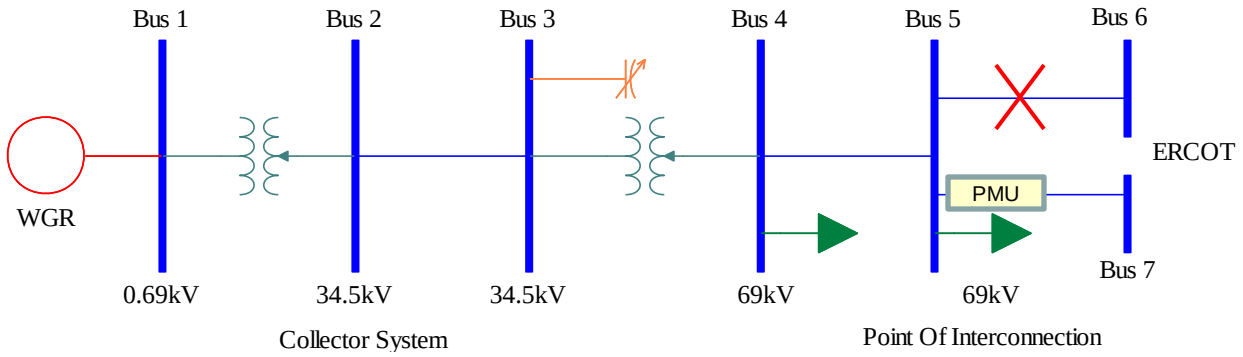
- ERAT is intended to show Operators when there is potentially high risk of a loss-of-load event (both on a Hour-Ahead and Day-Ahead basis)
- The risk is assessed considering Wind and Load forecast errors and potential forced outages of planned online generation

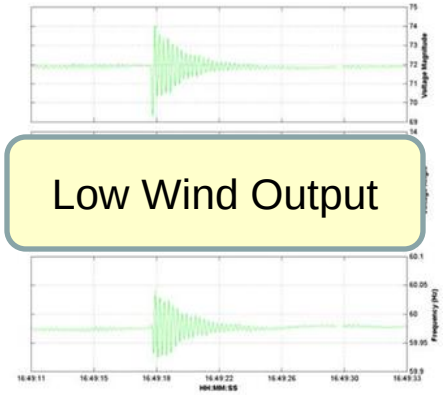


Market Analysis Interface:

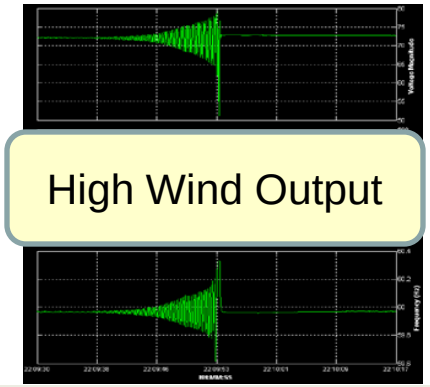
Refresh DATE & HOUR	HIGHEST LF	ONLINE HSL	ONLINE HASL	ONLINE ROOM	NON SPIN		DC TIE SCHD	WIND FORECAST		ERCOT_I	ERCOT_A3	Areva_A6	PRT Total
4/19/11 1:00	33218	40266	38661	5443	1626		-321	6353		32973	30878	30322	33218
4/19/11 2:00	31162	40937	39196	8034	1626		-297	6899		31019	27011	27594	31162
4/19/11 3:00	29936	40884	39239	9303	1424		-296	6848		29826	26958	26870	29936
4/19/11 4:00	29252	40392	38716	9464	1424		-319	6464		29091	26250	26134	29252
4/19/11 5:00	29459	40628	38932	9473	1424		-288	6257		29234	26259	25814	29459
4/19/11 6:00	31065	40556	38848	7783	1424		-155	6112		31016	28028	27702	31065
4/19/11 7:00	34704	44469	42621	7917	2000		-39	5967		34704	31459	31192	34538
4/19/11 8:00	36077	45853	44103	8026	2000		-37	5802		36077	32629	32597	35837
4/19/11 9:00	36473	45491	43758	7285	2000		-90	5129		36385	34880	34517	36473
4/19/11 10:00	38299	45520	43864	5565	2000		-675	4420		38228	35875	35716	38299
4/19/11 11:00	40783	45665	44071	3288	2000		-675	3742		40783	38601	38761	40685
4/19/11 12:00	43251	47414	45849	2598	2000		-725	3459		43251	40705	40914	42678
4/19/11 13:00	45558	48894	47350	1791	2000		-725	3081		45558	42913	43032	44939
4/19/11 14:00	48050	50071	48402	352	2000		-725	2616		48050	46631	45593	47353
4/19/11 15:00	49789	51372	49909	120	1737		-725	2599		49151	49789	46932	48660
4/19/11 16:00	51043	52347	50842	-200	1737		-725	2735		50725	51043	48523	50403
4/19/11 17:00	51911	52320	50736	-1175	1737		-725	2636		51911	51573	49637	51535
4/19/11 18:00	51839	52370	50890	-949	1737		-725	2659		51839	51641	49484	51212
4/19/11 19:00	50492	52225	50288	-204	1757		-725	2505		50179	50492	48256	49416
4/19/11 20:00	48885	51721	50029	1144	1757		-650	1942		48471	48885	46675	47979
4/19/11 21:00	49205	51241	49462	256	1757		-650	1957		48372	49205	46387	47627
4/19/11 22:00	46865	47896	46307	-557	1757		-205	1939		45923	46865	44018	45122
4/19/11 23:00	42768	43400	41424	-1345	1626		-199	1921		42256	42768	40234	41640
4/20/11 0:00	37644	40040	38500	856	1626		-8	1882		37644	37022	35565	37511

Challenges: Weak Grid Condition





Low Wind Output



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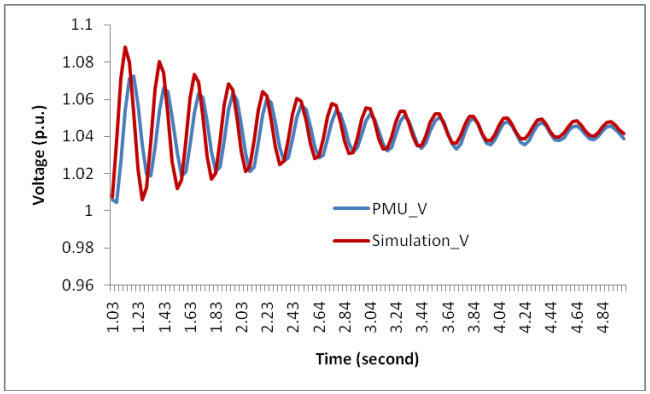

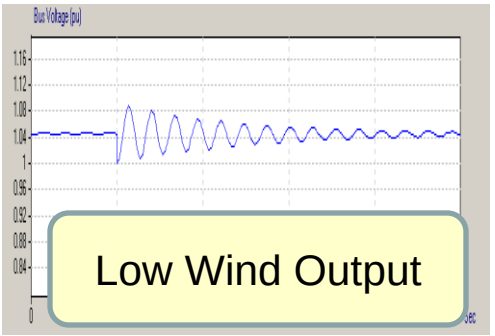

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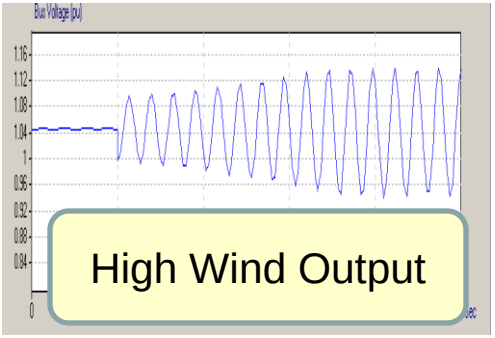
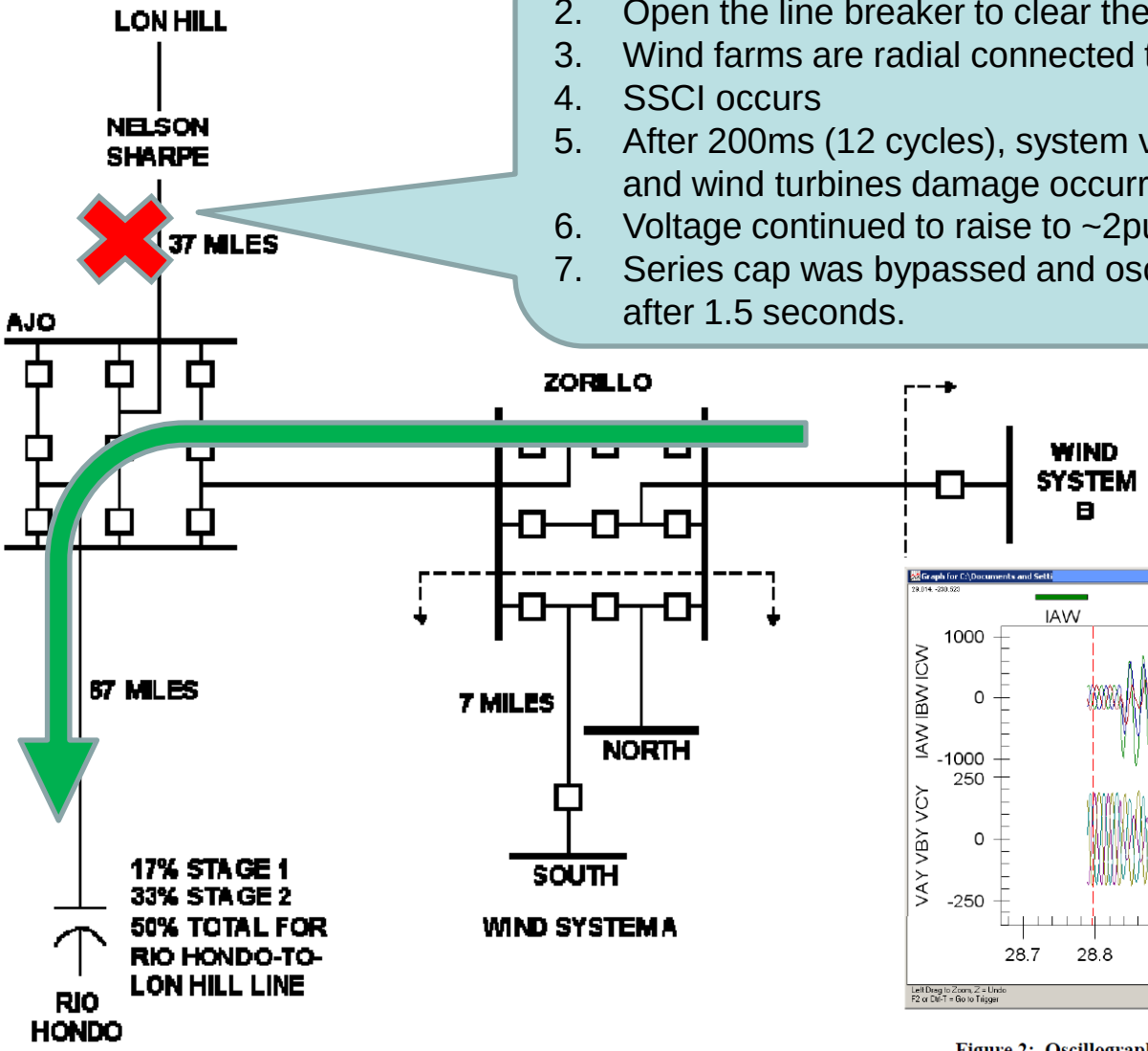


High Wind Output

Sub-synchronous Control Interaction: October 2009 SSCI Event

1. Single Line to ground fault
2. Open the line breaker to clear the fault in 2.5 cycles
3. Wind farms are radial connected to series cap 345 kV line
4. SSCI occurs
5. After 200ms (12 cycles), system voltage exceeded 1.5pu (520 kV) and wind turbines damage occurred.
6. Voltage continued to raise to ~2pu and series cap damage occurred.
7. Series cap was bypassed and oscillation was finally damped out after 1.5 seconds.



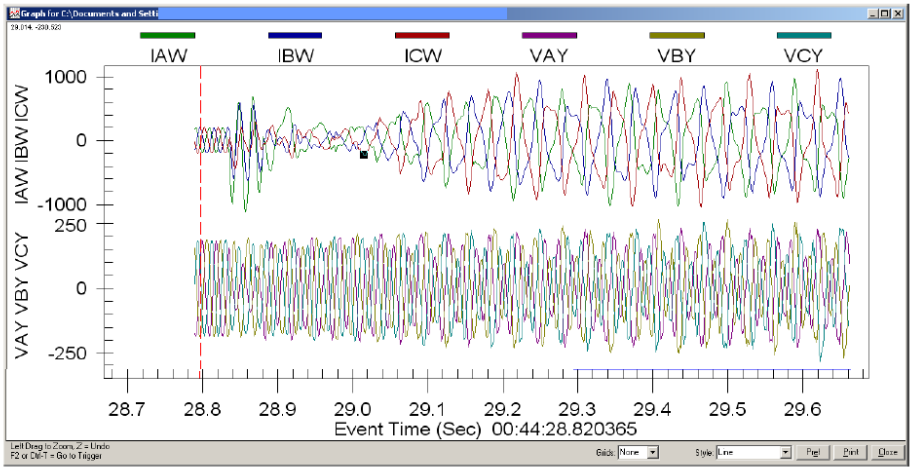


Figure 2: Oscillography Recorded at Wind System A during the Event.

Thanks for your time!

Questions?

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