Wind Generation
Part II – Case Studies

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New Mexico Wind Energy Center

204 MW Wind Farm
Eastern New Mexico

Geographic Location

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Project Overview

- 200 MW (net) PPA with Public Service of New Mexico
- Located in eastern New Mexico
- 136 GE 1.5 MW turbines
- Interconnect to PNM system
- COD - 7/30/03; 4 months to build

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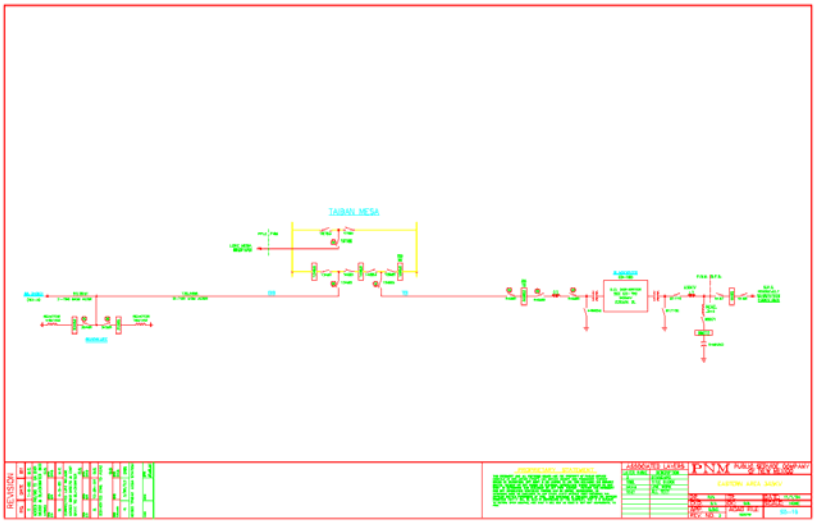
Location On PNM System



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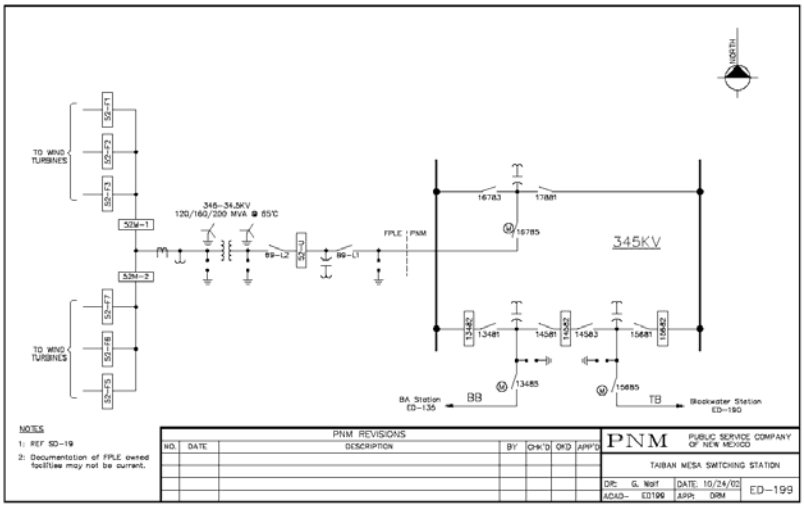
Collector System Layout



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Interconnection & Design Work

- PNM System Impact & Facilities Studies
- GE Low-Voltage Ride-Through studies and LVRT design
- ABB Sub-synchronous Tortional Interaction Study
- EMTP analysis of collector system
- Reactive capability analysis & testing

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PNM Studies & Operational Concerns

- No remarkable loadflow or short circuit results. No instability.
- Concern: PNM off-peak load is ~1500MW. The 200 MW wind farm is a large percent of that.
- Fault on EHV tie removed large import; plus, the attendant voltage depression caused the wind turbines to trip too.
- >>> Need for Low-Voltage Ride Through

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GE LVRT Studies & Design

- GE Wind engaged GE Power Systems experts from Schenectady, NY
- Design Studies
- Bench Tests
- Field deployment of solution coincident with initial wind turbine installation.
- Successful result

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ABB SSTI Study

- PNM concerned about potential interaction of equipment at wind farm and their Blackwater AC-DC-AC converter station at the sub-sychronous level.
- Contracted ABB to perform analysis
- Model development (MATLAB/Simulink)
  - Coordination between ABB & GE Wind
- Results: No SSTI concerns.

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Reactive Capability Analysis & Tests

- Loadflow modeling & analysis of collector system.
- Field tests to determine reactive capability range of entire wind farm at POI.
  - Coordination with PNM & GE
  - Adjust grid conditions to maximize VAR production & absorbtion.
- Comparison of analytical & test results.
- WTG reactive capability limist based of terminal voltage.

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GE EMTP Collector Design Study

- 3-leg Delta/Yg padmount transformer is a better choice that the 5-leg Yg/Yg, for reducing ferro-resonance related overvoltages.
- Grounding Tx for each feeder.
- Lightning arresters: 27kV gapped or 33kV non-gapped.
- Pre-insertion resistors on the 345kV main transformer breaker.

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Ongoing Model Validation Efforts

- Joint FPLE / PNM / NREL / GE / UWIG effort
- IEEE Paper on collector system equivalents
  - Effort to develop simplified spreadsheet-based tool
- Comparison of DFR traces for nearby system faults versus model simulation of same events

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FPL Energy North Dakota Wind II

19.5 MW Wind Farm
Southeastern North Dakota

Geographic Location - North Dakota

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Location On Grid

- Add scanned map of ND part of grid

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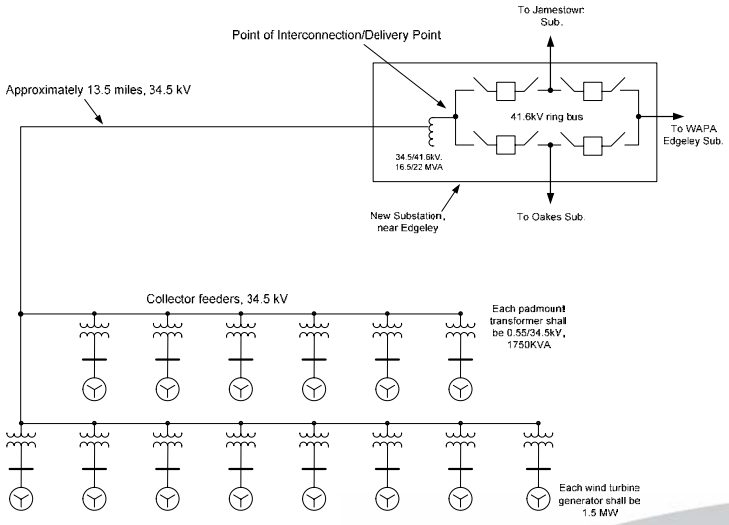
Collector System Layout



Proposed One-Line Diagram - 19.5MW
FPL Energy North Dakota Wind II Project

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Otter Tail Power Co. Studies

- Connection is to weak, 41.6kV system
- Concern over high voltages, particularly during light-load periods, due to injection of power by wind farm.
- Otter Tail performed detailed modeling and analysis of their 41.6kV system . FPLE did the same for our wind farm collector system.
- Efforts were closely coordinated.
- Changes in transformer taps and cap banks.
- Results have been successful.

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GE EMTP Switching Study

- Question whether a low side transformer breaker needed to energize the collector system separately from the transformer to reduce switching transients and maintain power quality.
- Findings:
  - No severe overvoltages or voltage distortion
  - Low-side breaker not required.

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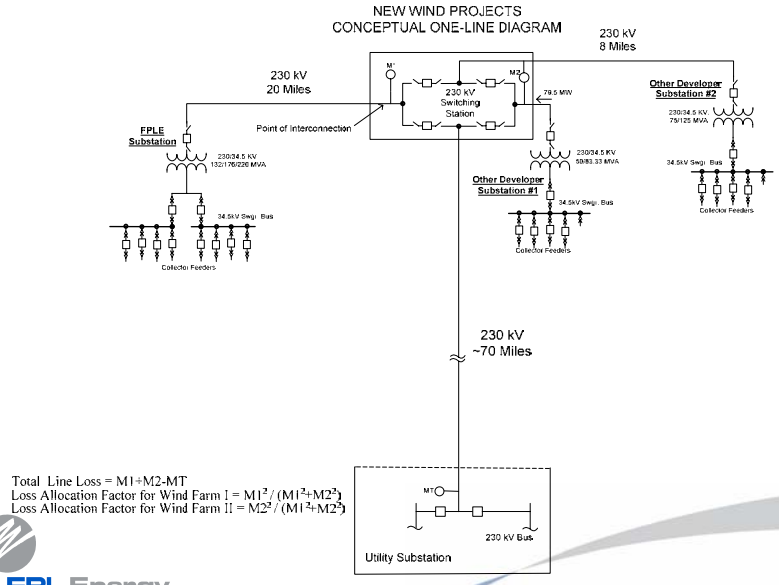
FPL Energy - New Challenge

200/400 MW Wind Farm

Interconnection Configuration



Total Line Loss = M1+M2-MT
Loss Allocation Factor for Wind Farm I = $M1^2 / (M1^2+M2^2)$
Loss Allocation Factor for Wind Farm II = $M2^2 / (M1^2+M2^2)$

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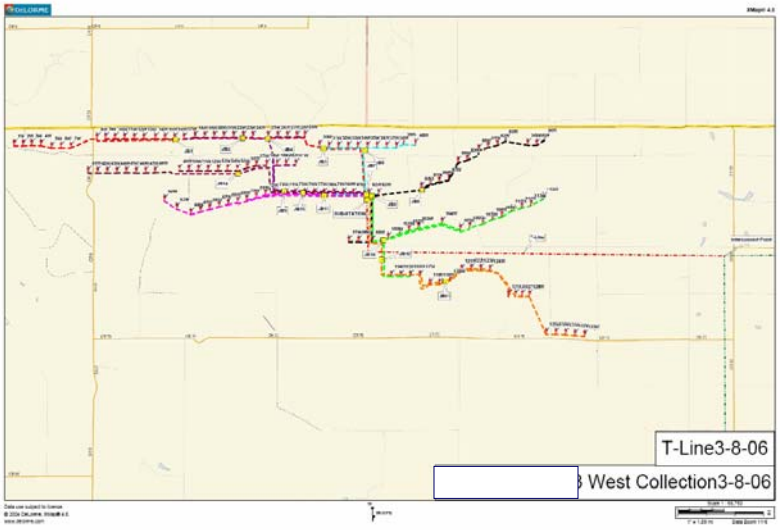
Collector System Layout



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Feeder Cable Takeoff

FEEDER CIRCUIT				4/0 AWG Cable			1000 kcmil Cable			Section Has		
	F7			Pt.-Pt. (Lf.)	End Coil		Pt.-Pt. (Lf.)	End Coil		WTG's	Amps	MW
62	To	63		1,682	40					1	27	1.5
63	To	64		1,748	40					2	53	3.0
64	To	65		1,104	40					3	80	4.5
65	To	66		1,107	40					4	106	6.0
66	To	67		1,109	40					5	133	7.5
67	To	68		1,112	40					6	159	9.0
68	To	69		1,116	40					7	186	10.5
69	To	JB13		10,138	40					8	212	12.0
	To				-						-	-
78	To	JB13		151	40					1	27	1.5
	To				-						-	-
70	To	71		1,109	40					1	27	1.5
71	To	72		1,112	40					2	53	3.0
72	To	73		1,204	40					3	80	4.5
73	To	74		1,109	40					4	106	6.0
74	To	75		1,109	40					5	133	7.5
75	To	76		1,109	40					6	159	9.0
76	To	77		1,109	40					7	186	10.5
77	To	JB13		1,194	40					8	212	12.0
	To				-						-	-
	To				-			-			-	-
	To				-			-			-	-
	To				-			-			-	-
JB13	To	SUB			-		5,238	40		17	451	25.5
J-Boxes	Sub-Total By Type:			28,322	680		5,238	40				
1	**FEEDER CIRCUIT TOTAL:**				**29,002**			**5,278**		**17**	**451**	**25.5**

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Feeder Impedance Calcs

Fr Bus#	LF Bus#	from bus name	To Bus#	LF Bus#	to bus name	Length	cable	R1	X1	Bc	Rating
						Ft	size	per unit	per unit	per unit	MVA
1	72001	W PM001	2	72002	W PM002	1,036	4/0	0.01147	0.00629	0.000220	15
2	72002	W PM002	3	72003	W PM003	971	4/0	0.01075	0.00590	0.000206	15
3	72003	W PM003	4	72004	W PM004	1,089	4/0	0.01206	0.00661	0.000231	15
4	72004	W PM004	5	72005	W PM005	1,236	4/0	0.01369	0.00751	0.000263	15
5	72005	W PM005	6	72006	W PM006	1,109	4/0	0.01228	0.00674	0.000236	15
6	72006	W PM006	7	72007	W PM007	1,109	4/0	0.01228	0.00674	0.000236	15
7	72007	W PM007	8	72008	W PM008	3,255	4/0	0.03604	0.01977	0.000692	15
8	72008	W PM008	501	72501	W JB001	9,187	4/0	0.10173	0.05581	0.001953	15
9	72009	W PM009	10	72010	W PM010	1,089	4/0	0.01206	0.00661	0.000231	15
10	72010	W PM010	11	72011	W PM011	1,091	4/0	0.01208	0.00663	0.000232	15
11	72011	W PM011	12	72012	W PM012	1,111	4/0	0.01230	0.00675	0.000236	15
12	72012	W PM012	13	72013	W PM013	1,109	4/0	0.01228	0.00674	0.000236	15
13	72013	W PM013	14	72014	W PM014	1,316	4/0	0.01457	0.00799	0.000280	15
14	72014	W PM014	15	72015	W PM015	1,109	4/0	0.01228	0.00674	0.000236	15
15	72015	W PM015	16	72016	W PM016	1,109	4/0	0.01228	0.00674	0.000236	15
16	72016	W PM016	501	72501	W JB001	171	4/0	0.00189	0.00104	0.000036	15
501	72501	W JB001	502	72502	W JB002	7,708	1000	0.03050	0.03283	0.002867	30
502	72502	W JB002	503	72503	W JB003	9,926	1000	0.03928	0.04228	0.003692	30
503	72503	W JB003	600	72600	W SUBLV	10,348	1000	0.04095	0.04408	0.003849	30
17	72017	W PM017	18	72018	W PM018	1,258	4/0	0.01393	0.00764	0.000267	15
18	72018	W PM018	19	72019	W PM019	1,109	4/0	0.01228	0.00674	0.000236	15
19	72019	W PM019	20	72020	W PM020	1,109	4/0	0.01228	0.00674	0.000236	15
20	72020	W PM020	21	72021	W PM021	1,109	4/0	0.01228	0.00674	0.000236	15
21	72021	W PM021	22	72022	W PM022	1,130	4/0	0.01251	0.00686	0.000240	15
22	72022	W PM022	23	72023	W PM023	1,109	4/0	0.01228	0.00674	0.000236	15

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Format Data For Loadflow Input

BUS DATA

Fr Bus#	from bus name	KV	IDE	GL	BL	AREA	ZONE	Vm	ANG	OWNER
72001	W PM001	34.5	1	0.0	0.0	70	702	1.03	88.000000	1
72002	W PM002	34.5	1	0.0	0.0	70	702	1.03	88.000000	1
72003	W PM003	34.5	1	0.0	0.0	70	702	1.03	88.000000	1
72004	W PM004	34.5	1	0.0	0.0	70	702	1.03	88.000000	1
72005	W PM005	34.5	1	0.0	0.0	70	702	1.03	88.000000	1
72006	W PM006	34.5	1	0.0	0.0	70	702	1.03	88.000000	1

GENERATOR DATA

I,ID,PG,QG,QT,QB,VS,IREG,MBASE,ZR,ZX,RT,XT,GTAP,STAT,RMPCT,PT,PB,O1,F1,...,O4,F4

Bus #	Mac #	Pg	Qg	Qmax	Qmin	Vsched	Reg Bus #	Mbase
72201	1	1.5	0.4	0.726	-0.726	1.045	72601	1.717
72201	1	1.5	0.4	0.726	-0.726	1.045	72601	1.717
72201	1	1.5	0.4	0.726	-0.726	1.045	72601	1.717
72201	1	1.5	0.4	0.726	-0.726	1.045	72601	1.717
72201	1	1.5	0.4	0.726	-0.726	1.045	72601	1.717

BRANCH DATA

I,J,CKT,R,X,B,RATEA,RATEB,RATEC,GI,BI,GJ,BJ,ST,LEN,O1,F1,...,O4,F4

72001	72002	1	0.011472	0.006293	0.000220	15	15
72002	72003	1	0.010752	0.005898	0.000206	15	15
72003	72004	1	0.012059	0.006615	0.000231	15	15
72004	72005	1	0.013687	0.007508	0.000263	15	15
72005	72006	1	0.012280	0.006736	0.000236	15	15
72006	72007	1	0.012280	0.006736	0.000236	15	15
72007	72008	1	0.036044	0.019772	0.000692	15	15

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Loadflow Output

PTI INTERACTIVE POWER SYSTEM SIMULATOR--PSS/E MON, OCT 02 2006 10:38
08SUPK;GSU T=1.025; PAD T=1.0; VSCH=1.045, REMOTE=71601 BUS DATA
ADD 200MW PROJECT, TIED TO SW STA VIA 20 MI LINE

BUS#	NAME	BSKV	CODE	LOADS	VOLT	ANGLE	SH U N T	AREA	ZONE	OWNER
72001	W PM001	34.5	1	0	1.1112	103.2	0	70	702	1
72002	W PM002	34.5	1	0	1.111	103.2	0	70	702	1
72003	W PM003	34.5	1	0	1.1107	103.2	0	70	702	1
72004	W PM004	34.5	1	0	1.1102	103.2	0	70	702	1
72005	W PM005	34.5	1	0	1.1093	103.2	0	70	702	1
72006	W PM006	34.5	1	0	1.1084	103.2	0	70	702	1
72007	W PM007	34.5	1	0	1.1072	103.2	0	70	702	1
72008	W PM008	34.5	1	0	1.1034	103.1	0	70	702	1
72009	W PM009	34.5	1	0	1.0965	103	0	70	702	1

PTI INTERACTIVE POWER SYSTEM SIMULATOR--PSS/E MON, OCT 02 2006 10:38
08SUPK;GSU T=1.025; PAD T=1.0; VSCH=1.045, REMOTE=71601 GENERATING
ADD 200MW PROJECT, TIED TO SW STA VIA 20 MI LINE PLANT DATA

BUS#	NAME	BSKV	COD	MCNS	PGEN	QGEN	QMAX	QMIN	VSCHED	VACT.	PCT Q	REMOTE
72201	W WT001	0.575	2	1	1.5	0.4	0.7	-0.7	1.045	1.045	100	71601
72202	W WT002	0.575	2	1	1.5	0.4	0.7	-0.7	1.045	1.045	100	71601
72203	W WT003	0.575	2	1	1.5	0.4	0.7	-0.7	1.045	1.045	100	71601
72204	W WT004	0.575	2	1	1.5	0.4	0.7	-0.7	1.045	1.045	100	71601
72205	W WT005	0.575	2	1	1.5	0.4	0.7	-0.7	1.045	1.045	100	71601
72206	W WT006	0.575	2	1	1.5	0.4	0.7	-0.7	1.045	1.045	100	71601
72207	W WT007	0.575	2	1	1.5	0.4	0.7	-0.7	1.045	1.045	100	71601
72208	W WT008	0.575	2	1	1.5	0.4	0.7	-0.7	1.045	1.045	100	71601
72209	W WT009	0.575	2	1	1.5	0.4	0.7	-0.7	1.045	1.045	100	71601

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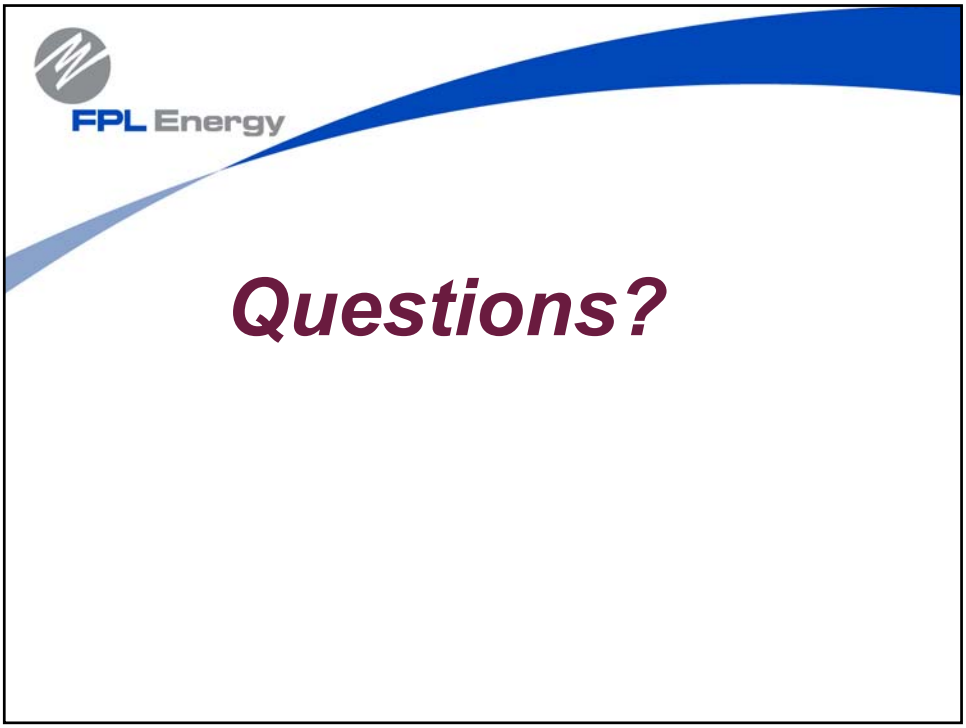
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Questions?