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Examples of Wind Energy Curtailment Practices

July 2010

Jennifer Rogers, Sari Fink, and Kevin Porter
Exeter Associates, Inc.
Columbia, Maryland

Subcontract Report
NREL/SR-550-48737
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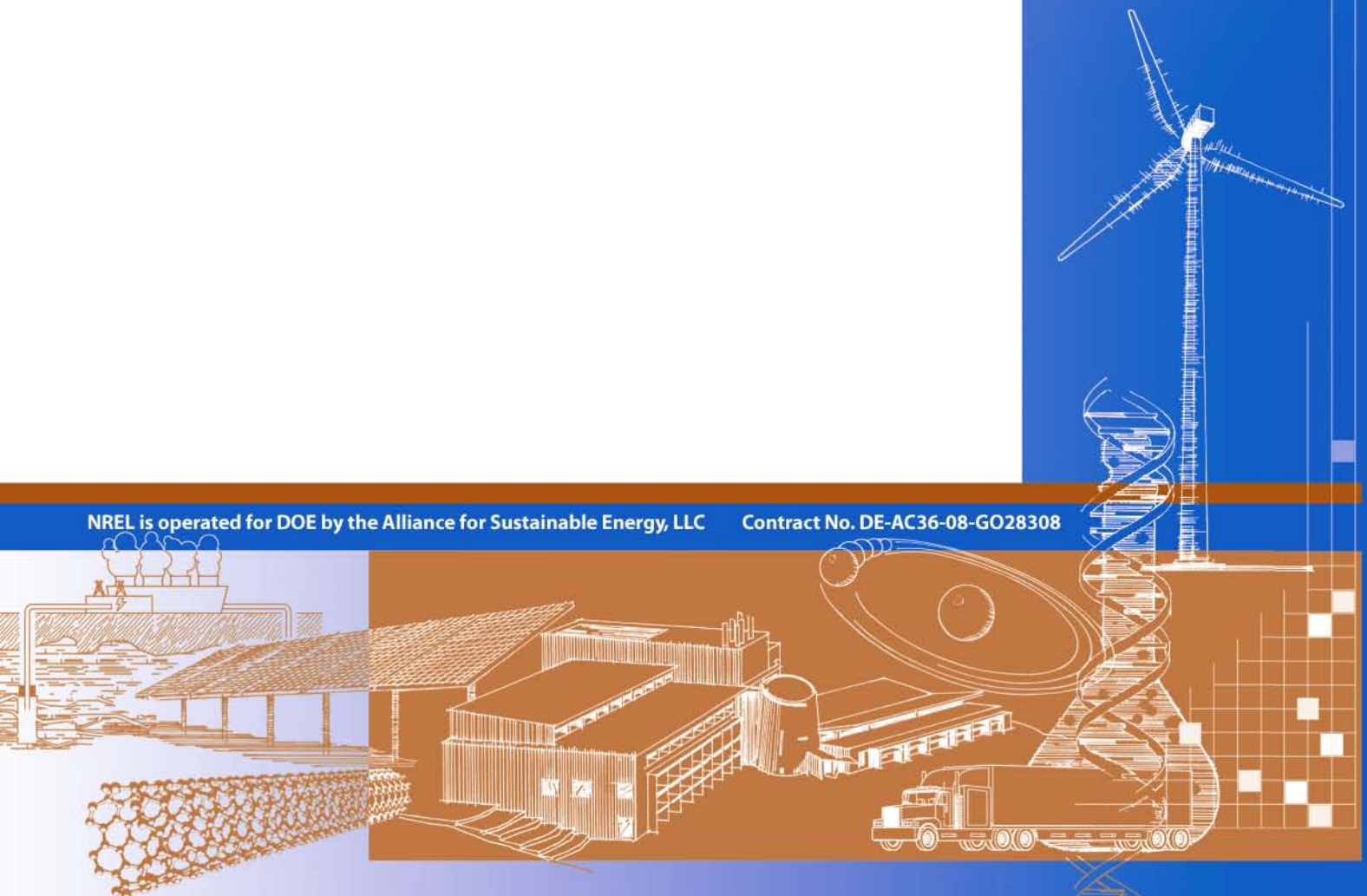

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NREL Technical Monitor: Erik Ela

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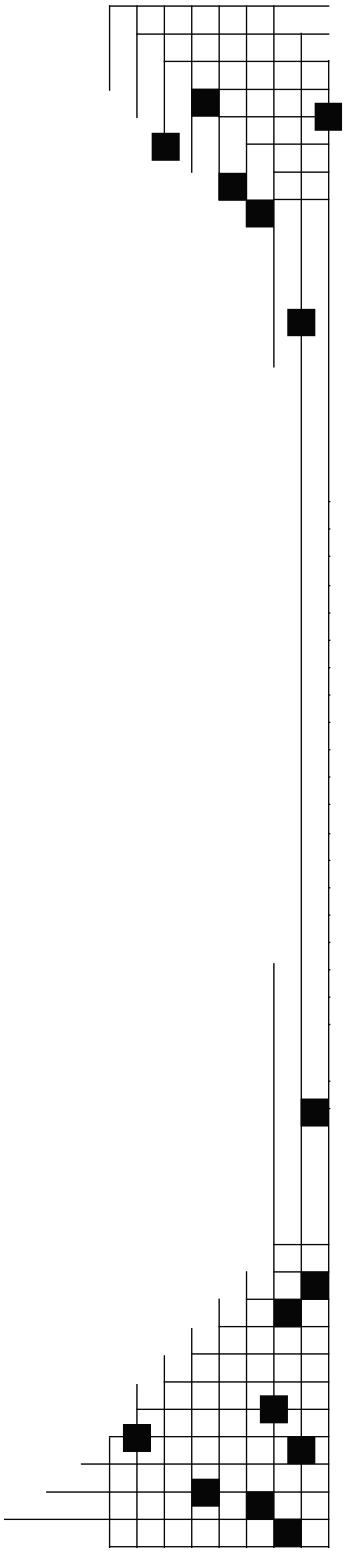

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Examples of Wind Energy Curtailment Practices

Compiled by Jennifer Rogers, Sari Fink and Kevin Porter

Exeter Associates, Inc.

July 2010

and incorporating review comments from:

Jacques Duchesne, Alberta Electric System Operator (AESO)
Alberto Ceña and Miguel Ángel Galán Peña, Asociación Empresarial Eólica
Bart McManus, Bonneville Power Administration (BPA)
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The following table addresses examples of wind energy curtailment practices internationally and in regions across the United States. Examples included from the United States consist of ERCOT, Midwest ISO, New York ISO, PJM, Bonneville Power Administration (BPA), Hawaiian Electric Company, Xcel Energy, and Southern California Edison. Also included are the practices of Ireland, New Zealand, Spain, Germany, and Canada's Alberta province. Table entries are organized as follows:

- A description of how wind curtailment is determined;
- Details of the constrained operation procedures;
- The amount of wind curtailed in recent years; and
- What compensation to wind generators is given for curtailment, if any.

	Description	Curtailment Procedures	Amount Curtailed	Compensation
Bonneville Power Administration	Curtailment procedures for system events included in large generation interconnection agreements for wind projects. Wind plants required to submit schedules based on the most accurate wind forecast they have available and be able to accept electronic base-point signals.	When 90% of BPA's balancing reserves are deployed, BPA requires wind generators to reduce generation to their scheduled amount plus their in-hour balancing reserve allocation if they are generating over this amount. If they are generating less than their schedule plus reserve allocation, BPA will curtail schedules to that value once 90% of the incremental balancing reserves are deployed. Subject to certain conditions, BPA may require wind generator to receive generation limits from BPA's energy management system if a wind project does not reach a BPA-specified generation limit three times in 24 months. Wind plants must respond to electronic basepoint signals within 10 minutes or BPA can disconnect the plant.	As of March 30, 2010, the estimated total amount of wind limited was 2900 MW, representing approximately 1000 MWh. (The MWh amount is a complete approximation, as these events may occur anytime during the hour.)	No compensation.
ERCOT	Congestion is currently managed by ERCOT on a zonal basis. The majority of wind is located in the west zone; however, ERCOT is beginning to see a significant number of wind MWs in the coastal region. ERCOT previously had special rules utilizing daily operating limits for wind plants for the western zone as transmission constraints limited transfers from the west to the load centers in central and eastern Texas. The special rules were removed, however ERCOT continues to curtail wind plants for congestion purposes. In ERCOT's new nodal system, wind plants will be incorporated into economic dispatch and treated like all other generators. Wind facilities will be required to respond to electronic signals setting dispatched generation base-points when needed for congestion or when the resource appears not to be economical.	ERCOT may call upon wind plants (and other generators) to make reductions in output during periods of transmission congestion. This will continue to be the case in ERCOT's new nodal market that will be implemented by the end of 2010.	January to August 2008, curtailed approximately 140-150 MW about 45-50% of the days, via restricted daily operating limits. From December 2008 to December 2009, curtailed between 500 MW and 2000 MW daily, and at times curtailing up to 3900 MW, but at other times curtailing 0 MW. In 2009, average annual wind curtailment was around 16%. Monthly averages ranged from about 24-28% of potential wind generation from February-April, to about 6% in December, ranging between 10-18% in January and from May-November.	If wind plants were called upon for curtailment beyond the daily operating limits, then ERCOT paid out-of-merit energy payments. Under the nodal market system, wind plants will be treated the same as all generator types.

	Description	Curtailment Procedures	Amount Curtailed	Compensation
Hawaiian Electric Company	All wind plants are equipped with curtailment interfaces controlled by the grid operator. Electronic base-point generation limits are set by the grid operator as necessary.	During system emergency events, the grid operator will use most effective control to address the issue (such as reducing a specific wind plant output). During light load times, must-run generators are reduced to minimum levels, then as-available generators (including wind) curtailed according to a pre-determined priority established via contractual agreements.	No data available.	No additional compensation; curtailments built into contractual agreements.
Midwest ISO	Will curtail variable generation during Minimum Generation Events after using the emergency range (between energy minimum and energy maximum) of conventional generation. Transmission constraints may lead to wind curtailments if market redispatch of conventional generation is not sufficient to relieve the constraint. Curtailment order is based on impact on the constraint and transmission service priority.	During Minimum Generation Events, Midwest ISO orders curtailments in the following order: 1. Generation identified through the Reliability Assessment Commitment process. 2. Variable generation above its Day-Ahead Schedule 3. With emphasis placed on shortest turn-around time (shut down and re-start) and reverse economic order, generation will be decomitted as necessary to maintain balance of load and generation.	In 2009, the Midwest ISO curtailed wind due to transmission constraints 10 to 170 times each month, totaling about 1,100 wind curtailments for the year. About 200,000 MWh were curtailed in 2009. In 2009, average wind curtailment was about 1% of wind generation, with monthly averages ranging from about 0.07% to 2.86% of potential monthly wind generation. The Midwest ISO curtailed intermittent resources once during Minimum Generation Events in 2009.	No additional compensation from Midwest ISO. Certain utilities in the Midwest ISO may have compensation programs for curtailing wind energy.

	Description	Curtailment Procedures	Amount Curtailed	Compensation
PJM	Wind included in procedures for Transmission Constraints and Light Load Events. Wind curtailed along with other generation based on $/MW effect for transmission constraints and economic bid for Light Load Events. Wind assumed to have emergency minimum of zero unless otherwise bid. Wind plants are required to be modeled by wind power forecasting services and be able to accept electronic base-point signals.	During events, all generation reduced to economic minimum first. If additional curtailment needed, all generation reduced to emergency minimum levels. Wind plants are required to respond to electronic base-point dispatch signals within 15 minutes or must notify PJM if they cannot respond that quickly.	No data available.	No additional compensation.
New York ISO	Wind integrated into real-time and day-ahead market dispatch. Wind bids a price-quantity curve into the real-time market and is dispatched economically along with other generation. Wind plants must participate in wind forecasting and be able to accept electronic base-point dispatch signals.	During constrained operations, generation will be curtailed according to economic bids. Wind plants must follow electronic base-point dispatch signals within 5 minutes or be assessed penalties for non-compliance.	No data available.	No additional compensation.
Southern California Edison	Wind curtailment may occur in the Tehachapi region due to transmission constraints. SCE's request to curtail wind under certain conditions is pending before the California PUC.	Agreement with Terra-Gen Power to reduce output on an as-needed basis.	About 15 MW for 3-4 hours about every two days (or 6-8% of the time).	Make whole payment for energy.

	Description	Curtailment Procedures	Amount Curtailed	Compensation
Xcel Energy	Northern States Power MN (NSP) is in the Midwest ISO and follows the Midwest ISO's direction on whether curtailment is required. Public Service of Colorado (PSCO) and Southwestern Public Service (SPS) have procedures to reduce all generation and prices/sales to minimum levels prior to ordering wind energy curtailments.	NSP: agreements with wind plants in Southwest Minnesota to curtail on a rotational basis when required by Midwest ISO. PSCO: contracts with certain wind plants to curtail a set amount per year on an as-needed basis. If additional curtailment required, PSCO will call wind plants to curtail on a rotational basis. SPS: call wind plants to curtail on a rotational basis.	NSP: 2007: 112,244 MWh 2008: 25,367 MWh 2009: 42,359 MWh PSCO: 2008: 2,464 MWh 2009: 18,991 MWh SPS-owned wind resources have not been curtailed to date. Data on curtailments of merchant wind within the SPS Balancing Authority is unavailable.	NSP: make whole kWh payments for both fixed and variable costs. PSCO: contracted amounts are at no cost. Additional amounts made whole for energy plus Production Tax Credit.

Examples of International Wind Energy Curtailment Practices

	Description	Curtailment Procedures	Amount Curtailed	Compensation
Alberta Electric System Operator (AESO)	Wind power curtailment occurs because of transmission constraints and other reliability events.	Wind curtailments are based on reliability concerns. Each wind project may have a Remedial Action Scheme defined in their interconnection requirements.	The AESO curtailed wind for 860 hours in 2008, for 838 hours in 2009, and for 236 hours during the period of January 2010 – March 2010.	Wind generators are not compensated if curtailed.
Germany	Electric power facilities over 100 kW are subject to generation management.	The distribution grid operator may curtail wind in the case of congestion in the local grid. The transmission service operator (TSO) must sell all renewable energy on the day-ahead market but may, under a rule in effect until the end of 2010, limit its sales of renewable energy orders for 100 hours per half year if the market cannot clear or extremely negative prices are expected. If there is some energy that cannot be sold on the day-ahead market and intra-day market prices are expected to be lower, the TSO may use bilateral contracts with the installation owner and curtail wind. If congestion is a threat to system reliability after the above methods have been tried, the TSO may curtail or shut down wind installations.	Between 2004 and 2006, 74 GWh of wind power were curtailed.	Distribution grid operators: compensation equivalent to lost revenues. Transmission service operator: in the case of bilateral contracts (discussed under 'Curtailment Procedures'), compensation equivalent to lost revenues. In the case of a remaining congestion threat after other methods have been attempted, there is no payment or compensation for curtailment.
New Zealand	Wind is curtailed on a case-by-case basis.	The system operator sends a dispatch instruction to the wind generator requiring output to be reduced to a fixed level. One wind project has automatic run-back that limits project output when loading on certain transmission lines reaches continuous rating.	No data available.	Wind generators are not compensated if curtailed.

	Description	Curtailment Procedures	Amount Curtailed	Compensation
Ireland	Wind in Ireland is only curtailed if there is a system security issue, as members of the EU are required to grant priority dispatch to wind. In the event of a system security issue, dispatch down occurs in the following order: indigenous peat stations, large combined heat and power, hydro, and then wind. This operational practice is under regulatory review. In 2009, wind was primarily curtailed due to transmission maintenance occurring in a high wind area with low load, following the global financial crisis. New transmission is under study; however, EirGrid expects wind will be increasingly dispatched down for non-congestion reasons.	The control of wind projects is done via remote control from EirGrid's control center. Response times occur within 10 seconds of receipt of the signal to curtail.	Less than 100 MWh was curtailed in 2008.	Wind generators that are dispatched down are paid in the energy market as if they generated the full available output, but Ireland's support mechanisms do not provide compensation in this case. Therefore, there are commercial consequences for wind that is dispatched down when the market price is lower than the guaranteed support price.
Spain	Wind may be curtailed in Spain for the following reasons: congestion, net stability, short-circuit power concerns, inadequate active/reactive power levels, and minimum load. Up until late 2009, the majority of curtailments were due to problems of congestion. In late 2009 and the first three months of 2010, the majority of curtailments were due to wind generation being greater than minimum load. There are two possible curtailments: - Programmed, before day-ahead market is closed. - Real time, in the intraday markets.	The system operator sends curtailment instructions to the wind farms (in fact, limits of production) via the Control Centre for Renewable Energies (CECRE) through the Generation Control Centers (GCC). Wind power facilities of 10 MW or more must be directly connected to the GCC, which are connected to them using an ICCP protocol. They also must have sufficient local controls to execute CECRE orders. These orders are refreshed every 12 seconds and they should be executed in 15 minutes. CECRE uses the GEMAS analytical model to determine need for curtailment of wind power facilities in case of net instability risks due to possible sudden voltage dips.	In 2007, 23.9 GWh of wind generation was curtailed, which represented 0.09% of total wind production. In 2008, wind generation curtailments represented about 0.3% of total wind production. In 2009, 54 GWh of wind generation was curtailed, representing about 0.15% of total wind production. In the first three months of 2010, 1% of wind production was curtailed with a loss of profits of around 10 M€. Wind power curtailments are expected to increase in the future, with the possibility of rising to as much as 6.8% of total wind production.	Programmed curtailments: wind generators are not compensated if curtailed in programmed curtailments. Real time curtailments: they receive a compensation of about 15% of the wholesale price for each hour without premium, which is multiplied by the theoretical production, based on the wind forecasts.

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