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Central Wind Power Forecasting Programs in North America by Regional Transmission Organizations and Electric Utilities

Subcontract Report
NREL/SR-550-46763
December 2009

K. Porter and J. Rogers
Exeter Associates, Inc.
Columbia, Maryland

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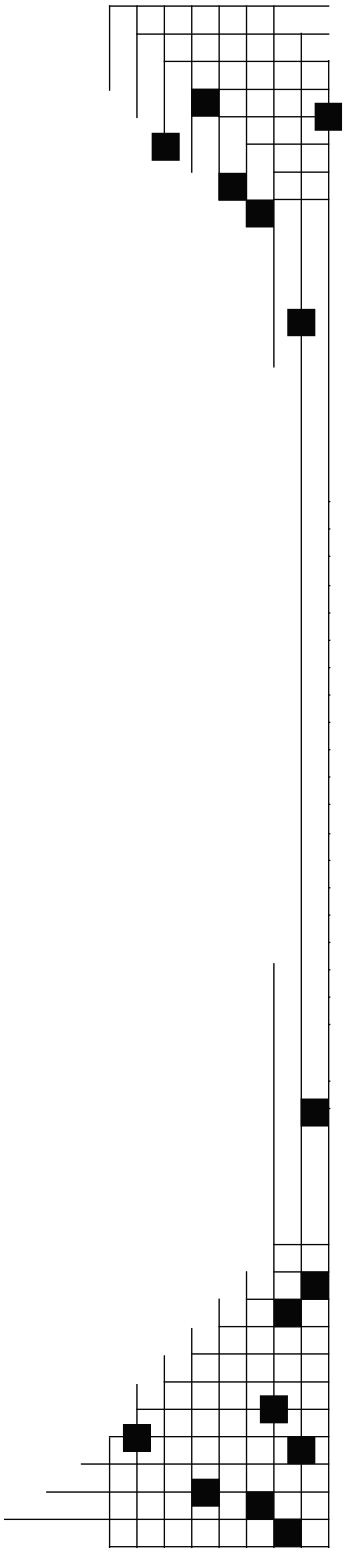
NREL Technical Monitor: J. Hein
Prepared under Subcontract No. LAM-9-99431-01



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Contract No. DE-AC36-08-GO28308

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This publication received minimal editorial review at NREL

Printed on paper containing at least 50% wastepaper, including 20% postconsumer waste

Central Wind Power Forecasting Programs in North America by Regional Transmission Organizations and Electric Utilities

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December 2009

and incorporating review comments from:

Sanjay Patil, PJM
David Edelson, New York Independent System Operator (NYISO)
David Maggio, Electricity Reliability Council of Texas (ERCOT)
Bart McManus, Bonneville Power Administration (BPA)
Mark Ahlstrom and Joe Sullivan, WindLogics
Martin Hastings and Michael Falvo, Independent Electric System Operator of Ontario
Keith Parks, Xcel Energy
Ulrich Focken, Energy & Meteo
Alain Forcione and Jacques Bourret, Hydro Quebec
Jim Blatchford, California Independent System Operator (CAISO)
James Shen, Alberta Electric System Operator
Kenneth Pennock, Dan Meade and John Zack, AWS Truewind
Erik Ela, National Renewable Energy Laboratory (NREL)
Michael McMullen, Midwest Independent System Operator (Midwest ISO)
Barry Gilman, Southern California Edison (SCE)
Charlie Smith, Utility Wind Integration Group

The following table addresses the implementation of central wind power forecasting by electric utilities and regional transmission organizations in North America. The first part of the table focuses on electric utilities and regional transmission organizations that have central wind power forecasting in place; the second part focuses on electric utilities and regional transmission organizations that plan to adopt central wind power forecasting in 2010. Table entries are organized as follows:

- When the wind power forecast was put into operation, or will be in operation.
- What wind power forecast vendor and model is used.
- What wind power forecast tools and techniques are used.
- What applications are the wind power forecast used for.
- How wind power forecasts are paid for.
- What data is required, by wind turbine and wind project.
- How the wind power forecast is conducted.
- Whether a ramp forecast is prepared.
- How the wind power forecast was performed.

	PJM	ERCOT	Midwest ISO
Record Peak Demand	144,644 MW (August 2, 2006)	62,339 MW (August 2006)	116,030 MW (July 31, 2006)
Available Generating Capacity	164,895 MW	80,076 MW	138,556 MW
Installed Wind Capacity	About 2500 MW	8,916 MW	About 7200 MW
Area Served	All or parts of Delaware, Illinois, Indiana, Kentucky, Maryland, Michigan, New Jersey, North Carolina, Ohio, Pennsylvania, Tennessee, Virginia, West Virginia and the District of Columbia.	85% of load in Texas; 75% of Texas by geography.	All or most of North Dakota, South Dakota, Nebraska, Minnesota, Iowa, Wisconsin, Illinois, Indiana, Michigan and parts of Montana, Missouri, Kentucky, and Ohio.
Date of Operation of Wind Forecast	April 2009	July 2008	June 2008
Wind Power Forecast Vendor	Energy & Meteo GmbH	AWS Truewind	Energy & Meteo GmbH
Forecast Model	Previento	eWind	Previento
Forecast Tools/Techniques	Physical model that uses Numerical Weather Prediction (NWP) forecasts as input. Energy & Meteo uses NWP input, a combination of several numerical weather models weighted according to the weather situation, site-specific power curves based on historical data, and a shorter-term model (0-10 hours) based on wind power measurements and NWPs. Wind turbine deration data is integrated in the forecast.	AWS Truewind uses a composite of the individual members of an ensemble of forecasts for each wind project in the ERCOT territory. Uses three NWP models, one run every 3 hrs and two run every 6 hrs; Wind Generation Resource (WGR) output model mixed approach: some statistical using WGR data and some specified power curve Plan to use: 9 NWP model ensemble run every 6 hrs; single NWP model run every hr (for Residual Unit Commitment); Statistical optimized ensemble procedure that will weight ensemble members according to performance in a rolling training sample; Statistical power output model: all WGRs with adequate data	Physical model that uses Numerical Weather Prediction forecasts as input. Energy & Meteo uses NWP input, a combination of several numerical weather models weighted according to the weather situation, site-specific power curves based on historical data, and a shorter-term model (0-10 hours) based on wind power measurements and NWP input.

	PJM	ERCOT	Midwest ISO
Forecast Applications	Developing process to automate the integration of day-ahead wind power forecast within existing PJM systems to determine whether there is sufficient generation scheduled within PJM to meet expected load, transaction schedules, and reserve requirements.	Day-ahead Unit Commitment uses 80% exceedance forecast for day-ahead planning (i.e., 80% chance production meets or exceeds wind power forecast).	Transmission security planning and outage coordination; and forward and intra-day reliability analysis. Also can use wind power forecast to determine impact of wind variability on transmission flowgates.
Forecast Payment Method	PJM pays for the central wind power forecasting service.	ERCOT pays for the central wind power forecasting service.	Midwest ISO pays for the central wind power forecasting service.
Wind Turbine Data Requirements	General turbine information (class of turbine, turbine capacity); min/max wind speed; manufacturer power curves; geographic location; hub height; ambient temperature operating limits and information on installation of cold weather packages. Along with these turbine-specific requirements, the initial project data required includes aggregate historic power output, meteorological and outage data; and the aggregate reactive capability curve.	The number, MW rating, and model of turbines. Also requires average hub height of the project and geographic location of the center of the wind project. Turbine Outage/Availability data is currently voluntary; however ERCOT is working on making it a requirement.	Not applicable - wind projects do not provide any turbine-specific information to Energy & Meteo. Wind turbine outages not currently factored into the wind power forecast, but the Midwest ISO anticipates doing so in the future.
Wind Project Data Requirements	Real time aggregate wind project MW output. Must install at least one meteorological tower (or wind speed and direction from selected wind turbine anemometers and wind vanes) with wind speed and wind direction data required; temperature and pressure data preferred; and humidity data accepted. Outage of turbines ≥ 1MW or an outage lasting 1 hour or more must be reported.	AWS Truewind Data Requirements: Observed Generation; Observed Availability; Observed Basepoint; Observed Meteorological Data (Wind Speed, Wind Direction, Temperature, and Atmospheric Pressure).	Market participants required to provide non-binding day-ahead intermittent resource forecast to Midwest ISO. Midwest ISO provides the latitude and longitude values of each wind project, the hub heights, maximum and historical MW output, and real-time output for each wind project to Energy & Meteo. Energy & Meteo then uses this information to create wind power forecasts.

	PJM	ERCOT	Midwest ISO
Description of Forecast	Long Term: Provided hourly, from 48 hours ahead to 168 hours ahead. Medium Term: Updated from 6 hours ahead to 48 hours ahead. Short Term: Updated with frequency of every 10 min, forecast interval of 5 min for next 6 hours. Confidence interval defined by PJM. Forecast on 5 aggregation levels. Statistical power curve for each wind project.	Wind power forecasts are updated hourly and cover 1-48 hours ahead. Forecast delivered by 15 minutes past each hour. Though not currently required, the following will be a requirement of the nodal market when it is launched in late 2010: Long-Term (one year) forecasts: The long-term forecast is a "typical" energy profile for each day of a future month out to 36 months. Wind developers will be required to submit the long-term wind power forecast each month for a rolling 36 month period.	Receives hourly updated forecasts from Energy & Meteo for each hour of the next seven days, for over 100 Commercial Pricing (CP) nodes. Forecasts available more frequently, but Midwest ISO has not yet determined that need. A short term forecast is provided for the next 6 hours and the remainder of the time is considered a medium/long-term forecast. Energy & Meteo provides forecasts at 4 levels: CP nodes, zones, regions and all of Midwest ISO. Generally, the CP nodes represent an individual wind project. Three different NWP models are used for each of these levels. Energy & Meteo also forecasts wind power output as an optimal combination of all three forecasts. Statistical power curve for each wind project.
Ramp Forecast	Updated every 10 minutes at 5 min intervals for next 6 hours.	In process of developing a ramp forecast.	Several wind power forecasts indicating possible ramps are provided; however, ramp forecasting metrics are still being developed.

	PJM	ERCOT	Midwest ISO
Forecast Performance Metrics	For all of PJM monthly averaged mean absolute error (MAE) for the May 2009 - July 2009 period ranged from 4.9% to 5.1% for intra-day; 5.9% to 7.9% for day-ahead; and 5.2% to 5.6% for the evening forecast at 4:00 PM, which covers 8 to 32 hours ahead. The monthly averaged Root Mean Squared Error (RMSE) for the May 2009 - July 2009 period ranged from 6.5% to 7.3% for intra-day; 8.3% to 10.3% for day-ahead; and 6.9% to 7.6% for the evening forecast. Forecast performance achieved without meteorological data.	For all of ERCOT, monthly averaged MAE for the 4:30 PM system-wide day-ahead forecast, for May 2009-August 2009, ranged from 8.28% to 10.73% of capacity for all hours.	For all of the Midwest ISO, monthly averaged MAE for the 4:30 PM forecast for day-ahead, for May 2009 - July 2009, ranged from 3.3% to 4.5% for all hours. The monthly averaged RMSE for intraday (0 – 24 hour) ranges between 4% and 7% for the period from August 2008 to August 2009. For monthly RMSE for day-ahead (24 – 48) ranges from 5 to 10%. This is the accuracy for the first year after the setup.

	NYISO	CAISO	SCE	Hydro-Québec
Record Peak Demand	33,939 MW (August 2, 2006)	50,270 MW (July 24, 2006)	23,303 MW (August 31, 2007)	37,230 MW (January 16, 2009)
Available Generating Capacity	38,190 MW (Summer 2009)	48,954 MW (does not include 10,350 MW of net imports).	SCE considers data as confidential.	43,664 MW
Installed Wind Capacity	1,275 MW	2,953 MW (CAISO total); 1,005 MW in CAISO's wind forecasting program.	1,073 MW	657 MW
Areas Served	New York	75% of California load	50,000 square mile area of California, excluding the City of Los Angeles and certain other cities.	Quebec, Canada
Date of Operation of Wind Forecast	June 2008 – for dispatch decisions; May 2009 – for individual wind plant economic dispatch decisions	June 2004	November 2000	November 2006
Wind Power Forecast Vendor	AWS Truewind	AWS Truewind	AWS Truewind	Environment Canada: operational GEM 15-km NWP
Forecast Model	eWind	eWind	eWind	Anemos/WPPT; HQ proprietary models; Forecasting tools operated by HQ.
Forecast Tools/Techniques	Uses ensemble forecasts and statistical analysis to prepare wind power forecast. Uses the following inputs: grid point output from regional-scale and global-scale NWP models; measurement data from several meteorological sensors; high-resolution geographical data; and meteorological and generation data from wind projects.	Uses ensemble forecasts and statistical analysis to prepare wind power forecast. Uses the following inputs: grid point output from regional-scale and global-scale NWP models; measurement data from several meteorological sensors; high-resolution geographical data; and meteorological and generation data from wind projects.	Uses ensemble forecasts and statistical analysis to prepare wind power forecast. Uses the following inputs: grid point output from regional-scale and global-scale NWP models; measurement data from several meteorological sensors; high-resolution geographical data; and meteorological and generation data from wind projects. SCE inputs outage and curtailment data both prior and post-production.	Statistical models using NWP and actual wind project generation and turbine availability as inputs. Extensive R&D program on additional and complementary forecasting tools at the Institut de recherche d'Hydro-Québec (IREQ), Hydro-Québec's research institute.

	NYISO	CAISO	SCE	Hydro-Québec
Forecast Applications	Used to review day-ahead unit commitment schedules to ensure enough generation is committed to meet load forecast. Also used in real time to make real-time commitment and dispatch decisions.	Used in hour-ahead market, as Participating Intermittent Resource Program (PIRP) participants must bid wind power forecast. Day-ahead wind power forecast advisory.	Energy scheduling.	Day-ahead scheduling; Intra-day rescheduling; short-term maintenance scheduling. The wind power forecast is taken into account in the intra-day scheduling (generation scheduled to meet expected load, transaction schedules, and reserve requirements).
Forecast Payment Method	Fee assessed to each wind project. Charge includes the sum of a monthly fee of $500 and a separate monthly fee of $7.50 per MW of nameplate capacity. Fees are subject to change as more wind projects are added.	Fee assessed on PIRP participating intermittent resources of $0.10/MWh, and the CAISO covers about $0.09/MWh from within its operating budget. Proposed change: Assess $0.10/MWh fee to non-PIRP intermittent resources as well.	SCE pays for the wind power forecasting service.	HQ pays for the wind power forecasting service.
Wind Turbine Data Requirements	Turbine manufacturer specifications; plant configuration (latitude/longitude of each turbine); manufacturer's power curve; plant/turbine availability; plant level or turbine level power output data.	Real-time telemetry data requirements: wind speed, wind direction, barometric pressure, ambient temperature, real-time MW production, MW production revenue meter. Data requirements: latitude/longitude and elevation of the turbine hub height that will be used as a designated turbine. A designated turbine is the turbine designated to send in anemometry data to represent a surrounding group of turbines.	MW production metering	Operational planning data (planned turbine availability); turbine specifications (power curve, control system, cold weather packages, etc); real-time data including kW of active power, nacelle direction, blade position, temperature at nacelle level, wind speed, wind direction, and turbine status.

	NYISO	CAISO	SCE	Hydro-Québec
Wind Project Data Requirements	Meteorological data from at least one point at least every 15 minutes (to be increased in 2010 requiring data every 30 seconds, and from locations such that no individual turbine is more than 5 km from a reporting sensor). On-site meteorological data [wind speed, wind direction, pressure, temperature, humidity, dew point] from multiple heights. Daily penalties of the greater of $500 or $20/MW for persistent lack of or bad data.	Minimum 1 met tower. Proposed data requirements: Outage reporting: Each wind project must submit outages of at least 1 MW and greater if their overall capacity is greater than 10 MW. A second met tower must be installed. Alternatively, a second data recording device may be on the same met tower, located at approximately 30 meters below the average hub height.	Meteorological data (wind speed, direction, temperature, humidity). SCE uses 12 met towers (six each in Tehachapi and San Gorgonio). SCE inputs outages and curtailments into the system both before wind production (for forecast correction) and after wind production (for calibration of the system).	Specifications (wind project layout). Real-time data including: kW of active power; kW power available from wind turbines, substation, and wind project; number of available turbines; numbers of turbines stopped due to weak wind, strong wind, and low temperature. Meteorological data (horizontal and vertical wind speed, wind direction, temperature, humidity, and atmospheric pressure).

	NYISO	CAISO	SCE	Hydro-Québec
Description of Forecast	Day-ahead forecasts updated twice daily, covering next two operating days at 4 AM and 4 PM. Real-time forecasts updated every 15 minutes on a 15-minute interval basis, covering an 8 hour time horizon. Real-time forecast is blended with persistence forecast to develop wind plant schedules in real-time commitment (which looks ahead in 15-minute intervals for 2.5 hours) and real-time dispatch, which looks ahead in 5 to 15 minute intervals for 60 minutes. 100% persistence used in very short-term.	Extended forecasts: production (MW) for each hour of days 2, 3, and 4 after delivery day; delivered by 5:30 AM on Thursdays, Fridays and selected days before scheduling holidays. Next day: production (MW) for each hour of next calendar day, delivered by 5:30 am. Next hour: production (MW) for each of the next 7 hours, delivered by 15 minutes after each hour and at least one hour and forty-five minutes before real time.	Forecast updated twice a day (at 5 AM and 5 pm), and both forecasts look forward 7 days.	NWPs updated twice daily [at midnight and 12 PM (UTC)], covering 48 hours ahead. Additional 6 AM and 6 PM runs operational by the end of October 2009. Wind power forecasts updated hourly. Alarms sent to the network and wind project operators when expected storms, icy conditions, or very low temperatures risking turbine shutdowns are foreseen.
Ramp Forecast	No ramp forecast; under consideration.	No ramp forecast currently working with the DOE and BPA to develop a Short Term Event Predictor along with a ramp forecast tool.	No ramp forecast; under consideration.	No ramp forecast.
Forecast Performance Metrics	For all of the NYISO and averaged for all intervals between June 2008 and March 2009: MAE of 4.8% for one hour ahead forecast. MAE of 11.5% for day-ahead operation.	Average RMSE for the period between July 2008 and July 2009: Day-ahead forecast: <15 % RMSE Hour ahead forecast: <7% RMSE	Comparable wind power forecast performance data is unavailable.	MAE for March 15, 2009 – June 1, 2009: 1 hr ahead: 8.5% 4 hrs ahead: 13% 8 hrs ahead: 14.2% 12 hrs ahead: 14.4% 24 hrs ahead: 15% RMSE for March 15, 2009 – June 1, 2009: 1 hr ahead: 12.6% 4 hrs ahead: 18% 8 hrs ahead: 19.8% 12 hrs ahead: 20.1% 24 hrs ahead: 20.7%

Central Wind Power Forecasting under Development in the United States and Canada

	Xcel Energy (Colorado)	Ontario IESO	Alberta ESO	BPA
Record Peak Demand	6,884 (Summer 2005)	27,005 MW (August 1, 2006)	9,806 MW (December 2008)	10,500 MW
Available Generating Capacity	7,738 MW	About 35,465 MW	About 12,700 MW	21,580 MW
Installed Wind Capacity	1,234 MW	About 1,200 MW	About 560 MW	2,284 MW
Area Served	Xcel Energy serves parts of eight states. This information is applicable only for Xcel Energy's operations in Colorado.	Ontario, Canada	Alberta, Canada	300,000 square miles All of Washington, Oregon, and Idaho, and western Montana, and small contiguous portions of California, Nevada, Utah, Wyoming, and eastern Montana
Status of Centralized Wind Power Forecasting as of November 2009	Not yet launched. Expected operation date around August 2010; receipt of test forecasts from NCAR began September 25, 2009.	Launch of centralized wind power forecasting expected to start in 2010. Request for proposal (RFP) expected to be issued in late 2009 or early 2010.	Completed a wind power forecasting pilot project in 2008; released wind power forecasting RFP issued in June 2009. Central wind power forecasting expected to start in 2010. Proposes to recover costs from wind generators via a $/MWh charge.	Not yet launched. Through 2009, conducting research on wind power forecasting with different vendors.
Wind Power Forecast Vendor	The National Center for Atmospheric Research (NCAR), with assistance from NREL.	To be determined through competitive RFP process.	For purposes of the pilot, 3 vendors were chosen: AWS Truewind, Energy & Meteo Systems, and WEPROG. AESO expects to complete contracting with a wind power forecasting provider by the end of 2009.	To be determined by January 2010 for operation by end of May 2010. May opt to produce the wind forecast internally or contract with a wind forecasting company.

	Xcel Energy (Colorado)	Ontario IESO	Alberta ESO	BPA
Forecast Tools/Techniques	NCAR will incorporate observations of current atmospheric conditions from a variety of sources using the Weather Research and Forecasting model and their Real-Time Four-Dimensional Data Assimilation system.	Currently operating a decentralized forecasting regime, whereby wind generators submit a forecast of generation output. Wind power forecast accuracy subject to compliance requirements. Wind generators are required to provide updates if actual output is reasonably expected to differ from their original forecasts by 2% or 10 MW, whichever is greater. Real-time scheduling done on a 5-minute basis, relying on a telemetry snapshot of wind output from 10 minutes prior to setting the schedule in real time. Decentralized forecasting regime will eventually be replaced by centralized wind power forecasting (expected to be in service in 2010).	In the pilot project: - AWS Truewind utilized the eWind system, which produced forecasts via an assembly of physics-based (NWP) and statistical models. - Energy & Meteo used NWP input, a combination of several numerical weather models weighted according to the weather situation, site-specific power curves based on historical data, and shortest-term model (0-10 hours) based on power measurements. - WEPROG used an ensemble forecasting system with a large number of members, based on their Wind Generation Pool (WGP) and NWP forecasts.	Forecasts to be made up to 36 hours ahead at four wind projects; two in Oregon and two in Washington. Will focus particularly on wind ramps. BPA has also installed 14 met devices in their Balancing Authority Area. Data feeds from met sites will be in place by late 2009 for forecast displays. BPA will be developing a “wind desk” over the next two years to help dispatchers.

	Xcel Energy	Ontario IESO	Alberta ESO	BPA
Data Requirements	Collect turbine-level and onsite met tower detail from wind projects into the Xcel energy scheduling system. They are also pursuing remote sensing technologies for short-term forecasting purposes.	To be determined.	For the pilot, 10-minute facility power (MW) output: historical and real time; 10-minute wind speed, wind direction, temperature and pressure: historical and real time; 10-minute real-time turbine availability (at 2 sites only). Subject to AESO rulemaking, AESO will impose data requirements on wind plants, i.e., 10-minute met tower and wind generation, and available capacity. Operational power limit will be used as well. Forecasts to incorporate up to two years of historical met and power data.	Wind power forecasters to use metrological data taken from wind facilities.

	Xcel Energy	Ontario IESO	Alberta ESO	BPA
Forecast Update Frequency	3-km nested forecasting grid updated every 3 hours.	As per existing market rules, the market participants submit day-ahead wind power forecast by 11:00 AM on a daily basis. Additional forecast updates are required as conditions change. Some wind companies update their forecast on hourly basis while others may not frequently update apart from the day-ahead forecast. Market Assessment and Compliance Division (MACD) of the IESO looks for evidence that the market participant has exercised due diligence in revising/updating dispatch data (forecasts) to reflect changed conditions or expected injection. Existing processes/rules will be updated upon start of centralized wind power forecasting (expected to be in service in 2010).	For the pilot, three forecasters delivered a 48-hour forecast, updated each hour. Forecasts were delivered in real time for 7 existing wind generation facilities (WGFs), 5 future WGFs as well as 4 regional aggregates of 3 WGFs each, and the aggregate of the existing WGFs, future WGFs and all WGFs. For the RFP, AESO wants hourly forecasts up to 48 hours ahead; and max and min forecast at several confidence levels; and forecasted maximum ramp rates within hour and notification of multi-hour large ramps. AESO interested in expanding forecasting to 72, 96, or 120 hours ahead and rolling 6-hour intra-hour forecast at 10-minute intervals.	Forecast likely updated every ten minutes. It will have 10-minute predictions out 6 hours, and hourly predictions out 36 hours.

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ORGANIZATION.

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
December 2009	Subcontract Report	

4. TITLE AND SUBTITLE
Central Wind Power Forecasting Programs in North America by Regional Transmission Organizations and Electric Utilities

5a. CONTRACT NUMBER
DE-AC36-08-GO28308

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
K. Porter and J. Rogers

5d. PROJECT NUMBER
NREL/SR-550-46763

5e. TASK NUMBER
WER9.5501

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Exeter Associates, 5565 Sterrett Place, Suite 310, Columbia, MD 21044

8. PERFORMING ORGANIZATION REPORT NUMBER
LAM-9-99431-01

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
National Renewable Energy Laboratory
1617 Cole Blvd.
Golden, CO 80401-3393

10. SPONSOR/MONITOR'S ACRONYM(S)
NREL

11. SPONSORING/MONITORING AGENCY REPORT NUMBER
NREL/SR-550-46763

12. DISTRIBUTION AVAILABILITY STATEMENT
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161

13. SUPPLEMENTARY NOTES
NREL Technical Monitor: Jeff Hein

14. ABSTRACT *(Maximum 200 Words)*
The report addresses the implementation of central wind power forecasting by electric utilities and regional transmission organizations in North America.

15. SUBJECT TERMS
Wind; integration; forecasting; regional transmission organizations; RTOs; utilties; North America; electrical

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
Unclassified	Unclassified	Unclassified	UL		19b. TELEPHONE NUMBER (*Include area code)*

Standard Form 298 (Rev. 8/98)
Prescribed by ANSI Std. Z39.18