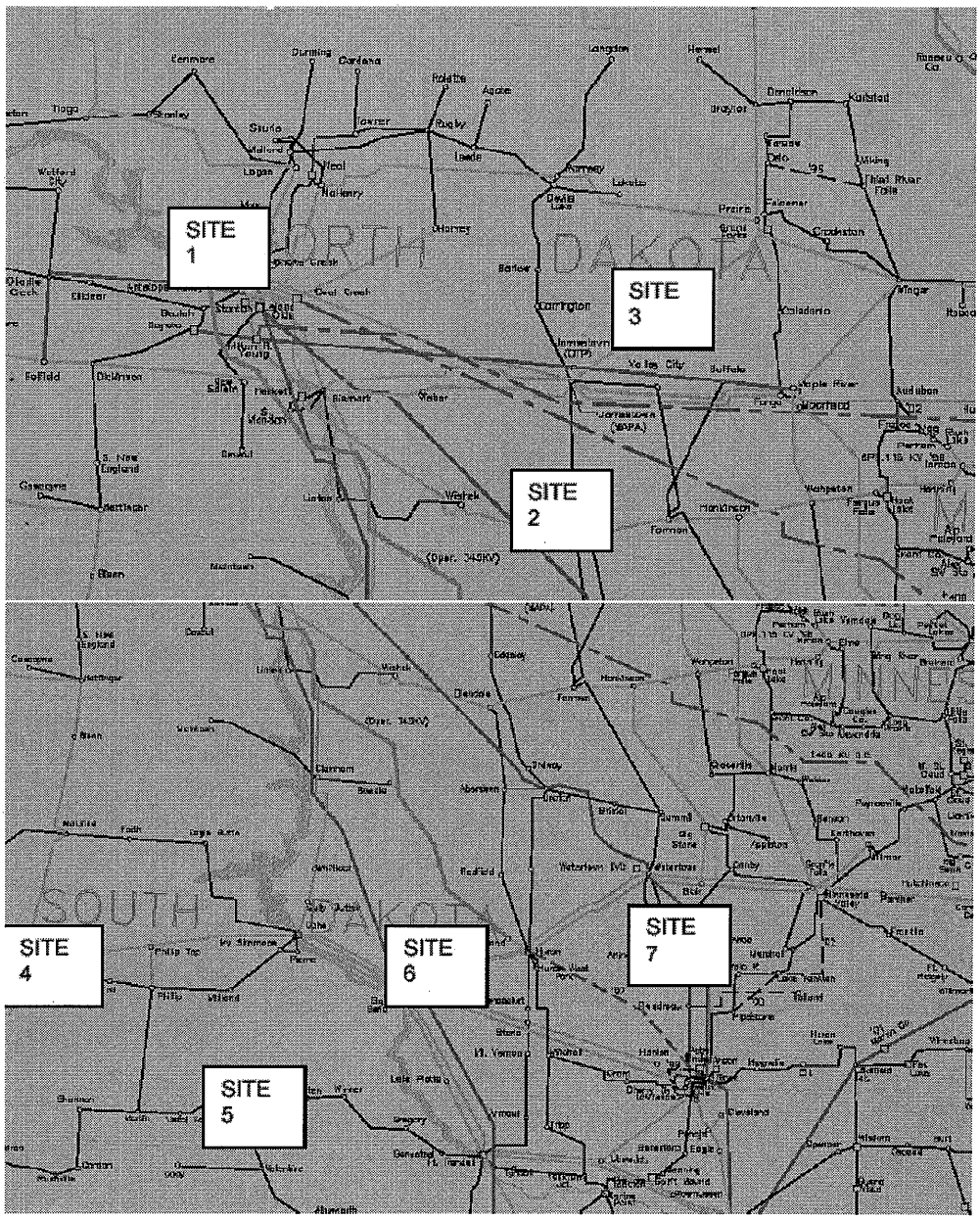
Task 1– Non-Firm Transmission Potential to Deliver Wind Generation

Task 1.1 – Develop Hourly Wind Generation for Historical Year

This task will develop the hourly generation for each of the seven sites for the historical year. The following seven sites are assumed.



The first stage of site selection will be based on publicly available wind resource maps of the Dakotas produced by NREL. The maps will be imported into a GIS and combined with other information such as the existing transmission grid, roads, and population centers. Parks, national forests, and other environmentally and culturally sensitive areas will be excluded from consideration. New wind resource maps of each selected site will then be generated using AWS Truewind's MesoMap system. The maps will be produced for an appropriate turbine hub height, with a 200 m grid spacing, and will be thoroughly validated using available on-site and off-site wind data.

The simulations will provide a self-consistent set of 8760 historical wind speed and direction values at the turbine hub height for any point in the region where a wind plant might be developed. The data will faithfully reproduce correlations between project sites caused by regional and local weather patterns, and thus will accurately capture the benefits of geographic diversity in reducing aggregate wind plant output variability over the entire grid. For each site, the mean speed will be scaled to match estimates of the average speed derived from onsite data (where available) and from the wind resource maps. Using a generic power curve for a large, state-of-the-art wind turbine, including expected plant and wake losses, we will convert the wind speed values to a time series of wind plant generation for several assumed plant sizes ranging from 50 to 500 MW. A weighted moving-average filter will be applied to simulate the effect of aggregating the output of individual turbines within a plant.

This task is being done by AWS Truewind. A weather model simulation is used to determine the wind and develop the wind energy production. Hourly wind estimates for the historical year will be made for a potential 50, 150, 250, and 500 MW of installed wind capacity at each site.

Task 1.2 – Develop Gridview Database

Gridview will be set up to monitor the flows in the following three corridors:

- The North Dakota Export (NDEX) Interface
- Each of the 230-kV lines from Watertown to Granite Falls
- The seven transmission lines from Ft. Thompson going east and southeast plus the 115-kV line from Bonesteel to Ft. Randall.

This task will develop the hourly loads and generation for the Dakotas without the new wind generation for the year 2003. ABB will extract the hourly NDEX (North Dakota Export) and North Dakota generation dispatch for the 2003 year from the WAPA supplied database. ABB will fine-tune the Gridview database to match the operation data provided by WAPA as closely as possible.

ABB will extract the summation of power flowing each hour in 2003 over the seven transmission lines going east and southeast from Ft. Thompson. The Generation dispatch of Oahe and Big Bend will be adjusted to match the Ft. Thompson interface flows for each hour in 2003.

Gridview benchmark the historical year by running a powerflow for each hour of 2003 and then comparing the monitored results of each of the three corridors against the actual use across each corridor using recorded historical data. The model parameters will be adjusted so as to develop a representative case for the historical year.

Task 1.3 – Simulate Historical Year with Proposed Wind Generation

-This task will determine the energy delivered by the wind farm by juxtaposing the hourly, chronological wind shape obtained from Task 1 with the hourly transfer capability of the three transmission corridors obtained from a Gridview simulation of the 2003 database developed in Task 2. The scenarios to be simulated are:

Scenario 1: 500 MW at the Garrison 230-kV bus
Scenario 2: 500 MW at a new substation on the Leland Olds-Groton 345-kV line near Ellendale
Scenario 3: 500 MW at Pickert 230-kV bus
Scenario 4: 500 MW at the New Underwood 230-kV bus
Scenario 5: 500 MW at the Mission 115-kV bus (Without extensive upgrades to Ft. Randal this site will not accommodate 500 MW so a lower MW may be used)
Scenario 6: 500 MW at the Ft. Thompson 230-kV bus
Scenario 7: 500 MW at the White 345-kV bus
Scenario 8: 50 MW at each of the 7 previous sites in Scenarios 1 through 7

Based on the results, the quantity of undeliverable wind energy based on constraints in the three defined corridors will be identified, together with the times and level of undelivered wind energy due to transmission constraints. These results will be compiled and presented as an annual flow duration curve for each corridor. In general, by first doing each proposed wind site separately any special impact that site has on a corridor will be identified.

Task 1.4 – Sensitivities with Proposed Wind Generation

The same wind generation used in Task 1.3 will be considered at each site. These same wind site scenarios will be simulated for with for the following sensitivities:

- A case with high hydro generation
- A case with higher load growth

The cases above will be simulated without wind and then for each of the eight wind scenarios.

Task 2– Potential Transmission Technologies to Increase Power Transfers

Western will need to provide ABB with a powerflow and stability case representing the summer off-peak conditions with maximum simultaneous transfers in order to evaluate transmission technologies to increased power transfers.

Task 2.1 – Steady-State Limitations and Potential Enhancements

This task will review the corridor limits that were noted in the Gridview analysis. These limitations will be reviewed to initially determine what available technologies may be applicable to overcoming these limits. For each corridor, a representative wind site will be selected to demonstrate the impact of potential transmission technologies. Any overloads resulting from the additional wind generation will be determined and applicable transmission technologies identified.

For steady-state thermal limits, the most applicable technologies will be:

- Add conventional series capacitors
- Add phase shifting transformers
- Re-conductor transmission lines
- Dynamic transmission line ratings

If steady-state voltages are limiting then shunt capacitors may be applicable. Application of series capacitors or phase shifting transformer are used when one or more transmission lines reaches a limit and capacity is still available in other lines. If just one line is limiting, re-conductoring that is one potential option.

After determining what may be the best technology, powerflow simulations with and without these enhancements will be made to determine the effectiveness of the technology.

A qualitative discussion of dynamic line ratings, transmission line re-conductoring, and transmission line voltage upgrades will be provided with some specific quantitative example calculations. ABB will coordinate with Western on

the potential for re-conductoring lines with new types of composite conductors. ABB has already done some preliminary investigation into upgrading the voltage on some of the transmission lines in the Dakotas and this information will be used.

Task 2.2 – Stability Limitations and Potential Enhancements

From Task 2.1, the three wind scenarios used in the steady-state analysis will be used to investigate the impact on stability. Of the technologies listed for steady-state enhancements above, the series capacitors will also improve system stability. Phase shifting transformers add impedance to the system and in general reduce the system stability, although in the Northern MAPP system they may be useful in redirecting flows away from critical interfaces (e.g., the Manitoba Hydro Export –MHEX- Interface), and thus can be helpful in increasing transfer capability. There will be little impact to stability by a line that is re-conductored or has dynamic line ratings. For steady-state the most applicable technologies are:

- Add conventional series capacitors
- Add controllable series capacitors
- Add SVCs or STATCOMs (They provide the same benefits)
- Add phase shifting transformers

After determining what may be the best technology, stability simulations with and without these enhancements will be made to determine the effectiveness of the technology. These simulations will first be made without the enhancements, the optimum enhancement will be chosen and included in simulations to compare the impact and benefit of the enhancement.

Task 3– Proposed Site Interconnection Studies

This task will include an interconnection study of each of the seven sites. For each site generation levels of 50 MW, 150 MW, 250 MW, and 500 MW will be studied. One case will be studied with 50 MW at each of the seven sites. The procedure will be to start with 500 MW at the site, identify the system enhancements and then go to the next lower level of generation. When the wind generation level is reached where no or minimum system enhancements are required then this will complete the interconnection study for that site.

These studies will investigate the local system requirements to connect to the power grid and will not include the impact on transfer capacity across the interconnected power system.

Task 3.1 – Develop Base Cases

ABB will coordinate with Western to obtain the system data to model the expected conditions and any system upgrades that are scheduled to be in service. For the steady-state and stability analysis, ABB proposes to use a winter peak case for the analysis.

Task 3.2 – Windfarm Models

The wind generation will be modeled as an aggregate 50 MW, 150 MW, 250 MW, or 500 MW generator unit. Since recent project have mostly been developed with the DFIG wind generating units, ABB proposes to use a DFIG model for the wind generation.

The impedance of the equivalent step-up transformer (12.5% on the transformer MVA Base), the wind turbine generator step-up transformer (typically 6% on WTG MVA base and rated 0.6/34.5 kV) and an estimated lumped model for the collector system will be represented. For DFIG units, they will be modeled as a standard generator in voltage control mode in the powerflow with reactive power limits. A DFIG model that specifically models the characteristics of a DFIG unit will be used in the stability simulations.

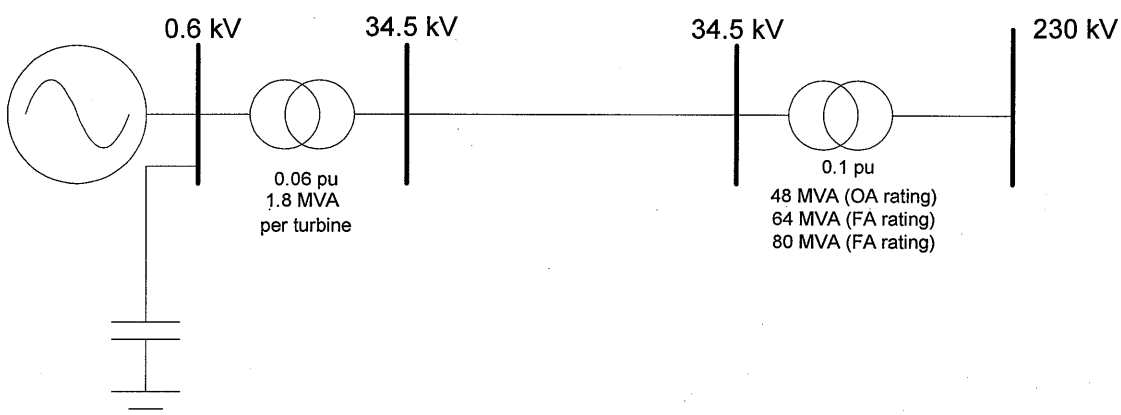


Figure 1: Example wind farm model, for a wind farm with conventional induction generators. With DFIG units, there would be no shunt capacitors at the turbine bus.

Task 3.3 – Steady-State Powerflow and Contingency Analysis

For the base case and the new wind generation case, ABB will develop a list of contingencies adjacent to each site. The contingencies will include single contingencies of the 345-kV, 230-kV, and 115-kV system in North Dakota, South Dakota and . Contingencies will also be taken of any new facilities proposed for the transmission alternatives being studied. Overloaded facilities and low voltage buses will be identified for each contingency and tabulated for inclusion in the report. In addition to contingency analysis, a comparison of system losses for each of the base cases will be provided. Each site will be modeled from 500 MW to 50 MW or to the level that system enhancements are not required. The requirements for local system enhancements to interconnect each level of generation will identified.

Task 3.4 – Short Circuit Study

The base case without wind and with the 150 MW and 500 MW alternatives at each site will have 3-phase and single-line-to-ground faults calculated for the new wind stations and the adjacent stations. For those alternatives requiring enhancements, short circuits will be calculated at each substation with new or upgraded facilities. The short circuit calculations will be done for both the base case without the new generation and the case with the new generation. These short circuit levels will be compared.

Task 3.5 – Stability Studies

A stability analysis of the MAPP system will be made with and without the new wind generation. Those cases that are critical to the local site will be simulated. Simulations will include critical line contingencies near the new generation and loss of generation. In addition, 3-phase, high side faults will be simulated at the new wind generation site to evaluate stability of the proposed generation. Each site will be modeled from 500 MW to 50 MW or to the level that system enhancements are not required for stable operation. The typical fault ride through capability of DFIG units as defined today by the manufacturers will be used to determine if the generation will ride through the faults.

Task 3.6 – Constrained Interface Impact Studies

Utilizing tools already available in the UIP Package (DFCALC Program), the impact of wind generation at each of the seven alternative sites on constrained interfaces will be assessed and reported.

Task 4– Transfer Capability for Wind Power to the Markets

Task 4.1 – Develop Base Case

ABB will coordinate with Western to obtain the system data to be used in this study. ABB proposes to investigate the following two conditions for steady-state analysis:

- Summer Off-Peak
- Winter Peak

ABB proposes to investigate power transfers to the Twin Cities, central and eastern Iowa, and Omaha and Kansas City plus a combination of all three. The four most favorable wind sites will be matched up with each of the market scenarios and these cases will be analyzed for the transfer capacity to deliver the wind power. Based on the results of Tasks 2 and 3, transmission enhancements will be investigated to increase power transfers to get the power to the markets.

Task 4.2 – Steady-State Powerflow and Contingency Analysis

ABB will develop a list of contingencies for each of the critical interfaces between the wind generation and the potential market. ABB will use the MUST program option in PSS/E to identify the transfer capacity across these interfaces for each of the four wind sites and compare this to the system without any new wind generation. ABB will also identify the system limitations to transfer capacity from each of the four wind sites with each of the marketing scenarios and make an assessment on potential enhancements that can increase these transfers. The most promising enhancements for each transfer limit will be demonstrated.

Task 4.3 – Stability Studies

Those interfaces that are limited by stability will have a stability analysis of the transfer capacity for each of the four sites with those market scenarios that affect the interface. The analyses will be conducted under summer off-peak loading conditions which is the most severe case for stability. Those cases that are critical to determining the limits of the interface will be simulated. The most promising enhancement for each stability limit will be demonstrated.

Task 4.4 – Identification of Enhancements

The enhancements identified and simulated in Tasks 4.2 and 4.2 will be further evaluated based on cost and land impact as well as performance. Each enhancement will be ranked by performance, costs, and land impact.

REVISED TIME SCHEDULE
FOR THE DAKOTA WIND TRANSMISSION STUDY

SCHEDULE

ABB fully understands that timely completion of this project is important to HDR and Western. The proposed schedule will meet the following dates.

- Signed agreement November 19, 2004
- Received line power transfers for 2003 on December 13, 2004
- Begin Task 1.1 Wind generation, December 16, 2004
- Begin Task 1.2 Gridview model, December 9, 2004
- Assumptions, methods, & models identified by January 6, 2005
- Task 1.2 complete December 31, 2004
- First Meeting on Assumptions and Methods, January 19, 2005
- Task 1.1 data available February 15, 2005
- Start Task 1.3 February 15, 2005
- Complete simulations for Task 1.3 March 15, 2005
- Start Task 2 January 5, 2005
- Complete Task 2 initial analysis February 20, 2005
- Tasks 1 – 2 Results -- due date -- March 15,2005
- Start Task 3.1 and 3.2, February 1, 2005
- Start Task 3.3 and 3.4, February 20, 2005
- Start Task 3.4 and 3.5, March 20, 2005
- Complete Task 3, May 1, 2005
- Start Task 4.1 and 4.2, February 1, 2005
- Start Task 4.3, February 24, 2005
- Start Task 4.4, March 15, 2005
- Complete Task 4, May 10, 2005
- Tasks 3 – 4 Results -- due date -- May 17, 2005
- Draft Report Tasks 1-2 -- due date -- July 15, 2005
- Draft Report Tasks 3-4 -- due date -- August 12, 2005
- Final Report – due date – September 23, 2005