Transmission System Impacts Due to Wind Generation

Wind resources have a highly variable output. The electric transmission system has to be designed such that it can accommodate the wind generation at maximum output, as well as, accommodate the loss of the wind resource when the wind exceeds the cut-off speed or drops below the cut-in speed. The case of most impact may be when the cut-off speed is exceeded and the wind generation goes from full output to none. Also, wind generation may be required to participate in remedial action schemes that can disconnect the wind generation from the grid or cause it to reduce its output in order to preserve system reliability. The addition of any new generation in NorthWestern Energy's (NWE) control area will likely result in an equal amount of generation that has to be exported. This is due to the low load growth in the area.

Study Process for Integrating Resources

Any new resource that wants to interconnect to the transmission system and transmit its energy to customers has to follow the FERC mandated process under the NWE Open Access Tariff. The generator makes a request for interconnection of NWE that is date and time stamped. All requests that were already in the generation interconnection queue have priority over requests with later time stamps. The party signs an agreement for interconnection studies for which it will pay the costs. The studies include a feasibility study that assesses the feasibility of the project using power flow studies, a System Impact Study which assesses reliability of the transmission system using power flow and stability studies, Fault Duty Studies that determine the need to upgrade system protective equipment such as circuit breakers, Facility Studies that determine the additional facilities required to interconnect the project and Other Studies that encompass any special requirements such as potential sub-synchronous resonance as an example. These studies take into account the generation that is in the queue ahead of the project being studied. If it is found that because of the other resources in the queue that the proposed project is not feasible, the developer has some options for Additional Studies. These include Added Transmission Co-existing Studies, Choose Senior Queue Position Generation Study in which the customer decides which senior projects to include, or Choose Senior Queue Generation and Load Study which is like the previous study but has load designated in NWE's service territory. Once these studies are done the resource developer knows the costs associated with interconnecting to the transmission system.

But this does not provide the developer with the ability to move its power to any customers across the transmission system. The developer or a power purchaser must make a Transmission Service Request on NWE's OASIS in order to transmit the energy from the resource site to its customers. The request will identify the type and magnitude of the service required. This study will determine if there is sufficient Available Transmission Capacity to accommodate the request. If there is not, then the additional studies will determine what system additions are required to increase the system capacity sufficiently to move the energy across NWE's transmission system. For transmission of energy beyond the NWE system, the developer will need to make a Transmission Service Request for each of the transmission systems that will be crossed.

A developer can have its project in both queues simultaneously.

Potential Impacts Due to Wind Additions

Studies have indicated that if 900 to 1000 MW of generation is added to the existing generation in NWE's service territory, more export capacity will need to be added to the transmission system. Queue position is used to assign responsibility for system upgrades to the party causing the need for an upgrade. The analysis below will indicate if queue position is assumed or a stand-alone approach is used. For the wind additions, it is assumed that the each addition is 150 MW nameplate wind project with an average output of 50 MW (33.5% of nameplate). The National Renewable Energy Laboratory developed this capacity number for the Rocky Mountain Transmission Study (RMATS).

In the Colstrip area, the addition of 150 MW of wind will probably require an additional 230 kV line from Colstrip into the Billings/Broadview area. This is based on the generation that has already made transmission service requests coming on line. If the proposed projects do not materialize, then the system may require upgrading the series capacitors on the Colstrip-Broadview 500 kV lines and increasing the transformer capacity between the 500 kV and 230 kV substations at Colstrip. If the project desires to sell off system, additional capacity for export may be needed if the 900 MW of new generation has been exceeded. The upgrades to the series capacitors and a new transformer at Colstrip were estimated to cost about $11 million in the RMATS study. A new 230 kV line is estimated to cost about $250,000/mile or more. These estimates may be low since NWE has not built any 230 kV or higher voltage transmission in a long time. Once the system upgrade for the first block of wind has been added there may be sufficient capacity for a second 150 MW block. Even with these system additions, projects in this area may need to participate in the Colstrip Remedial Action Scheme (RAS) to maintain system reliability.

A wind generation block of 150 MW in the Judith Gap area might be accommodated provided the project connects to the 230 kV system and is prepared to reduce generation or be disconnected for certain outages that overload the Judith Gap 230/100 kV autotransformer. Studies will be needed to confirm this. Increasing the capacity of the autotransformer may lead to overloads on the 100 kV system in the Judith Gap areas. This will particularly true with a 230 kV outage to Great Falls and 100 kV outage in the Judith Gap area. A second block may require a new 230 kV line to Great Falls to accommodate loss of a 230 kV line from the project to Great Falls. The cost per mile is in the previous paragraph. Without this addition, the wind farm would need to be tripped for this outage and generation levels above 150 MW. As at Colstrip, if the 900 MW new additions limit is reached, additional export capacity will be needed or resources in Montana will be operating at reduced output.

In the Whitehall area, a 150 MW block of wind can be handled if it is connected to the 161 kV system. There may be some minor overloads of lower voltage transformers for some outages. Reducing the wind farm output during those outage conditions can mitigate the overloads. Adding a second block of wind generation will require a connection to the 230 kV transmission in the area. The cost may be several million dollars. Certain outage conditions such as loss of the 230/161 kV autotransformer, will require reduction of the wind farm output. Again, if the new generation additions exceed 900 MW, there may be need for additional export capability.

Operational Issues

NWE operates a control area that covers much of Montana. The control area operator is charged with maintaining system frequency and net schedules with other control areas taking into account the variable nature of the system. This is handled by regulation that matches the generation to the load on a moment-to-moment basis as either the load or generation changes, reserves that can be called on within minutes to replace generation that is reduced or lost (load following), and be able to obtain energy to replace generation unscheduled outages that extend beyond an hour (energy imbalance). Since NWE does not own any significant generation in Montana, it must rely on the market to provide these services. The costs for these services are $7.25/kw-month (capacity charge), there is an energy component if the rolling 4-hour average exceeds 30 MWH and is indexed off the Mid-C index which for December 2004 was about $46.80. Additionally NWE has recently paid $5/MWh for reserve capacity plus energy priced at the Mid-C indexed price. System balancing energy is purchased at the market rate (Mid-C is a good approximation).

The variability of the wind resource output can put a significant strain on the ability for the control area to provide adequate control. The output can go from maximum capability to no generation if the wind exceeds the cut-out speed or stops. This situation places the most burden on the system. The reserve requirement is the responsibility of the generator. The Northwest Power Pool requires that wind generators have reserves equal to 5% of their output. The other ancillary services described above are obtained by NWE and charged to the generator.

To get an idea of the impact of a new wind farm on the system from an operational perspective, let's assume that a 150 MW wind farm requires a regulation increase of 5 MW and that the wind speed exceeds the cut-off speed for three hours. The capacity charge for regulation will increase by $36,250/month (if the capacity is available). If it is assumed that the 4-hour rolling average was about 30 MWH prior to the unit trip and it takes 10 minutes to get the reserves up to the 150 MW level. This is an average of 25 MW in that hour and 6 MW for the four hour rolling average. This average will remain at this level for four hours assuming the following hours did not have any net regulation energy. The cost will be 25 MW at the Mid-C price of $46.80/MW or $1,170. The reserves cost for the first hour is 150 MWH at a price of $5/MWh or $750. The energy imbalance cost for 2 hours at 150 MWH/hour at a price of $47.80 or $14,340. This last amount is paid either by the generator or the load. Assuming the wind generation is being sold at $31/MWH, the delta for the energy imbalance is $16.80/MWH that results in an incremental cost of $5,040. The net cost of the outage to the system is $6,960. This can happen fairly often when the wind is near the cut-out speed. Similar costs are incurred when the wind speed varies.