Reclamations Role in Integrating Wind Energy

Executive Summary

Reclamation along with the hydro power industry will have a significant role in the successful integration of wind energy. Wind generation differs from tradition generation in that it is an energy resource that provides very little power system capacity or reserves. Hydro power is the only advantageous and realistic generation available to support wind energy by providing the power system reserves needed to maintain system dependability, stability, and reliability.

Optimizing the use of hydro assets to assist in the integration of wind energy will maximize the amount of wind and hydro renewable energy available which will help to minimize CO_2 emissions. In fact, hydro resources can have a larger impact on reducing CO_2 emissions than wind resources. Hydro energy CO_2 reduction benefit is the same as wind energy but hydro also contributes to system reserves which further reduce CO_2 emissions.

In addition, implementation of a demand response program for Reclamation pumping plants can provide additional reserves. By controlling when pumps are used these plants can assist with integration of wind energy while also possibly lowering the cost of the electric energy they consume.

There are various technical items that Reclamation can begin to address to prepare for more wind energy. Improvements made today in plant equipment, unit operations, maintenance, cost recovery, and hydro model used in power system studies will prepare Reclamation to meet the challenges of tomorrows wind integrated power system.

Introduction

The electric power industry in the United States is in the midst of some profound changes that will change the way it produces, transmits, and controls electric energy. High energy prices, national security, supply uncertainties, and environmental concerns are driving public policies and utilities to develop renewable energy sources. As a result the US wind energy industry is growing rapidly. Various scenarios have been proposed and studied regarding the new electrical generation profile. This past year the Department of Energy (DOE) released a comprehensive and detailed report documenting one of these studies entitled “20% Wind Energy by 2030.”[1]

To achieve the goal of producing 20% of the United States electric energy from wind will require about 1.16 billion MWh of wind energy. This will require more than 300 GW of wind installation to be built, which is equivalent to 150,000 2-MW wind turbines. A majority of potential wind resources are located in the 17 west western states, the same region that Reclamation serves. Wind generation in this region could be significantly higher than 20%.

The DOE study indicates that this level of penetration is reasonable but will come with challenges. One of the main challenges is that wind is primarily an energy resource, not a capacity resource. Capacity resources are generators that are available on demand to insure generation meets system load. They support the reliability of the power system, insuring that "the lights stay on." Wind is an energy source, but because of it variability, contributes little to capacity. Thus incorporating wind energy will require a new way of managing and scheduling the power system that contains a large energy resource that contribute little to capacity. Power system reserves which contribute to capacity will become more important in the future power system.

Power System Reserves

Studies and actual operating experience indicate that it is easier to integrate wind energy into a power system when there are flexible and dispatchable generators available to provide balancing energy and precise load flowing/support capabilities. Flexible generators are needed that can change load rapidly. This capacity is referred to as power system reserves and among various utilities is often subdivided into three broad categories of regulatory[1] reserves, contingency[2] reserves, and supplemental[3] reserves.

Regulatory reserves consist of generators that are synchronized, loaded, and are available immediately to increase or decrease generation in response to power system demand changes. Contingency reserves consist of generators that are able to change load within 10 minutes. It includes units that can be started and loaded and/or unloaded within 10 minutes to meet system demand changes. Hydroelectric units are typically the first choice to provide these reserves followed by gas turbines.

Supplemental reserves are met with dispatchable generators that can respond to meet the 10 minute to 30 minute changes in load. These resources consists of generator capacity that takes longer to respond than the contingency reserve generators and includes generators that are currently offline but can be started and brought online in about 10 minutes and loaded within 30 minutes. Again, hydroelectric units are typically the first choice to provide these reserves followed by gas turbines

Contingency reserves can include loads that are interruptible. Typically these are provided by large commercial customers that are willing to have their supply interrupted in an emergency in return for a discount on their energy rates. Some utilities are moving to control more loads during peak demand by switching them off and on. A good example would be air conditioning units that are cycled on peak demand days to reduce demand.

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[1] Also referred to as frequency-response reserve or Automatic Generation Control (AGC).
[2] Definitions vary between control areas. Also referred to as spinning, 10-minute spinning, 10-minute non-synchronous, and 10-minute non-spinning reserves.
[3] Also referred to as non-spinning reserves.

Integrating Wind Energy

At its very core the power system must reliably deliver energy. Wind generation is a non-dispatchable source of energy that has zero emissions and zero fuel use. The limiting value of wind energy is the energy available varies and is somewhat unpredictable. Power system load is also variable and somewhat unpredictable thus power system reserves are required to match changes in demand. Wind can not be scheduled on the days and time that energy is needed to meet load demand. Further, wind turbine output changes minute-to-minute to hour-to-hour. Thus wind generation can not be relied on for capacity or reserves. The wind and utility industries have been able to mitigate many of the variability issues by improvements in wind forecasting, dispersion of wind turbine sites, and the creation of larger power system control areas. However, flexible and dispatchable generators will continue to be required to provide system capacity, balancing energy, and to match load. In fact as more wind energy is added to the power system additional reserves will be required. Studies have shown that for every 100 MW increase of wind generation added, the power system could require up to an additional 0.3 MW of contingency reserves and up to 2 MW of supplemental reserves.[2] The 20% wind energy scenario requires about 300 GW of wind. Thus the reserve requirements would be roughly 7 GW.

Hydropower Resources will be Required to Provide Additional System Reserves

Hydroelectric generation is uniquely positioned to facilitate the integration of wind energy. Hydro is the only renewable source of electricity presently available[4] that can support wind energy by providing the capacity and reserve needs of the power system. Hydropower is the preferred method to provide system reserves and unlike gas turbines it has zero emissions and zero fuel cost.

In fact hydro resources have a larger impact on reducing CO_2 emissions than wind resources. Hydro energy CO_2 reduction benefit is the same as wind energy (both wind and hydro have the same capacity factor values). 1 MW of wind or hydro energy displaces 1,800 Tons of CO_2 per year.[5] In addition hydro generation can supply the capacity and reserve needs of the power system. This increases the environmental benefit of hydro by displacing fossil fuel generation needed for system reserves. On average every 1 MW of regulation supplied by hydro power would reduce the emissions from a peaking gas combustion turbine by 560 Tons of CO_2 per year and from a coal peaking plant by 1540 Tons of CO_2 per year.[3] For example a 75MW hydro generator at a capacity factor of roughly 30 percent (national average for hydro) would displace 135,000 tons of CO_2 per year based on the energy it would supply. If the plant was also used for regulation with a swing of ± 20 MW it would displace an additional 11,200 tons of CO_2 per year by displacing a peaking gas turbine. Its total contribution would be a reduction of 146,200 tons of CO_2 per year. In this example 1 MW of hydro displaced

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[4] Geothermal can supply capacity and reserves. Presently it makes up less than 0.3 percent of existing capacity.

[5] Data from “20% Wind Energy by 2030” technical report

1,950 Tons of CO_2 per year, an 8% improvement when compared to factoring only the energy contribution of hydro power.

Demand Response Load – System loads can supply reserves

The hydro industry also is uniquely positioned to facilitate the integration of wind energy by controlling water deliveries in response to system demand. Demand response is basically controlling the consumption of energy based on supply conditions and can be viewed as a method to provide system reserves. Demand side management is typically used to reduce power system peak demand but can also be used to increase demand at times of over production of energy. Demand response loads can be divided into two broad categories. The first category includes price sensitive loads, which are loads that are willing to reduce or increase for the right price. The other category includes interruptible loads which are loads consumers are willing to have interrupted or curtailed under low generation or emergency situations.

Typically water delivery systems have built in water storage capacity that would allow, to some extent, for pumps to be scheduled. Pumps would run when there is an abundant supply of energy from wind and prices are low. Thus, pumps can be categorized as price sensitive loads. Flexible and dispatchable pump loads would contribute to power system reserves by being made available to the power system dispatchers as a resource to use in balancing energy capacity.

Reclamation's Role in Integrating Wind Energy

Hydro power will have a significant role in the successful integration of wind energy. With more wind resources being introduced, power system reliability, dependability, and stability will be eroded and major blackouts will occur if changes are not made to the way the power system is managed and scheduled. This is an opportunity for the hydroelectric industry to adapt and manage its resources to assist in addressing these national issues. Reclamation is in a unique position to consider the issues and new opportunities in managing and scheduling its resources in the best interested of the American people. Optimizing the use of hydro assets to assist in the integration of wind energy will maximize the amount of renewable wind and hydro energy produced while also maintaining and enhancing power system reliability, dependability, and stability.

Reclamation is also uniquely qualified to participate in demand response management to assist by providing additional reserves. Reclamation operates and/or owns several pumping facilities with pumps that range from tens-of-thousands of horsepower to hundreds of horsepower. These pumps use a significant amount of energy. By controlling when these pumps are used Reclamation could not only assist with the integration of wind energy but lower the actual cost of the electric energy used to deliver water.

Reclamation is in a position to take a lead role in this integration given that: 1) hydro power is the preferred method to provide reserves, 2) hydro power is the only renewable source of energy that can provide reserves, and 3) Reclamation is the second largest producer of hydropower[6] and the largest supplier of water in the western United States. By providing reserves hydro will play a significant roll in maintaining the reliability of the power system as more and more wind generation is added to the system. It also is in the national interest for utilities to be proactive rather than reactive. A reactive response would be responding to an increase in system blackouts due to a lack of preparation for the integration of wind energy.

Reclamation support of new renewable energy resources, such as wind, would require action on several fronts. Items that need to be considered include technical issues (e.g. operations, maintenance, cost recovery, modeling, and equipment improvements), water issues (e.g. project water, stream flow, and reservoir levels), and policy issues (e.g. renewable portfolio standards, power marketing agencies agreements, and project requirements, all requiring policy office involvement). The water and policy issues are beyond the scope of this paper and would require the involvement of several agencies, and end users; however, many of the technical issues can be addressed internal to Reclamation.

What Technical Issues Can Reclamation Powerplants Address Today?

There are several technical issues that Reclamation and the hydro industry need to address in integrating wind energy. Generators will be started and stopped more frequently and their load cycling will increase. They also will need to operate at varying load points. Providing additional system reserves will require updating some hydroelectric equipment, changing current practices, and updating controls. BPA, Western, and the Corps also are addressing these same issues and Reclamation involvement and cooperation with these agencies would be advantageous.

Equipment

Circuit Breakers – The number of circuit breaker operations will increase. Older equipment will need to be updated to handle the increased duty cycle. Several Reclamation plants have already replaced aging breakers; however, the frequency of this update will need to be accelerated.

Runners - To help provide system reserves, generators will need the flexibility to operate at various load points. Old turbine runners were typically designed to have a relatively small operating range. New runner designs allow a runner to have a wide and relatively flat efficiency curve and in many cases the new designs actually increase overall efficiencies. This will increase the efficiency of the generator at a wide range of load levels. Reclamation has begun to update runners at several plants. The importance of off peak operations needs to be address when runners are replaced.

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[6] In the United States there is roughly 100 GW of installed hydropower. Reclamation operates about 15% of these resources. It operates 58 powerplants and 194 hydro generators with an installed nameplate capacity of nearly 15 GW and produces nearly 44 million MWh of energy

Cooling Water Controls - As stated above the generator will be cycled between various load points. To reduce the stress on the stator winding insulation, the cooling water can be throttled back to help maintain a constant winding temperature. This will reduce thermal expansion and contraction cycles and increase the life of the stator winding. Very few hydro plants have this option available, but it can be added at a relatively low cost.

Operations

SCADA System- Plant and river system optimization systems will need to be modified to account for the additional variability wind energy will introduce. Hydro generation forecast and potential power swing estimates are some of the variables that need to be added to the optimization equipment. Additional research will be required to develop and implement these changes.

Governor and Exciter – To provide contingency reserves (generation reserves required within 10 minutes) it will be necessary to quickly start a unit. By updating to digital governors and exciters a hydro unit can be started and synchronized in about 1 minute. This will allow a generator at stand still to provide contingency reserves without wasting water to keep the unit spinning at no load. Reclamation needs to accelerate replacement of these older systems with these new digital controllers.

Unit Controls - Unit controls will need to be modified to increase the reliability of a unit start and to allow the start to proceed quickly. Auxiliary equipment will need to come online quickly and the start sequence optimized. Each Reclamation plant needs to check start controls and make the changes necessary to expedite a unit start.

Unit Protection – Reclamation's hydro generator must continue to support and contribute to power system stability and reliability. This will require properly tuned excitation and Power System Stabilizer (PSS) systems and well coordinated relay settings. Reclamation has excellent exciter and relay maintenance and testing resources. Implementation of these resources at all levels within Reclamation should be encouraged. Research also needs to be performed to ensure that system stability is not compromised as wind is added to the power system. Reclamation does not want to be responsible for causing or contributing to the next regional blackout.

Maintenance

Condition Monitoring Systems – As the number of load cycles and start/stops increase the amount of wear and tear on the generator and associated equipment will also increase. It will become more difficult to judge the condition of the generator and associated equipment based on time. Condition monitoring systems that monitor the health of the unit will become necessary to preserve an effective, efficient, low-cost maintenance program. Currently use of such systems is very limited within Reclamation. Continued research into condition monitoring should continue and the deployment of hydro based diagnostic systems should be seriously considered as opportunities arise.

Cost Recovery

Cycling and Start/Stop Cost - Little is known about the additional hydro generator stator related costs associated with increased maintenance and the loss of life that occurs because of load cycling and start/stops. These cost need to be researched and identified so that the cost of providing system reserves can be recovered. Reclamation has begun a small research effort to look into these issues but much more work is required.

Maintenance Costs – Maintenance cost are currently funded mainly by Reclamation's water and power customers. As maintenance cost increase as the result of integrating wind energy the question of who pays for these increased costs need to be addresses. Research needs to be performed to identify and quantify these costs.

Wind Integration Studies

Hydro models – Models for past industry studies regarding the impact of wind energy on the power system used very simplified models of a hydro electric plant. Hydro models need to account for the water and energy constraints at the plant. This information is not readily available so often times power system models simply base-load hydro plants effectively negating the reserve capability that the plant can provide. The models used in the industry need to be updated. Fairly detailed models of large hydro plants need to be developed as they will have the largest impact on the wind integration studies. In addition a generic model that could be applied to medium and smaller hydro plants is needed as these plants make up a majority of the hydro plants in the United States. Improving the hydro models will improve the quality of the wind integration studies and better define the impact and opportunities.

Development of a Reclamation Demand Response Management Program

Reclamation should consider using its large loads to help provide system reserves via a demand response management program. Reclamation operates and/or owns pumps that range from several kW to over 100 MW. Typically the cost of power and how it is generated has not been considered when making decisions on when to pump water. To assist in the integration of wind and to capitalize on the availability of excess wind energy (low-cost, renewable energy) it will be necessary to begin to optimize pumping schedules. This will require developing optimization routines that consider the various water demands and constraints along with the power system needs to optimize when/how to run these pumps. Western's and BPA's input and participating in this effort would be critical. Optimizing the pumping schedule would most likely result in moving pump loads from peak load periods (morning and early evenings) to low load periods which typically occur at night. It also should result in cost saving to water users as the revenues derived from providing power system reserves should lower the cost of delivering water. The full impact of demand response management should be researched to quantify the benefits and to determine what changes and upgrades to the water delivery system are required.

Conclusion

Reclamation along with the hydro power industry will have a significant role in the successful integration of wind energy. Wind generation it is an energy resource that provides very little power system reserves. Hydro power is the only renewable source of energy available to support wind energy to help insure the power system remains reliable, dependable, and stable. Optimizing hydro assets to assist in the integration of wind energy will maximize wind and hydro renewable energy which helps to minimize CO_2 emissions. In addition, Reclamation's pumping plants can provide power system reserves by participating in demand response programs. Controlling when pumps are used provides system reserves while possibly lowering pumping costs.

References

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