Advanced Controls for Wind Turbines and Farms Boost Efficiencies, Profitability

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Abstract

Advanced control technologies hold perhaps the greatest potential in the wind energy industry for improvements in individaul turbine and entire wind farm efficiency. Using sophisticated, nimble controllers built on innovative principles could be the key to making wind more profitable, even in light of falling government subsidies and research support.

At $1 million per megawatt of power, wind turbines are big investments, and they're expected to put out by generating huge sums of energy in order to stay competitive with cheap fuels like coal and natural gas. It's no surprise, then, that wind turbine researchers and manufacturers are racing to budget bottom by looking for the next big technology that will boost turbine efficiency, increase reliability, and improve availability.

In many cases, the answers lie with innovations in the electric and electronic components of turbines and the grid. One of the biggest areas of interest in the wind industry today is that of advanced control systems using electric and electornic theories and components to get the maximum energy production out of both individual turbines and entire wind farms.

Advanced Control Technologies for Greater Turbine Efficiency

Advanced control systems and integrated sensors hold some of the greatest promise for increasing a turbine's energy production and lowering capital costs for both onshore and offshore applications, especially when they're married to floating substructures. Advanced control technologies, which rely on complex algorithms and sophisticated software, are used to optimize a turbine's performance under varying conditions. Additionally, by reducing the load on turbines, advanced controls help to stabilize a turbine's behavior as well.

There are many areas in which advanced controllers can improve the performance of a wind turbine. From pitch angle to wind modeling to transitions from one wind region to another, the impact of advanced controllers within the wind industry will surely be one of the most beneficial in the next few years.

Advanced Control Technologies: Pitch Control

Pitch angle is of upmost importance in wind turbine efficiency, and many innovations have recently been developed to improve the ability of controllers to adjust pitch for optimal energy generation. Fixed pitch wind turbines offer the advantage of being less expensive initially, but because of the lack of ability to control loads or adjust the aerodynamic torque on these turbines, they ultimately reduce their energy producing power. As such, variable pitch blades that can rotate along their longitudinal axes are becoming more common in utility scale turbines.

Depending on the number of blades and design of the turbine, it is possible to adjust variable pitch blades either collectively or independently. Increasingly, the preference is to use individually-calibrated advanced control technologies for each blade to adjust pitch control to compensate for increased rotor size and the spatial load variations along the blade. Advanced pitch controls can be used to adjust the aerodynamic torque from the wind input, which allows the turbine to adjust individual blades as needed and act quickly enough to provide a positive impact on power generation.

REenergy Electric (Suzhou) Co., Ltd., for instance, has created an ultracapacitor pitch control system. When combined with a battery, these ultracapacitors increase the overall power density and decrease the strain on the battery.

Advanced Control Technologies: Speed Control

But pitch isn't the only factor that has an impact on a wind turbine's energy output. Another area being explored extensively in the world of advanced controls is that of variable speed turbines. Fixed speed turbines operate at one speed, providing a more stable flow of generated electricity. Variable speed turbines, on the other hand, can operate close to their maximum aerodynamic efficiency because they're able to function in a variety of wind speeds, allowing them to generate electrical power for significantly more time throughout the year. Though this type of electrical power requires processing in order to be fed into the electrical grid, the results for individual turbines is greater power per kilogram, which boosts the return on investment.

But with variations in wind speeds in both space and time from blade to blade and even along the same blade, and given the effect of the interaction of the blades with the wind directly, the challenge of compensating for these changes at the supervisory, operational, and subsystem levels is incredibly complex. Advanced control systems for variable wind speed and direction are particularly useful given the incredible dexterity with which they can compensate for deviations in wind across the rotor plane. Allowing for much more agile adjustments based on a myriad of data points, advanced control systems hold incredible potential for increasing a turbine's overall power production.

Another challenge being overcome by advanced controls is nimble turbine and blade adjustments when transitioning between wind regions, especially Regions 2 and 3, each of which requires its own control loop. It is during this transition that significant structural damage can occur as a result of increased extreme fatigue loads. Researchers are currently working on methods for using adaptive controls for these types of parameters to smooth the transitions and minimize damage caused by them.

Given the innovations in advanced control technologies, variable speed turbines are gaining in popularity because of their ability to increase uptime and power generation. Gamesa is one of the major players in this field. They were recently awarded a grant to work with the National Renewable Energy Laboratory (NREL) in the US to develop control technologies that will improve energy capture while decreasing loads through advanced controllers. Their approach is to create more sophisticated algorithms that will measure changes in aerodynamic loads, blade profile response, and pitch actuation and their impact on output and power fluctuation.

Other Advanced Control Technologies Innovations

Turbine stoppages are an additional source of concern for the wind industry. Emergencies may require the sudden stopping of a turbine, but the act of shutting down the turbine can cause damage to the overall system. To overcome this problem, control systems are being developed that will provide advanced fault detection and turbine protection to protect the machine.

One final area of interest for advanced control systems engineers is that of modeling accuracies, which is essential to achieve maximum energy production. Conditions such as turbine wear and tear, environmental conditions, dynamic weather patterns, and debris build-up are used to tune a wind turbine to achieve optimal performance. Even minute errors in modeling can cause energy losses of even 1%, which can have significant financial consequences for a wind farm.

These advanced controls are required to be exceptionally agile and sophisticated in order to compensate for multiple control loops and degrees of freedom, many of which interact in complex relationships. These challenges become even more pronounced in offshore applications where the degrees of freedom are even more dramatic on floating platforms. As a result, advanced control systems are required to work within a unified multi-input, multi-output (MIMO) framework to control each blade individually in order to reduce loads significantly.

Advanced Control Technologies for Greater Farm Efficiency

Wind farms are some of the most technologically advanced forms of renewable energy on the planet, with growth rates in the wind industry of more than 30% annually for the past 10 years. Globally, the economic value of the wind market is estimated to be US$36 billion annually in new generating equipment, with utility scale wind farms making up the vast majority of new installed capacity. The potential for optimizing the cost-effectiveness and generating capacity of these large scale installations is substantial.

Nevertheless, much of the research in the advanced control systems industry is focused on control over the amount of power generated by individual turbines. That leaves a huge area of potential research into advanced controls focused on increasing the efficiency of a farm, with particular attention needed in how to reduce the negative impact of turbine aerodynamic interaction. The challenges in this field include things like preventing a wind farm from contributing to grid faults, protecting turbines from grid faults, and developing control strategies for voltage control.

Of particular importance is using advanced controllers to minimize aerodynamic interaction by coordinating the function of each individual turbine within a farm. Though not as much research has been done in this area, it is one of growing interest, and great potential. Being able to achieve high array efficiencies within vast wind farms will have a significant impact on making wind energy more financially competitive with conventional fuels.

Conclusion

Advanced control technologies are the key technological focus in today's wind energy research sector, and rightly so. By making it possible to control individual blades, individual turbines and entire farms with increased refinement and detail, advanced control systems will provide massive increases in efficiencies with incremental, cost-effective adjustments in turbine design and construction.

Author Bio

A student of all things green, Maryruth has a special interest in cleantech and green buildings. In recent years, Maryruth has worked as the senior editor of The Green Economy magazine, is a regular blogger for several green business ventures, and has contributed to the editorial content of not one, but two eco-living websites: www.ecolife.com and www.GreenYour.com. You can learn more about Maryruth's work by visiting her site, www.jadecreative.com

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