Optimum Maintenance Strategies for Maximizing the Availability of Wind Farms

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Abstract:
In principle, improving system reliability and reducing Operations and Maintenance (O&M) costs are top priorities of electric utilities. Recently, there has been a growing concern with regard to improving efficiency and quantifying the availability of wind farms. An effective maintenance strategy is essential to preserve the health of wind turbines in particular, and for reliable, safe, efficient, and economical operation of wind power plants as a whole. Inspection, corrective maintenance, preventive maintenance, condition monitoring, or replacement are some of the options currently being practiced by maintenance supervisors. At the same time, a balance is required between the dollar amount spent on the maintenance activities and their resulting benefits to improve the efficiency of wind power plants. Moreover, quantifying the impact of various maintenance strategies on the availability of wind turbines and the reliability of wind farms is essential. Using the estimated cost of selected maintenance strategies as well as penalties and rewards for having unhealthy or healthy equipment, the cost/benefits can be determined. There is also a variety of safety hazards associated with wind farms. The quantification of risks associated with ice build-up on the blades and others will assist in wind farm O&M decision-making processes. We propose to develop an analytical technique for repairable equipment such as wind turbines, and quantify the equipment maintenance rate by maximizing the availability of equipment. Also, reliability indices for wind power plants are calculated, and the impact of maintenance are determined. Moreover, risks associated with safety hazards at wind farms are quantified.

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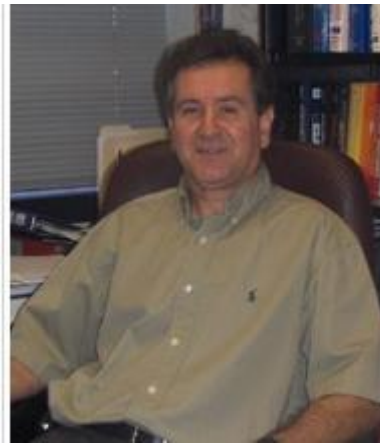

Wind energy is becoming a key part of the electric energy mix, and performance of wind energy systems will play a bigger role on the overall grid system performance and reliability. Wind turbines are in remote areas which unlike conventional power plants are exposed to harsh environment and highly variable conditions such as severe winds, heat, lightning, and ice. As a result, the wind turbine undergoes a high mechanical stress and requires a rigorous and effective maintenance strategy to provide a reliable, cost-effective, and safe power output. Reliability analysis of wind energy systems can contribute to increased efficiency and reduced operating cost. The results of this analysis can assist maintenance supervisors and decision makers with appropriate actions for increasing availability of equipment in the systems and reducing their downtimes thus increasing the efficiency of power generation.

We will attempt to address the following questions: How do we allocate maintenance resources to maximize wind power plant reliability and minimize cost? What are the impacts of various maintenance activities on plant's reliability and cost? What are the key equipment in a wind farm and how much maintenance is sufficient to satisfy a "target" reliability? Does it worth to install condition monitoring? How do we achieve an effective maintenance plan and sustained reliability for a wind farm? How long can we delay maintenance, yet achieve a "target" reliability, without affecting the degradation of equipment? How do we develop a knowledge-based maintenance management system to properly maintain various parts of a wind farm depending on a range of parameters such as operating temperature, lubricant viscosity, and turbine size.

Mathematical models will be developed to represent the state of equipment, to incorporate the desired monitoring level and maintenance activities, and to quantify the effect of maintenance on reliability of wind energy plants. A life cycle cost model will be used for evaluating the performance of wind energy systems. Sensitivity analysis will be performed to determine the impact of various maintenance activities on the reliability and cost of wind farms.

A probabilistic framework for assessing the safety of wind power plants will also be developed. This includes a guideline which focuses on safety risks associated with wind energy systems.