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Development, implementation, and testing of fault detection strategies on the National Wind Technology Center's controls advanced research turbines

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ABSTRACT

The National Renewable Energy Laboratory's National Wind Technology Center dedicates two 600 kW turbines for advanced control systems research. A fault detection system for both turbines has been developed, analyzed, and improved across years of experiments to protect the turbines as each new controller is tested. Analysis of field data and ongoing fault detection strategy improvements have resulted in a system of sensors, fault definitions, and detection strategies that have thus far been effective at protecting the turbines. In this paper, we document this fault detection system and provide field data illustrating its operation while detecting a range of failures. In some cases, we discuss the refinement process over time as fault detection strategies were improved. The purpose of this article is to share field experience obtained during the development and field testing of the existing fault detection system, and to offer a possible baseline for comparison with more advanced turbine fault detection controllers.

1. Introduction

Concern over climate change and global politics associated with traditional fossil fuel energy sources has driven significant increases in wind energy utilization over the past decade within the US and around the world. According to the American Wind Energy Association, the US added more than 10 GW of installed wind capacity in 2009, bringing its total to more than 35 GW [1]. Globally, capacity grew by 31% in 2009, bringing the global total to 157.9 GW [2]. Despite these impressive statistics, more research is necessary to reduce the cost of wind energy and increase its reliability. In 2008, the US Department of Energy's Office of Renewable Energy and Energy Efficiency published a guide outlining the research activities that are necessary to support its vision of supplying 20% of the US electrical energy needs from wind by the year 2030 [3]. A 10-fold increase in the US installed wind capacity, to about 300 GW, is required to achieve that goal. The key initiatives to improving turbine performance outlined in the report are avoiding problems before installation, performance monitoring, and rapid deployment of problem resolution. Condition monitoring is one of many areas listed that can help to reach the 20% wind goal, and is particularly important for offshore wind technology where regularly-scheduled O&M is expensive due to poor accessibility.

Condition monitoring-based maintenance, which is preventative maintenance dependent on monitoring outputs, has shown advantages for wind systems compared to scheduled and corrective maintenance despite initially higher set-up costs [4]. Amirat and colleagues [5] emphasize that condition monitoring can in some cases detect problems while components are still operational and before other components are damaged, allowing more opportunity to plan fixes while reducing down time.

According to Verbruggen [6], existing condition monitoring techniques from other industries such as vibration analysis, oil analysis, thermography, strain measurements, acoustic measurements, performance monitoring, and self-diagnostic sensors may be relevant to wind energy condition monitoring. Wind turbine condition monitoring is of such interest that it is the topic of a recent control development challenge, with a benchmark paper presented at a 2009 conference [7]. Due to the proprietary nature of the research, not many articles exist in the public domain containing detailed hardware and field test results. One exception is the final report and article from a European Union study related to wind turbine fault detection and condition monitoring was field tested with promising results, and thorough descriptions of the hardware and software systems can be found in [8,9].

At the National Wind Technology Center (NWTC), the two- and three-bladed, 600 kW Controls Advanced Research Turbines (CART2 and CART3) have a combined decade of advanced control research field test data. Although testing of fault detection techniques was not the primary focus for these turbines, the development of a network of algorithms and sensors for fault detection

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