Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 110 (2017) 328 – 333

Energy Procedia

1st International Conference on Energy and Power, ICEP2016, 14-16 December 2016, RMIT University, Melbourne, Australia

Life cycle reliability and maintenance analyses of wind turbines

Daniel Chan, John Mo*

RMIT University, Melbourne, VIC 3000, Australia

Abstract

Wind power generation is an effective form of clean, renewable energy which operate both on land and offshore. The primary means of converting wind to power is by wind turbines. The issue with wind turbines is the life cycle reliability, operation and maintenance tasks associated. Frequent premature failures resulting in reactive maintenance can be costly which results in downtime and loss of production. Currently, prognostic health management is conducted on wind turbines by a supervisory control and data acquisition system. However, using this approach, only reactive and preventative maintenance is being utilised. This paper analyses life cycle reliability and maintenance of wind turbines which applies the concept of failure mode and effects analysis (FMEA) and bond graph modelling to simulate the effects of maintenance strategies on the life cycle cost of wind turbines. To ensure wind turbines life cycle reliability, the components failures would occur in sync with the biannual maintenance. This will ensure effective use of resources, such as transportation and personnel costs, associated with the maintenance action. Preventative maintenance can also be conducted in accordance to the MTTF values.

Peer-review under responsibility of the organizing committee of the 1st International Conference on Energy and Power.

Keywords: Wind power; wind turbine; operation; maintenance; life cycle reliability

1. Introduction

Wind power is an effective form of clean, renewable energy which operate both on land and offshore. It does not consume fuel or emit carbon emissions during its operation and is predicted to be 'the most cost competitive electricity source on macro-economic level by 2025 [1]. The primary function of a wind turbine is to harvest wind energy. It is done through converting kinetic energy of blades rotating into electrical energy.

* Corresponding author. Tel.: +61 3 9925 6279; fax: +61 3 9925 6108.
E-mail address: john.mo@rmit.edu.au

Peer-review under responsibility of the organizing committee of the 1st International Conference on Energy and Power.
doi:10.1016/j.egypro.2017.03.148

Wind farms are unreliable sources of energy generation which require frequent maintenance. They need to continuously adapt to different wind loads as wind conditions change over time and are highly unpredictable. The conditions in which wind turbines operate often cause system failures. Saxena and Rao [2] analysed wind turbine failures for a wind farm in India. They found that failure duration of yaw motor was highest, followed by failure duration of gear-oil pump, and then hydraulic unit of blade tip air brakes system.

Technology has improved significantly to minimize failure rates of components, however, failures of common parts are continually occurring. These failures are critical as it cause downtime and prevents the primary function of power generation. There have been 1868 accidents reported since 1900, of which 118 were critical, 174 structural failures and 345 blade failures [3]. Failures are highly undesirable in any system, whether it be mechanical or physical. Historical data shows a high failure rate in the gearboxes which require replacing every 5 to 7 years [4]. Structural damage occurs frequently as a consequence of high wind loads, fire damage and wildlife impact which have high financial risks due to environmental impacts. Due to the complexity of the components, the repair cost of is very high [5]. It is the general belief that better quality of components would lead to more reliable systems, however, not much research is found in literature on predicting these failures at the design stage.

Wind turbine operation is dependent on wind speeds to generate power. Elmore and Gallagher [6] found that use of non site-specific wind velocity data, such as that available from a regional database could be a cost-effective means for predicting wind turbine performance. The concluded that Monte Carlo models could predict wind turbine performance using remote wind velocity data. Heller [8] from Lawrence Livermore National Laboratory published the results of statistical analysis of field observations to help turbine manufacturers to refine their power curves and incorporate findings about what atmospheric processes are important in wind power forecasting. However, many wind turbines' performance still declined significantly and became uneconomical to operate after 10 years of operation. The wind turbine would then be decommissioned and replaced with a newer replacement.

This paper analyses life cycle reliability and maintenance of wind turbines. The analysis applies the concept of failure mode and effect analysis (FMEA) and Bond graph modelling to simulate the effect of changing maintenance strategies on the life cycle cost of wind turbines. The analysis results can be used to determine the optimum maintenance schedules and preventive part replacements.

2. Literature review

A wind turbine is a complex collection of components comprising rotors, pitch system, drive train, gearbox, generator, electrical system, mechanical brakes, yaw system, sensors, control system and hydraulics. To understand how these intervals and what activities are required in each visit, it is important to develop mathematical models to analyse the effect of different visit intervals and maintenance strategies. This literature review examines the key modelling research relevant to wind turbine lifecycle operation analysis.

2.1. Wind turbine reliability

Wind turbine reliability depends on the reliability of some key components. For example, gearbox failures are seen as the most common and most critical failure. A gearbox failure ceases the primary function of electricity generation and faces downtime for repairs or replacement. Structural damage to the blades and tower are another common mode of failure. The blades may have experienced high wind loads or bird strikes, resulting in broken blades. Chou & Tu [9] analysed the failure of a wind turbine tower caused by Typhoon Jangmi. They concluded that the bolts were inadequate and quality control was the cause of the damage. Lui & Shang [10] conducted failure analysis on wind turbine blade bolts. Laboratory testing of stress, strain, alternating loads, tensile loads, hardness and toughness were undertaken and concluded failure of bolts occurred from fatigue due to high alternating loads.

Electrical system within the generator can cause an ignition, burning fuel vapors within the nacelle. Once a fire has started within the nacelle, it is highly unlikely to be extinguished due to the location and height of the fire. Since the 1980s, up to 30% of reported wind turbine accidents related to fire, with 90% of those leading to significant downtime or total loss of system [11].