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WIND ENERGY O&M VALUE ASSESSMENT FOR PING MONITOR BLADE ACOUSTIC MONITORING

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Dr. Zhang is a Managing Consultant with a focus on the North American wind and solar technology trend, market development and O&M. Feng lends his significant expertise to provide business strategy, technology assessment, market study, due diligence support, competitive benchmarking, LCOE analysis and digital solutions strategy support.

Prior to Wood Mackenzie, Dr. Zhang was Director of Global Digital Energy Center for Envision Energy in Houston, TX. Concurrently, he is also Director of Global turbine engineering and research and is a member of Envision executive committee. As one of the key Envision executives, Dr. Zhang led many strategic efforts and new initiatives for Envision, including digital transformation of wind business, digital strategy for future networked energy and Energy Operation System (EnOS), product management of cloud-based energy analytics software, technical due diligence for M&A and investment, establishing R&D center, global wind turbine system engineering, wind turbine product management, wind farm operation and maintenance and advanced technology research, etc.

Dr. Zhang began his career as a Senior Researcher for Powertrain in Ford Motor Company. He joined GM and SAIC joint venture in China where he led large scale engine program with annual budget for more than 100 million USD, in charge of the entire lifecycle of diesel engine development and manufacturing, from prototype, test validation to series production and launch.

Dr. Zhang received his PhD from Mechanical Engineering in University of Houston. He earned both BS and MS from Tsinghua University in Beijing, China. He is based in Wood Mackenzie's Houston office.

1. INTRODUCTION

Blade replacement and repair cost is a significant part of turbine O&M cost. The current turbine blade maintenance approach is to repair damage if necessary. Typically, repairs are carried out following an annual inspection of the rotor blades, which are undertaken through visual methods, including drones, ground based cameras and rope access. This approach may be sufficient when damage propagates slowly. However, most unscheduled expensive blade corrective actions happen between the blade inspection interval are due to a sudden and accelerated deterioration of known minor defects or rapid propagating new damages. The late detection of damage propagation can result in expensive major repairs and blade replacements.

Condition monitoring is widely used in the wind turbine industry to predict and reduce the risk of failures in rotating components such as bearings, gear boxes and generators. However, there is currently no widely adopted method to continuously monitor the health of wind turbine blades. The Ping Monitor provides a solution for continuous condition monitoring of wind turbine blades opening the door to predictive maintenance of blades and significant blade O&M cost reduction.

The Ping Monitor is a device that continually monitors the health of wind turbine blades based on their acoustic signatures during operation. The Ping Monitor is placed permanently at or near the base of a wind turbine, continuously listens to noise from the wind turbine and detects damage based on the subtle difference in sound generated by damaged blades when compared to healthy undamaged ones. It is powered by a solar panel and uses a range of communication systems to send blade health information and alerts to maintenance personnel when blade damage is detected or extent of damage changes. The continuous monitoring of a wind turbine’s blade health brings several benefits to the wind farm operator:

- The ability to detect blade failures in the early stage and reduce the severity of the blade failures. Many minor blade defects will be fixed in early stage and major repairs and replacements are avoided. The cost and downtime due to unscheduled blade repairs will be reduced.
- Reduce inspection frequency and saving O&M spending for drone and other inspection methods.

Ping Monitors were applied on many wind turbines at different sites and locations. It can detect various types of blade failures at different stages. The following types of blade damage and defects have been detected by the system to date, including root cracks, cord cracks, surface delamination, leading edge erosion, tears in leading edge protection tape, holes, split tips, lightning damage. Based on the data provided by Ping services on the existing trial fleet of 7 turbines, the system is not demonstrating false positives or false negative for damage detection. However, large scale testing needs to be conducted to validate the initial accuracy and detection rate.

2. BENEFIT ASSESSMENT OF PING MONITOR

To assess the benefit of the Ping Monitor for O&M, we use a generic 2 MW turbine with 100-meter rotor, which is representative of the existing global operating fleet from 5 to 15 years in service. The benefit will be estimated and compared to annual drone inspection case. The detail assumptions of the representative turbine are listed in Table 1. The associated O&M costs and downtime assumptions are listed in Table 2. Based on the early trial data provided by Ping Services, it is reasonable to assume up to 80% of reduction for drone services because there is no need to inspect every turbine. Ping monitor will limit drone inspection only to those turbines with potential surface defects.

Table 1. Turbine assumption

Turbine Assumption	
Turbine Capacity	2MW
Turbine Rotor	100m
Capacity Factor	35%
Wholesale Power Price	71 $/MWh
Technical Availability	97%
Planned Downtime	40 hr/Year

Table 2. O&M assumption

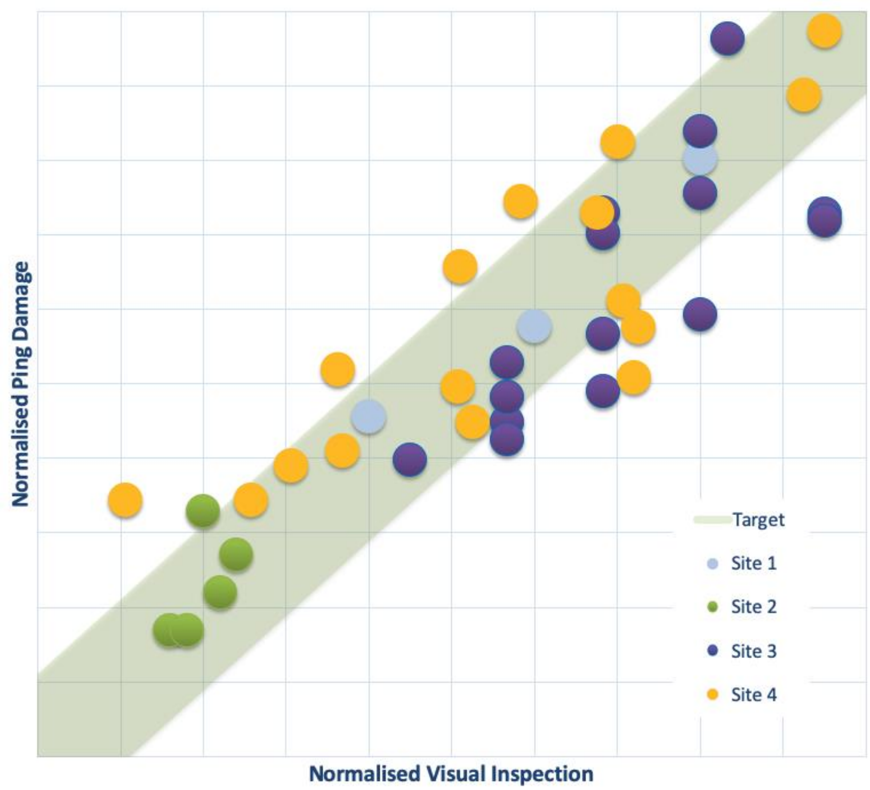
O&M assumption	
Drone inspection cost	$400/turbine
Blade replacement downtime	285 Hr/failure
Blade repair	104 Hr/failure
Blade replacement cost	$300000/failure
Blade repair cost	$15000/failure

Source: Wood Mackenzie

As part of the Ping Monitor continuous improvement and refinement of the damage detection ranking algorithm, a detailed correlation between Ping Monitor measurements and current industry standard visual defect ranking is on-going. Early results show a promising correlation between Ping Monitor and trial site inspection data sets. The results are presented in Figure 1. The Ping Monitor can not only identify defective blades, but also at the correct severity level. Based on this data and the capability of continuous monitoring, defective blades can be fixed at early stage and therefore reduce blade repair cost. Furthermore, many blade replacements can be avoided if minor defects are fixed early. Based on available blade O&M data, Woodmac estimate 25% reduction in blade repair cost and 30% blade replacement can be avoided if failure can be detected and repaired between annual inspection.

The blade failure rate is another factor impacting the business case for the Ping Monitor. Different turbines will have different blade failure rates and therefore different level of benefits the Ping Monitor can bring. In this paper, we studied the benefits for 3 levels of blade failure rate (High, Medium and Low). The corresponding assumptions are presented in Table 3. The benefits are evaluated by considering both the repair cost saving and repair downtime reduction. The repair downtime reduction is then converted into revenue loss reduction using average revenue loss per downtime hour which is determined by capacity factor and wholesale electricity price. Drone inspection saving is calculated based on assumed drone inspection price and estimated inspection frequency reduction. The benefits assessment results are presented in Table 3. The main benefits for ping monitor are from reducing blade O&M cost. The significance of the benefits is directly related to blade failure rate. For a typical 100MW wind farm, the benefit could range from $31,850 to $121,000 per year based on the health level of the turbine blades.

Figure 2 – Correlation analysis between Ping Monitor and Visual inspection data



Source: Ping Services

Table 3 – O&M benefit assessment (2MW-100m turbine)

Blade Failure Rate Scenario	Low	Medium	High
Annual blade replacement failure rate per turbine	0.30%	1%	2%
Annual blade repair failure rate per turbine	1.50%	5%	10%
Revenue increase by downtime reduction ($/turbine/year)	11	31	59
O&M Cost saving ($/turbine/year)	306	1020	2041
Drone inspection cost saving ($/turbine/year)	320	320	320
Total benefit ($/turbine/year)	**637**	**1371**	**2420**

Source: Wood Mackenzie

3. CONCLUSION

In this paper, the O&M value of blade acoustic monitoring - Ping Monitor is assessed using a generic 2MW 100-meter rotor wind turbine. Based on the initial field trial data provided Ping Services, Ping Monitor will be able to identify blade failures and severity accurately. Therefore, it can be used for blade continuous condition monitoring to reduce repair cost, revenue loss due to repair and drone inspection cost. The overall benefits are directly related to blade failure rates. The higher the blade failure rates are, the greater the benefits are. Thus, Ping Monitor is an ideal solution to reduce blade O&M cost for out-of-warranty wind turbines with medium to high blade failure rates. For a typical 100MW wind farm, the benefit could range from $31,850 to $121,000 per year based on the health level of the turbine blades.

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