PO.078

The Effect of Pitch System Reliability on Wind Power Levelized Cost of Energy

DNV-GL
Joint Presentation

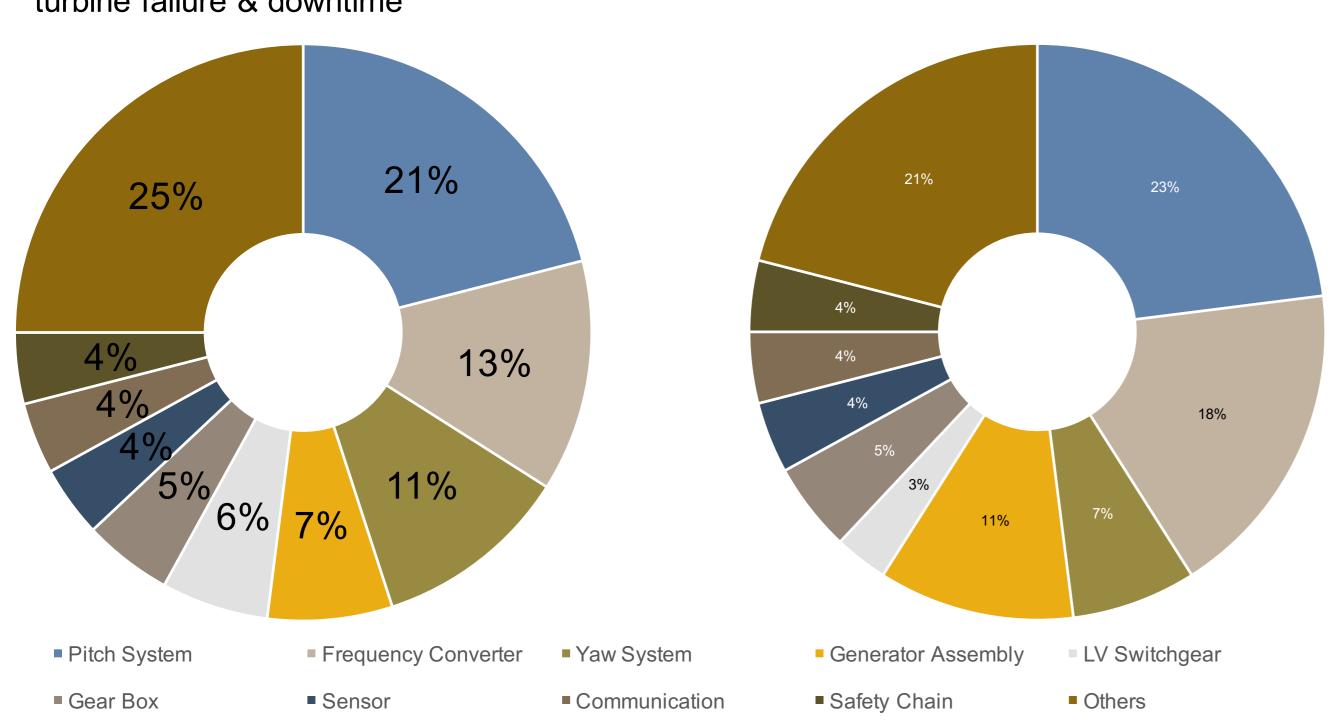
Moog Pitch System 3

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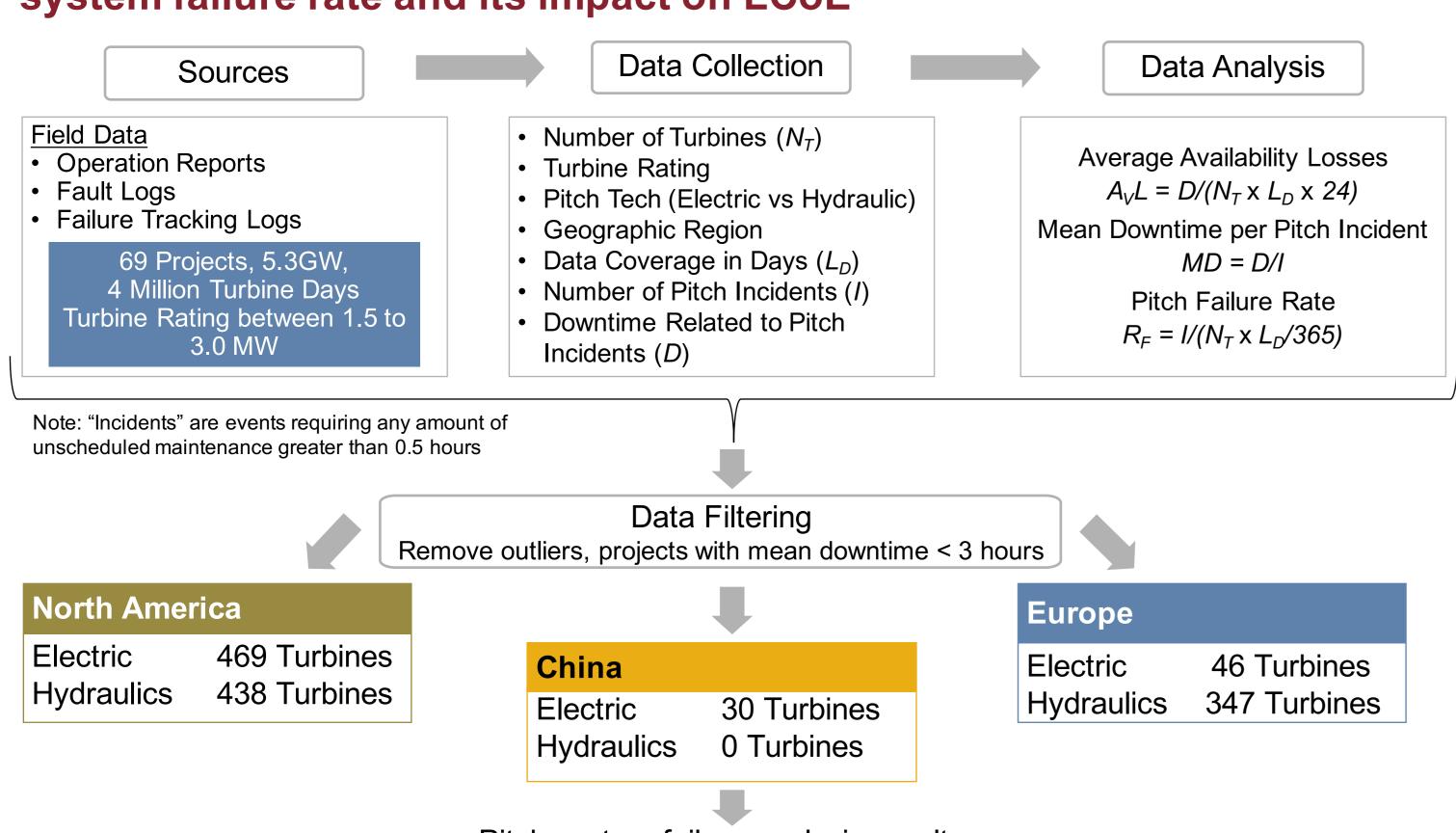
Introduction

 The Reliawind project identifies Pitch Systems as the #1 component contributing to turbine failure & downtime



- Pitch systems in a wind turbine represents:
 - Less than 3% of wind farm CAPEX investment (source: Moog, BNEF)
 - 20 to 30% of wind turbine O&M expenses (source: OEM interviews by Moog)
 - 21% of wind turbine failure rate and 23% of downtime (source: Reliawind)
- Moog / DNV GL study confirms that pitch system reliability improvements can save up to 12% of wind farms O&M expenses

Moog – DNV GL research uses operational data to benchmark pitch system failure rate and its impact on LCoE



Pitch system failure analysis results

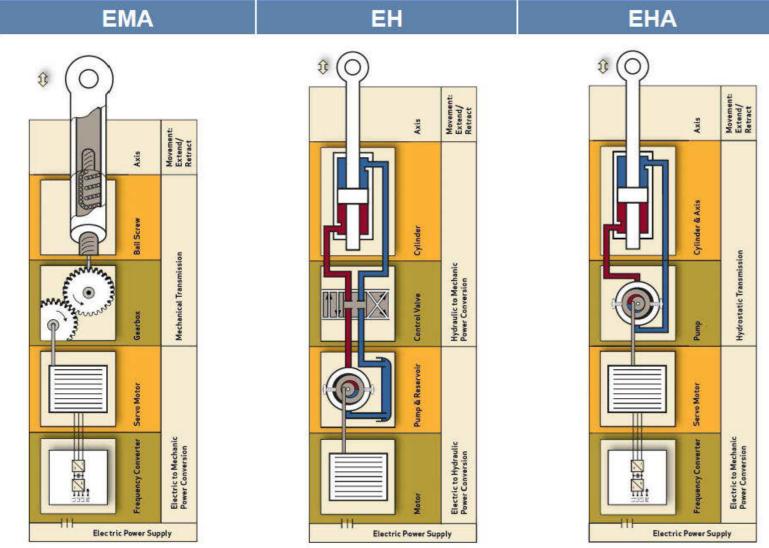
	Failure rate ¹	Projects	Turbines
North America	0.6	23	907
China	0.7	3	30
Europe	0.9	19	393
All regions – 1.5 MW < X < 2.5MW	0.5	38	1,136
All regions $-2.5 \text{ MW} \leq X \leq 3.0 \text{MW}$	1.6	7	194
Overall	0.7	45	1,330

¹ Incidents per turbine per year from projects with mean downtime > 3 hours

- Pitch system reliability benchmarking study reconfirms that:
 - Pitch systems (electric & hydraulic) are a major failure component in a wind turbine
 - The larger the turbine, the greater the failure rate of pitch systems

Pitch technology comparison

Moog evaluated the following technology options for pitch system reliability improvement Technology Comparison



Attribute	EM	EH	ЕНА
Compactness (size, weight and reduced part count)	+++	+	++
Design/Supply Chain Simplicity	+++	+	++
Control Quality	+++	+	++
Pre Tested Hardware	+++	+	++
Force Range	++	+++	+++
Ease of Maintenance	+++	+	++
Reliability	+++	+	+

+ Improvements from Next Generation Technology + Current Industry Design

Design improvement analysis

Feature

System reliability - MTRF (hours)

- Moog Pitch System design optimization study confirms that:
 - There are limited or no options to improve pitch system reliability further with EH/EHA technology
 - EM offers significant potential for reliability improvement due to:
 - R Pluggable (highly integrated) electronics design for drives
 - AC servo motor technology
 - Advances in ultra capacitors design
 - Tests validated by Moog using a new and improved pitch system design (Moog Pitch System 3) showed a significant improvement in reliability

Current Industry Design

5 760

System reliability – WITBF (nours)	5,769	18,743
Predicted failures in 20 years	33.4	9.3
4000 3500 3000 2500 2000 1500 1000 500		Component Count Volume (Itr)

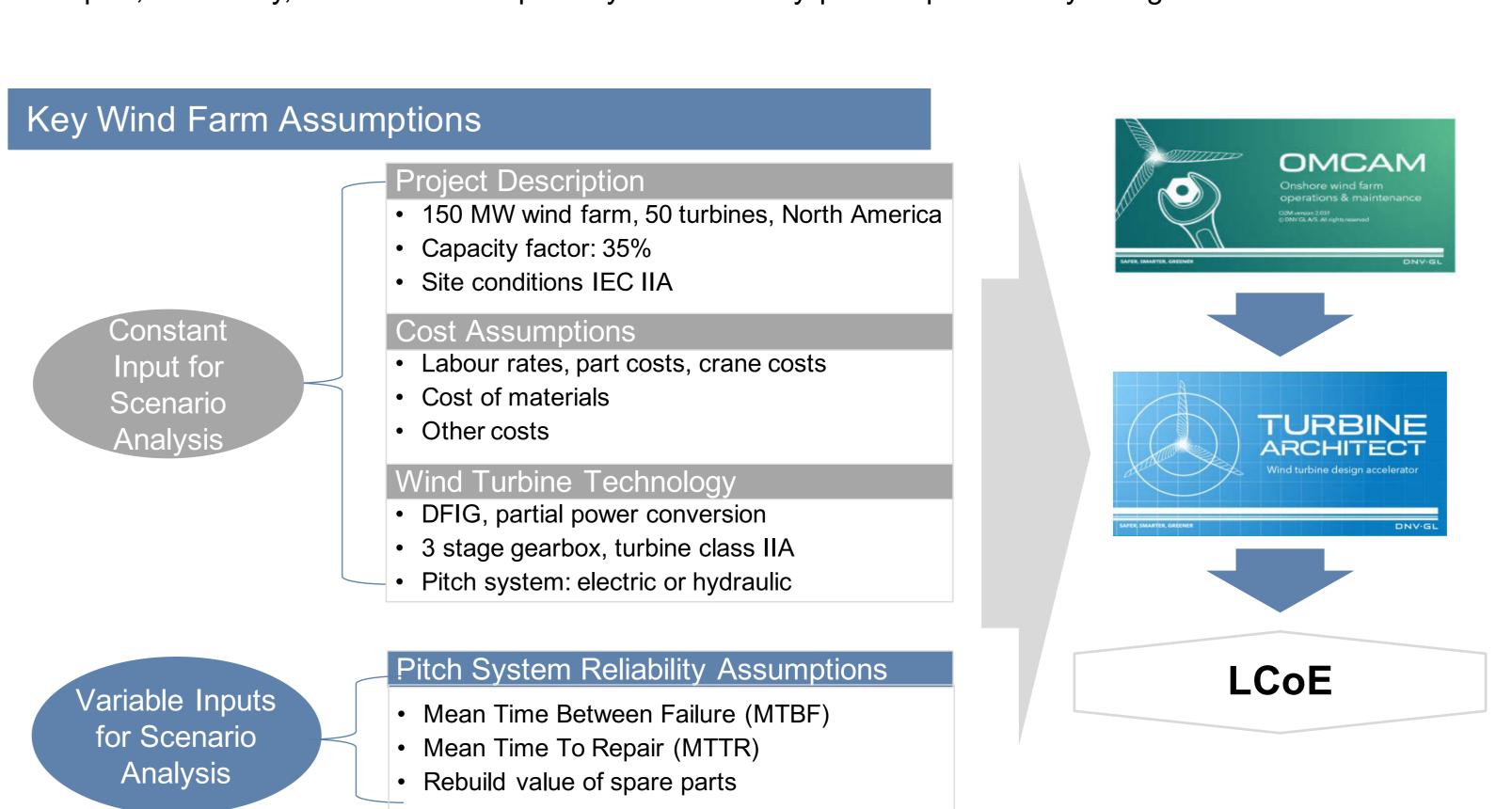
DNV GL cost of energy model

Current Industry Design

 Using the findings of the benchmarking study as inputs, DNV GL carried out an analysis to calculate the LCoE to for the new Moog Pitch System 3 with an optimized design and high reliability

Moog Pitch System 3

• The study made use of two DNV GL modeling tools (Turbine.Architect and OMCAM) to calculate CapEx, OpEx, and finally, LCoE based on pitch system reliability profiles provided by Moog



Potential LCoE reductions by improved pitch system for a typical 3MW turbine

Wh] LCoE Savings [\$/MWh]
_
1.70

Total savings/year for typical 3.0MW turbine @35% capacity factor:

1.70 (\$/MWh) x 3.0 (MW) x 365 (days) x 24 (hours) x 0.35 (capacity factor) = \$15,640 in savings /year/turbine

Conclusions

- Reducing Wind LCoE is important for the industry
- Improving turbine reliability can help reduce LCoE
- Pitch systems (electric and hydraulic) currently used by the industry are a major failure component
- Significant opportunity exists to improve pitch system reliability through design optimization
- DNV GL LCoE model shows that Moog Pitch System 3 can save up to \$1.70/MWh for a typical 3.0MW turbine





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