

Wind Turbine Reliability Benchmarking to Reduce O&M Costs

Drivetrain Reliability Collaborative(DRC)
Workshop

Feb 22nd, 2023



Agenda



EPRI Overview

Industry Needs, Wind Collaboration



Drivetrain Reliability

WinNER Live Demo - Gearbox and Generator Reliability Issues and Mitigation Strategies



Summary, Next Steps

WinNER features and functionalities, Value

COLLABORATION

EPRI's collaborative platform is unrivaled. Our R&D:

- Leverages your research dollars
- Connects you to a global network of peers
- Accelerates deployment of technology
- Mitigates the risk and uncertainty of going it alone
- Positions you as a leader in addressing industrywide challenges

CREDIBILITY

EPRI's independent research is guided by our mission to benefit the public.

We offer:

- Objective solutions
- A proven track record
- Scientifically based research you can trust

Who We Are

EPRI is a non-profit organization that performs research to advance safe, reliable, and environmentally responsible energy for the public benefit.

**\$440M
Annual
Global
R&D**

Our Members

EPRI members represent 90% of the electricity generated and delivered in the United States, with international participation extending to 45 countries.

EXPERTISE

For nearly 50 years, EPRI has been applying R&D to help solve real challenges. With EPRI, you can:

- Reduce expenses and increase productivity
- Be more resilient today and better prepared for tomorrow
- Access an industry repository of collective experiences, technical expertise, and training resources
- Extend your staff and make your teams more robust and more confident
- Benchmark, learn and share best practices
- Increase your awareness of challenges that others are facing and alternate solutions to challenges you might be facing
- Save time and money troubleshooting problems EPRI and its stakeholders have seen before

Renewables - Wind

Reducing costs while increasing reliability, performance and flexibility

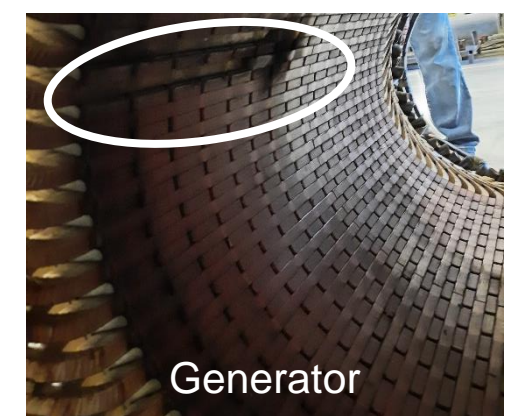
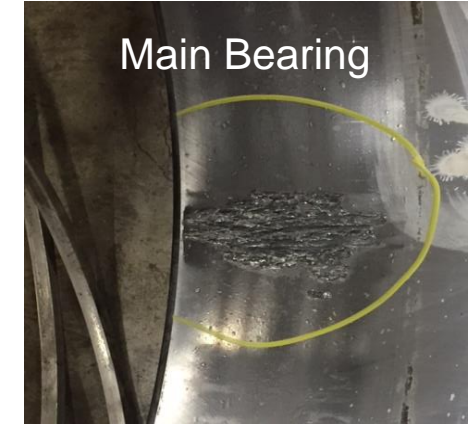
- **Operational Excellence**
Turbine digitalization and automation
- **Cost Reduction**
Monitoring tools for early damage detection, proactive repairs
- **Maximize Efficiency**
Improve turbine availability and production revenue
- **Environment**
Efficient bird/bat curtailment strategies, materials sustainability
- **Reliability and Safety**
Benchmarking tool for reliability assessments, mitigation strategies



EPRI technologies providing \$1M value per year at a typical wind farm

Wind Industry Needs – Reliability Tracking and Analysis

- Asset Management
 - Turbine digitalization and reliability data standardization
- Benchmarking
 - How is my wind fleet performing compared to the industry average?
- Operational Efficiency
 - Failure rate and optimum O&M budgeting forecasting
- Cost Savings
 - OEMs/suppliers quality assessments and inventory management

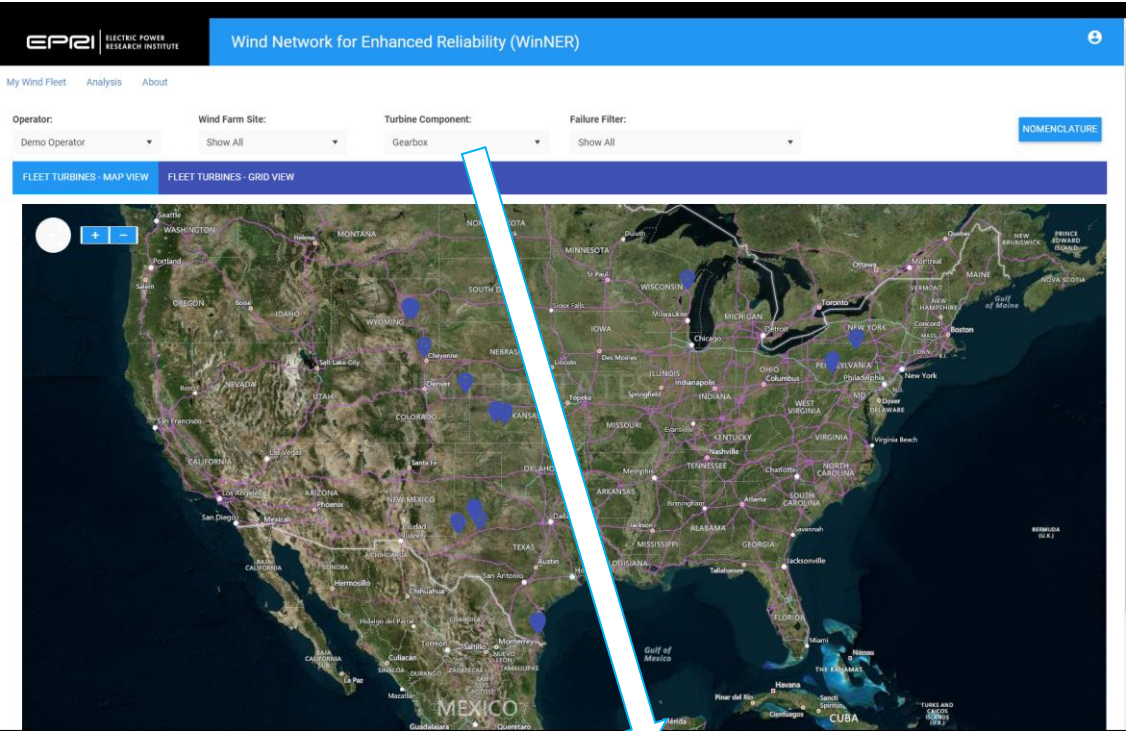


Wind Turbine Digitalization to Reduce O&M Costs

EPRI's Wind Network for Enhanced Reliability (WinNER) Web-based Tool – 22GW+

- NREL and 25+ owners/utilities/operators collaborative effort
 - 22GW+ wind fleet
 - 170+ wind farms
 - 10 Turbine OEMs
 - 30 turbine models
 - 100+ system models
- WinNER value and financial impact
 - Reliability benchmarking
 - Failure rate and optimum O&M budget forecasting
 - OEM/suppliers quality assessments, inventory management
 - O&M optimization and cost savings

Industrywide collaboration to reduce O&M costs and increase production revenue



Turbine Component:

Gearbox	↔	2022
Blades	↔	2020
Gearbox	↔	2021
Generator	↔	2023
Main Bearing	↔	2023-24
Pitch Bearing	↔	2023-24

Expected Release

<https://windturbinereliability.epri.com/>



WinNER – Live Demo

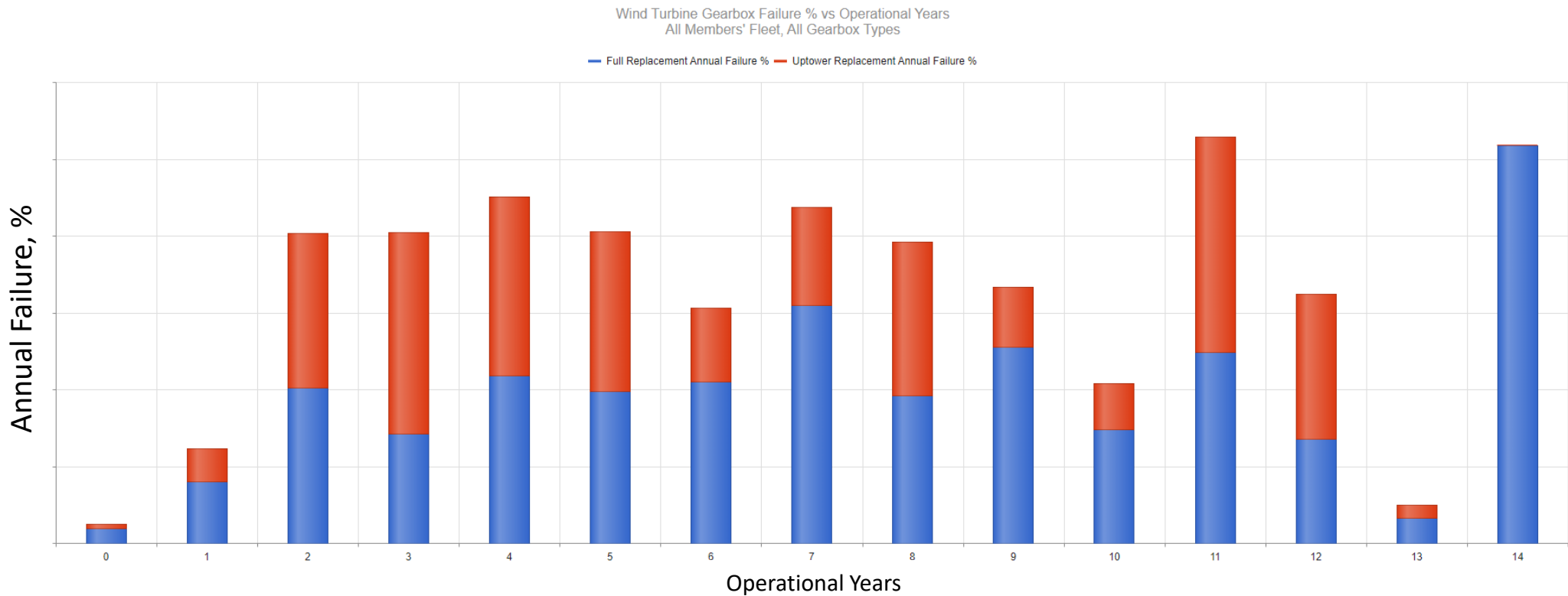
Wind Network for Enhanced Reliability (WinNER) Web-based Tool – 22GW+

EPRI | ELECTRIC POWER RESEARCH INSTITUTE | Wind Network for Enhanced Reliability (WinNER) ⊞

My Wind Fleet | Analysis | About | Admin

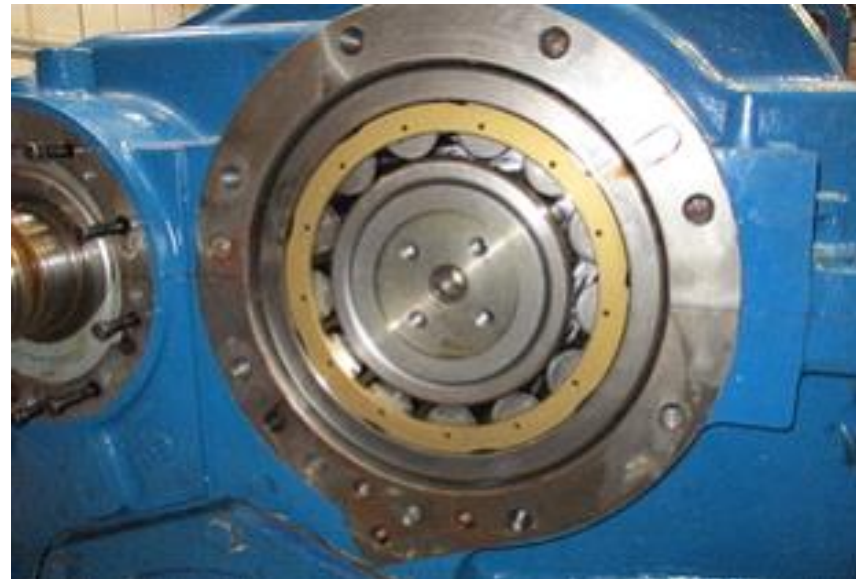
Operator: Wind Turbine System: Turbine OEM Supplier OEM Turbine OEM: Turbine Model: [NOMENCLATURE](#) [EXPORT DATA](#) [SAVE AS IMAGE](#)

[TURBINE DATA OVERVIEW](#) [OEM % BREAKDOWN](#) [ANNUAL FAILURE RATE](#) [CRITICAL COMPONENTS](#) [FAILURE RATE FOR VARIOUS TURBINE INSTALLATION YEARS](#) [RELIABILITY FORECASTING](#)



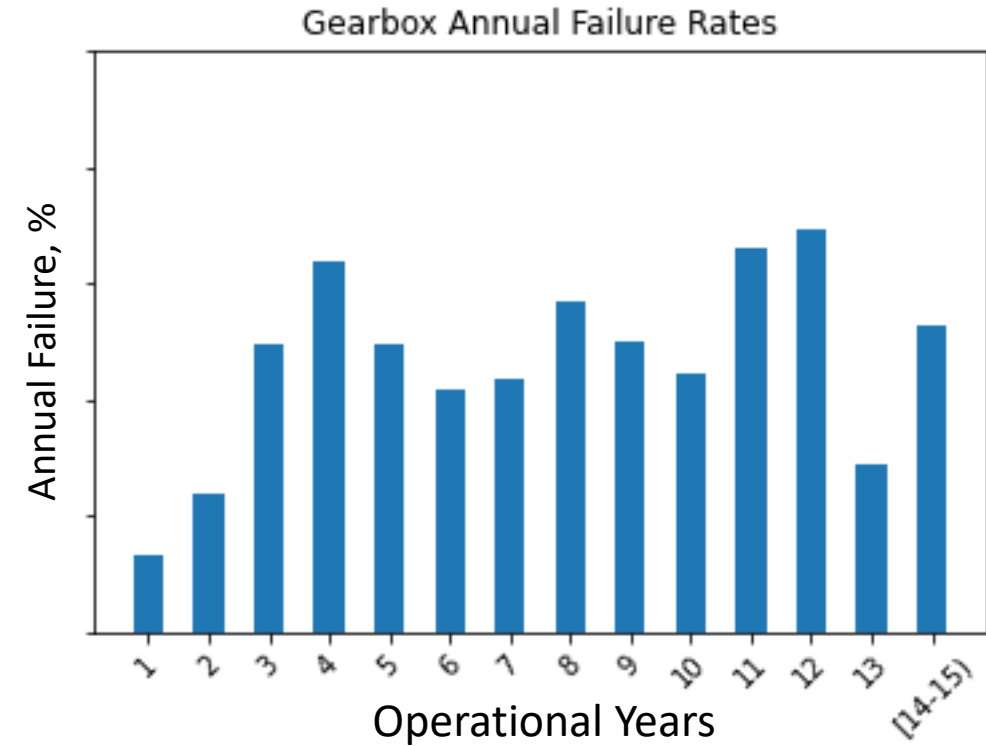
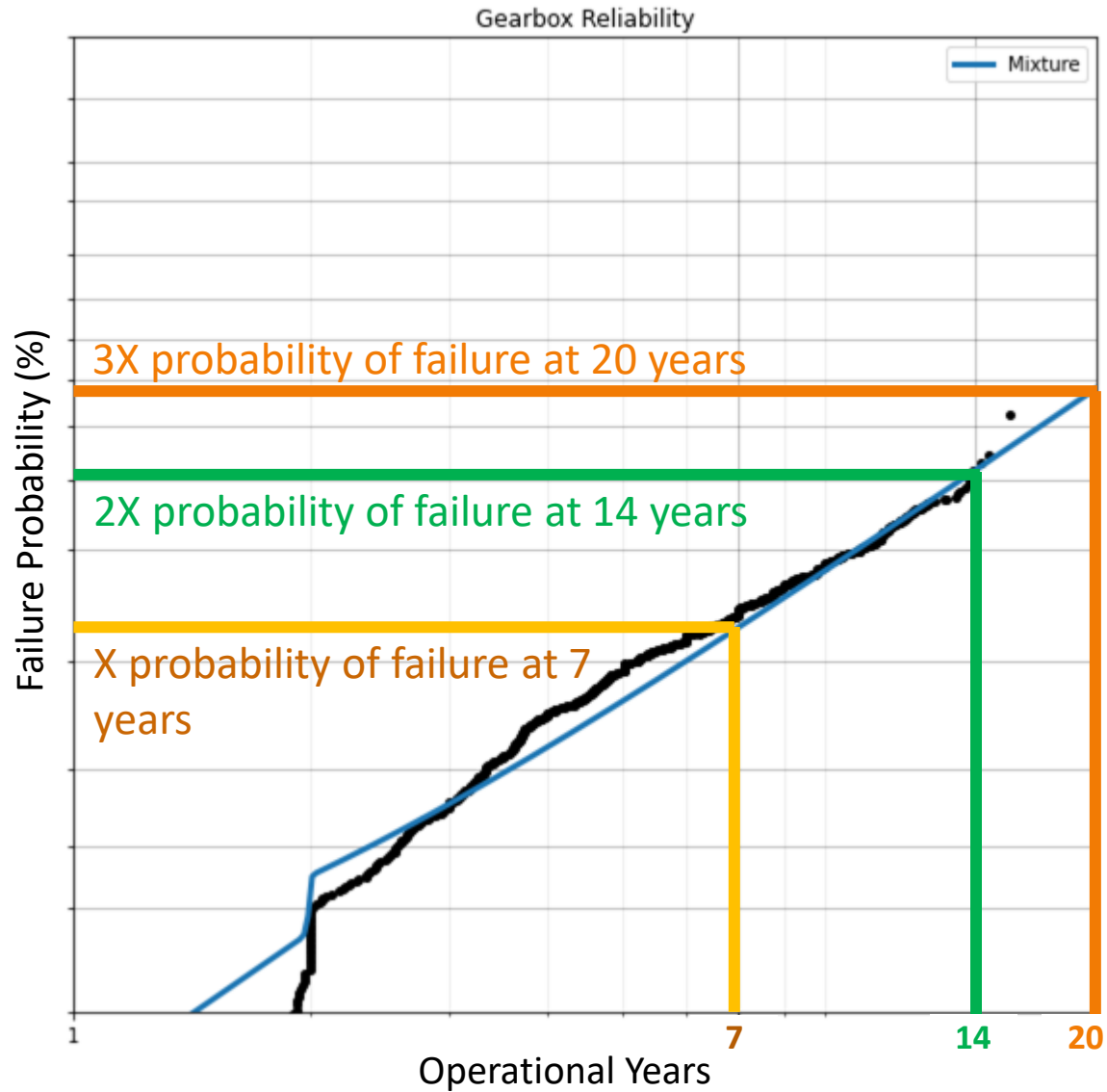
Tracking reliability at fleet-level, turbine-level, system-level and component-level will assist in reducing O&M costs

Gearbox Reliability Issues & Mitigation Strategies



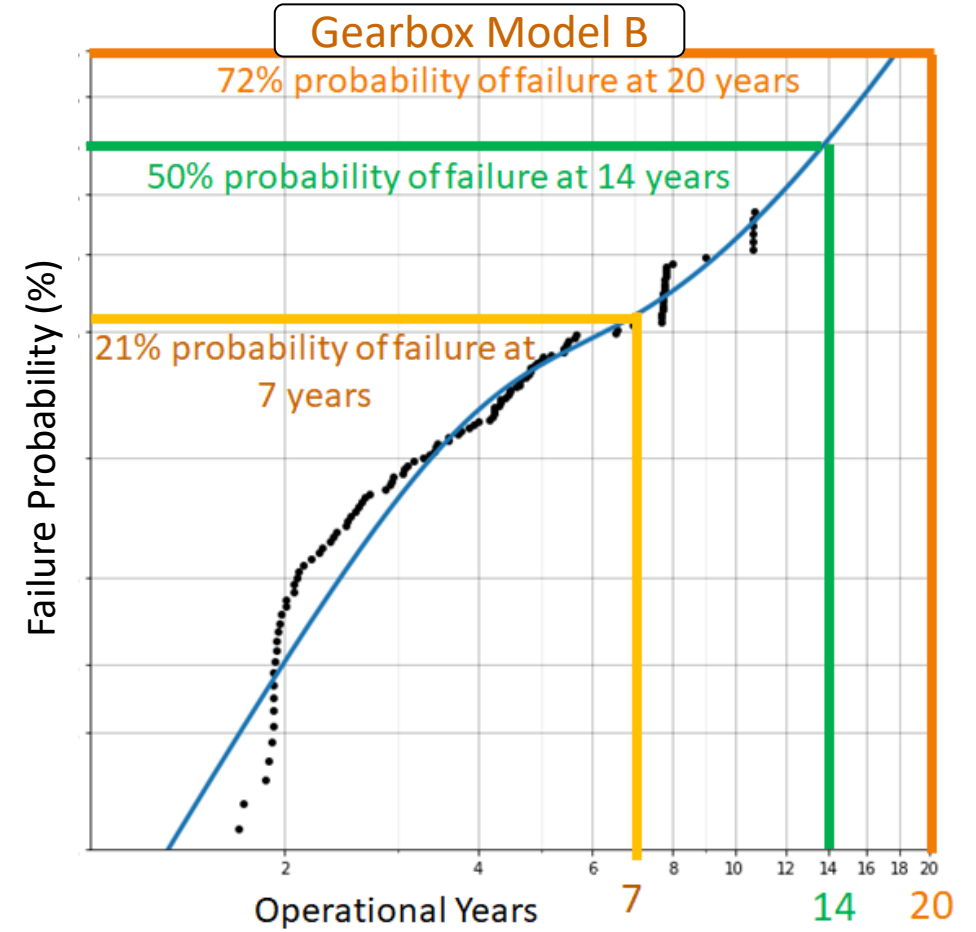
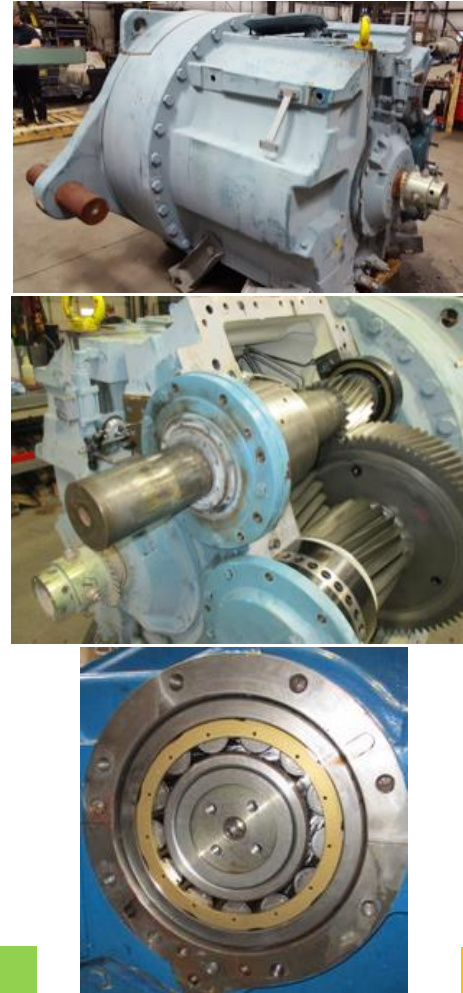
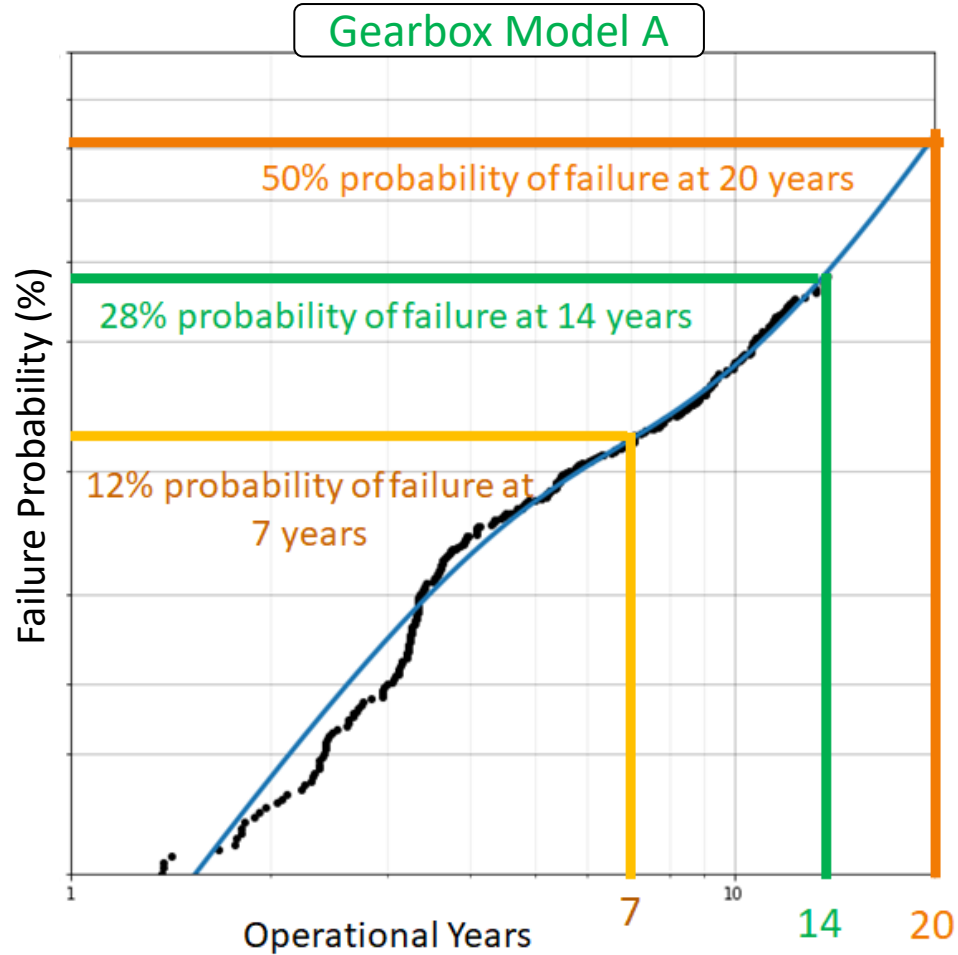
Gearbox Fleet-level Analysis

Full Gearbox + Uptower Replacements



- Reliability analysis includes turbine ratings ≥ 1.5 MW
 - Average gearbox annual failure rate is 2.5%.
- Full gearbox and uptower replacements is 62% and 38%, respectively.
 - Proactive uptower replacements increased in the last 5 years due to preventive repairs and better monitoring technologies reducing O&M costs

System-level Reliability Analysis – Impact on O&M Costs

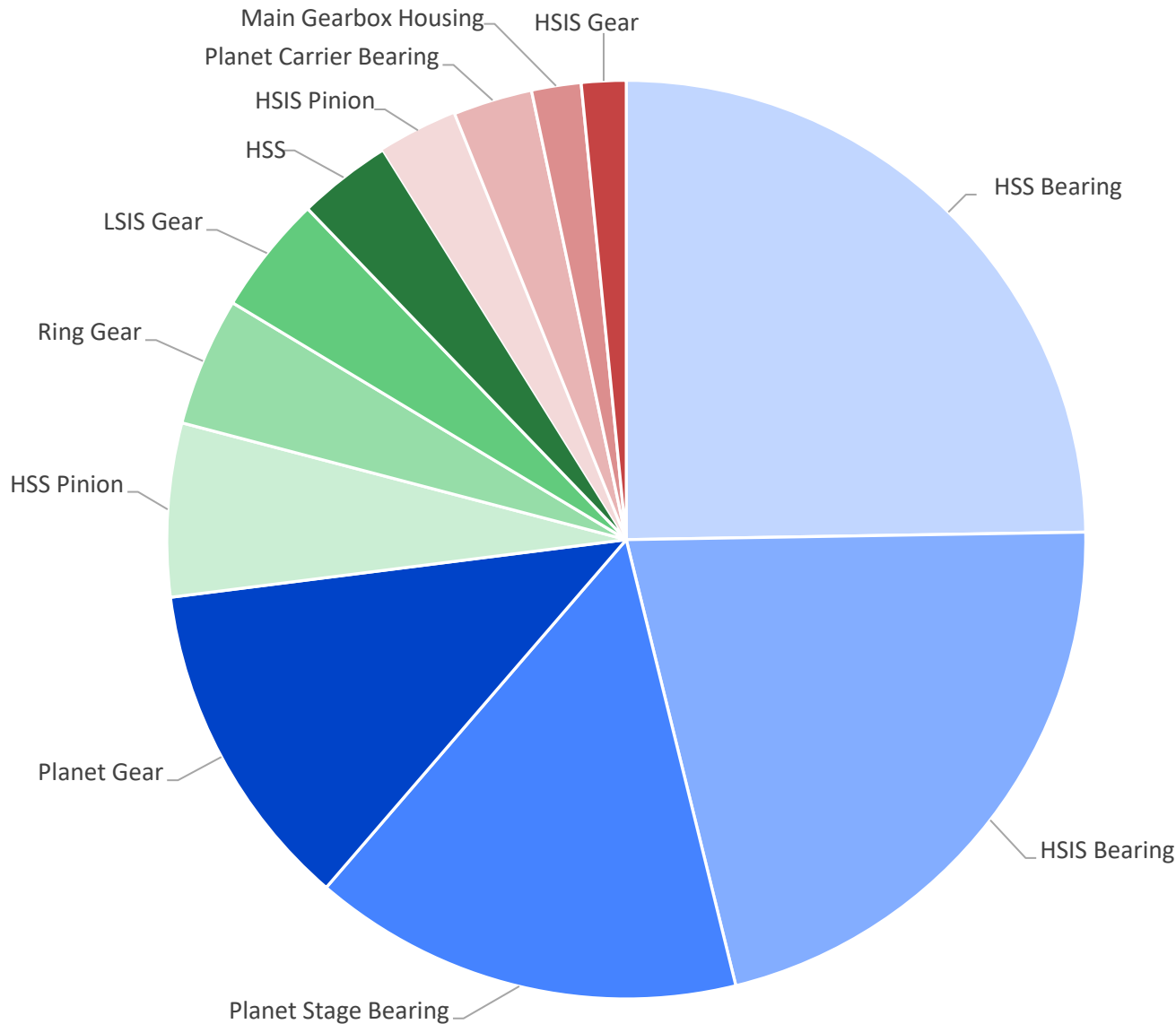


- Gearbox Model A annual failure rate is relatively higher after 8 years of operation
- Planet gear and high-speed pinion tooth fracture failures leading to increase in O&M costs

- Gearbox Model B annual failure rate is relatively higher during the initial 5 years of operation
- Relatively higher percentage of uptower replacements

Gearbox Fleet-level Analysis

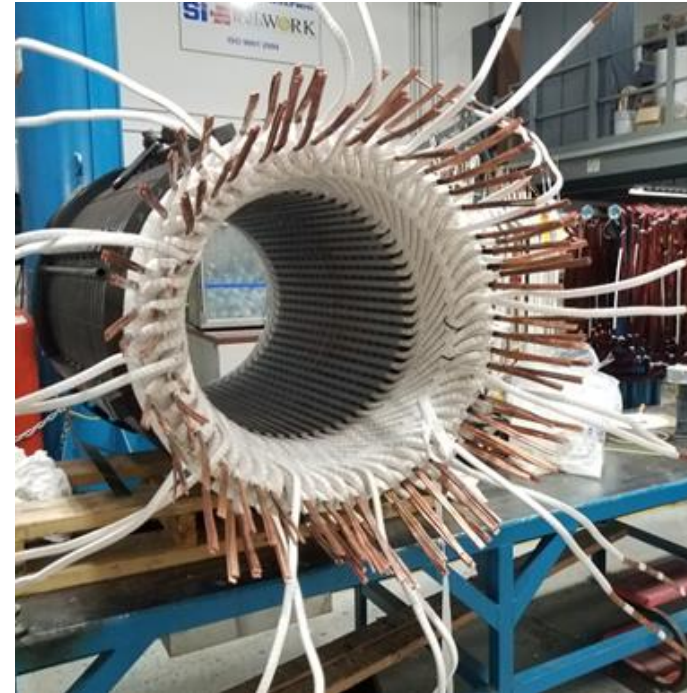
Full Gearbox + Uptower Replacements – Critical Components



Top 5 Gearbox Critical Components

1. High Speed Shaft (HSS) Bearing
 2. High Speed Intermediate Shaft (HSIS) Bearing
 3. Planet Stage (PS) Bearing
 4. Planet Gear
 5. HSS Pinion
- Planetary stage failures leads to full gearbox replacements
 - O&M cost \$350,000 - \$400,000, includes component, crane, and labor/travel
 - HSS and HSIS failures can be fixed uptower
 - O&M cost \$15,000 - \$70,000
 - 23% gear and 67% bearing related failures

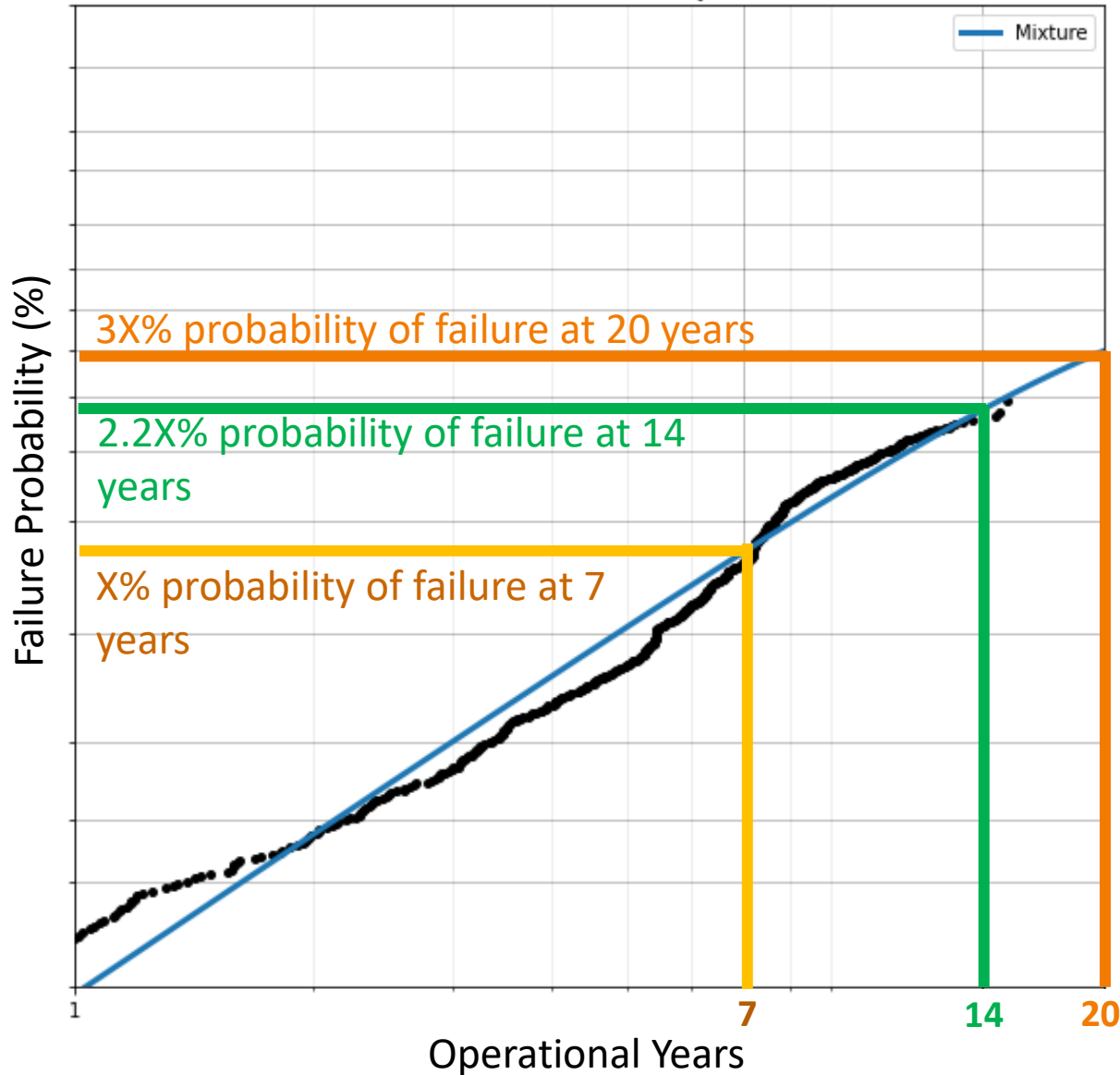
Generator Reliability Issues & Mitigation Strategies



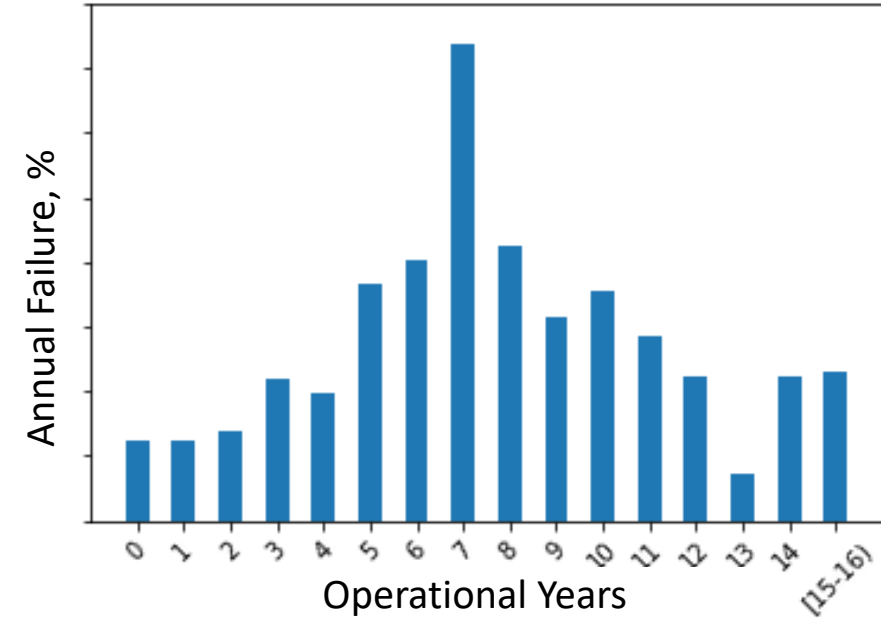
Generator Fleet-level Analysis

Full Generator + Uptower Replacements

Generator Reliability



Generator Annual Failure Rates

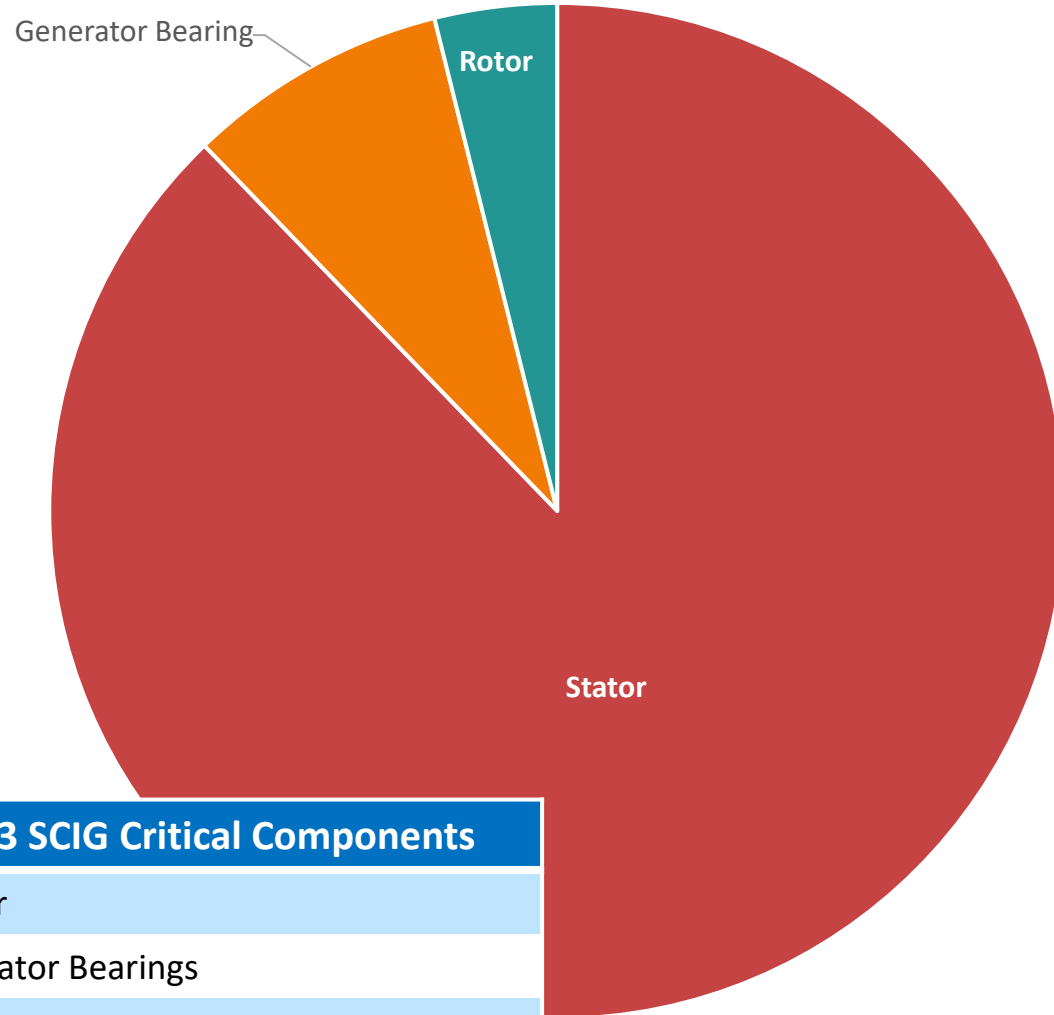


- Average generator annual failure rate is 2.77%.
- Full generator and uptower replacement rates is 73% and 27% respectively.
- Significant increase in generator failure rates after 4 years of operation.
- Relatively higher percentage of uptower replacements during 7th year of operation.
 - 51% uptower replacements (Wye ring failures)
 - 49% full generator replacement (Rotor and stator failures)

Generator Fleet-level Analysis

Full Generator + Uptower Replacements – Critical Components

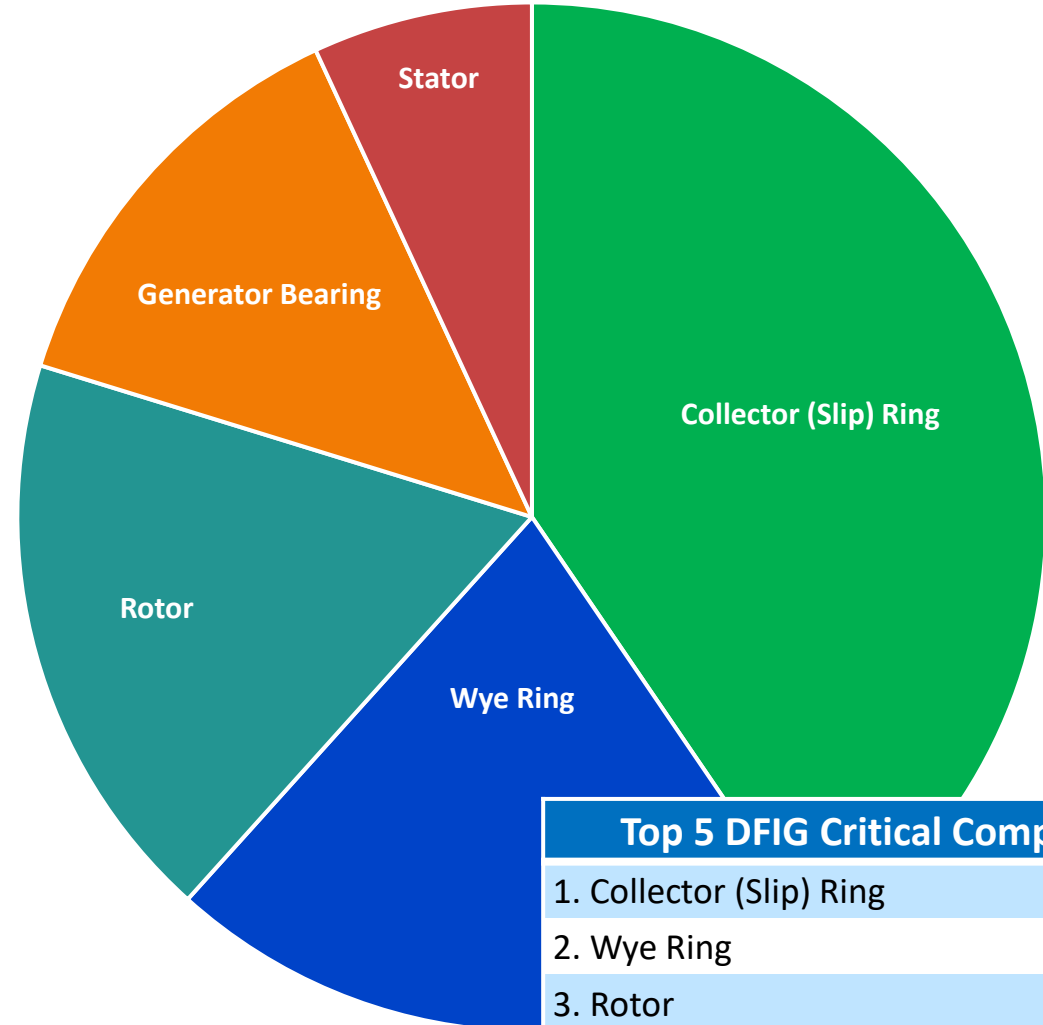
Squirrel Cage Generator Critical Components



Top 3 SCIG Critical Components

1. Stator
2. Generator Bearings
3. Rotor

Doubly-Fed Induction Critical Components



Top 5 DFIG Critical Components

1. Collector (Slip) Ring
2. Wye Ring
3. Rotor
4. Generator Bearings
5. Stator

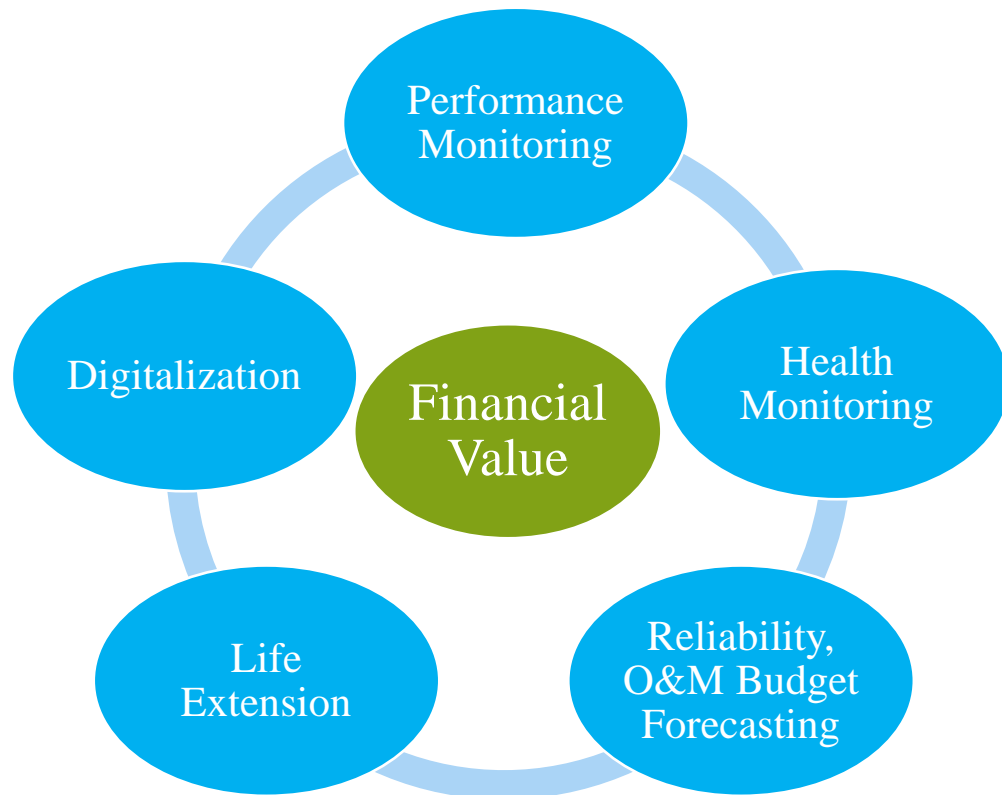
Wind Turbine Optimum O&M Budget Forecasting Using WinNER Advanced Reliability Mixture Models

Wind Farm Issues	Actions	Financial Benefits at a Typical 200MW Wind Farm
Supplier Identification	Supplier selections based on not just cost and availability, but also fleet and industry reliability	\$2M-\$4M in O&M cost savings at a typical wind farm over its full lifecycle
Large Corrective Costs	Cost avoidance using condition-based maintenance tools in conjunction with reliability forecasting	\$1M-\$2M in cost savings/avoidance through predictive initiatives and maintenance and asset strategy optimization
O&M Budget Allocation	Identifying critical wind farms that have higher failure rates assisted in allocating budget, parts, and resources in a timely manner. This results in reduced downtime.	Increase in annual energy production by \$150,000 - \$200,000/year

“Duke Energy is using advanced analytics to improve its commercial renewables availability and reliability. EPRI’s WinNER and input has enabled optimization of our asset’s performance for our company and our customers.” James Bezner, Director at Duke Energy

Financial Value

- EPRI in collaboration with NREL and utilities/operators developed WinNER providing short-term and long-term value
- Converted reliability data into actionable information providing financial value
 - Increase in annual energy production (AEP), reliability improvements, and reduction in O&M costs



“EPRI’s WinNER reliability projections assisted our O&M strategy. We expanded this technique to other major wind turbine failure modes impacting availability and operational costs. Reliability projections will enable us to prioritize optimized maintenance efforts and better estimate the future costs” Alex Triplett, Wind Performance Lead at PGE

“Participating in EPRI projects has allowed WEC to adopt wind turbine performance and health monitoring practices in-house which has led to substantial avoided capital costs. We are now able to proactively obtain notifications across our wind fleet that lead to low-cost repairs rather than running the equipment to catastrophic failure which is substantially more expensive to replace.” Cody Craig, Asset Manager at [WEC Energy Group](#).

WinNER References, Value Story

Value story from Duke, Xcel and PGE.

- [A new web-based tool named WinNER uses reliability data to lower operations and maintenance costs](#)
- [Wind Turbine Gearbox Reliability Assessment: Value of Increased Reliability and Reduced Operations and Maintenance Costs](#)
- [Wind Network for Enhanced Reliability \(WinNER\) Web-Based Tool](#)
- [Wind Innovators Network \(WIN\)](#)

EPRI CONTACT INFO

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