WHITE PAPER

The planetary gearbox blind spot

Adding load to the monitoring mix

Sensing360 GearUp | White Paper for Wind gearbox monitoring

How direct load measurement identifies planetary gearbox failures 6-9 months before vibration, enabling controlled derates instead of emergency stops and protecting your warranty position.

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The failures convential monitoring platform cannot see

Your turbine condition monitoring system detects surface damage. When a planet bearing begins to spall or a gear tooth begins to pit, vibration signals travel through the planet carrier, through the ring gear, through the housing, to the accelerometer on the outside. At the slow rotation speeds of the planetary stage, typically 5-20 RPM, this transmission path introduces severe signal attenuation and modulation. The result is a 2-6 week detection window, at a stage when the damage is already advanced, and the repair outcome is almost always a full gearbox replacement.

Vibration is a lagging indicator. It tells you the gearbox is screaming, not why.

More than 90 percent of planetary failures is shown by planterary load sharing inequality, unequal distribution of load across the planet paths. This inequality begins with manufacturing and assembly tolerances on day one. It progresses silently as bearing clearances increase through wear or unbalance and carrier geometry shifts. And it runs a self-reinforcing cycle: inequality accelerates wear, wear increases inequality, until failure.

> *Inequality drives wear, and wear feeds inequality, until failure.*

Field-representative NLR (former NREL) testing has documented planet bearings supporting up to 46-47 % more load than their design assumption under standard pure-torque conditions, in gearboxes that passed conventional commissioning checks. Standard turbine CMS cannot see this. LumiSens GearUp can via planet load sharing shown in figure 1, months before it becomes a vibration event.

90%

of planetary failures are detectable by load sharing inequality

46-47%

excess load observed on planet bearings in field testing

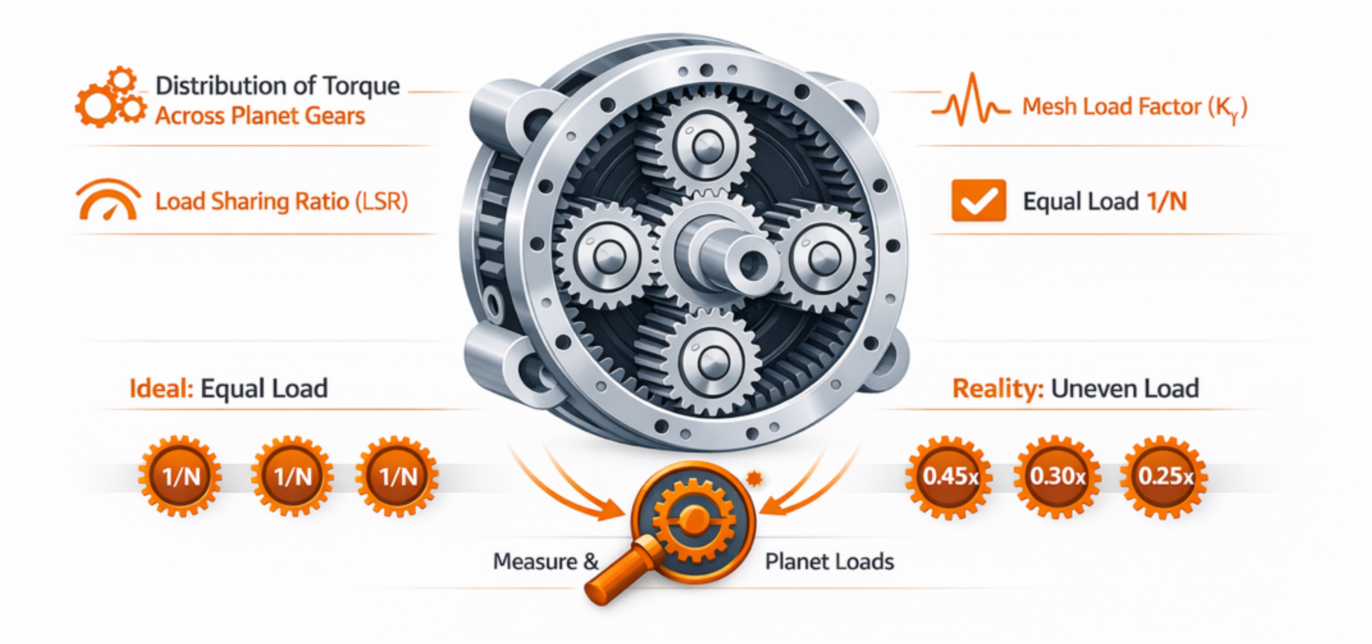

Figure 1: Basics of load sharing

The four unique parameter load add to the monitoring

GearUp fiber optic sensor strip, mounted on the stationary ring gear, outputs four continuous signals that together provide complete planetary stage visibility.

LSII (Load Sharing Inequality Index)

The primary leading indicator of planetary health. LSII detects the root cause, load imbalance, with 6-9 months of lead time before vibration registers any surface damage. LSII changes only when something physically changes in the gearbox: bearing clearance increasing through wear, gear tooth stiffness changing through damage, carrier geometry shifting. Unlike vibration, it is not confounded by background noise, variable speed or load changes.

Thresholds are physically intuitive. LSII of 1.10 triggers a warning; above 1.25, a planet is carrying 25 percent excess load and its remaining life is approximately half of the design assumption.

CDI (Cumulative Damage Index)

Tracks actual fatigue life consumed per component, updated hourly per IEC 61400-4 and ANSI/AGMA 6006 using Sensing360 patented methodology. This is not a SCADA-extrapolated estimate. It is computed from direct torque measurements at 100 Hz, incorporating every start/stop, gust, curtailment event and dynamic transient that SCADA cannot capture. CDI is the data behind your warranty position, your life extension offering, and your service contract economics.

Torque and speed

Feed directly to your SCADA and PLC via ModBus TCP at 100 Hz, the actual mechanical torque on the planetary stage, not inferred from power output. Having the exact operating data independently available with a simple retrofittable solution.

Superior gear and bearing diagnostics

Via torque-synchronised vibration (FFT, Order) spectra, normalised against actual load at each sample to ensure vibration data comparision at the exact same conditions. This eliminates the false alarms that drive customer challenge to analyse the data with conventional CMS. Detects planet, teeth and sun issues at component -level: which planet has an issue, which component and at what progression rate.

Adding load to the monitoring mix

Addition of load and load sharing follows a predictable progression on the P-F curve, see figure 2. In the early phase, load sharing (LSII) is elevated but components are intact. This is the intervention window, the point at which a asset manager with access to load sharing data can identify which units are accumulating damage faster than the design model assumed, and act.

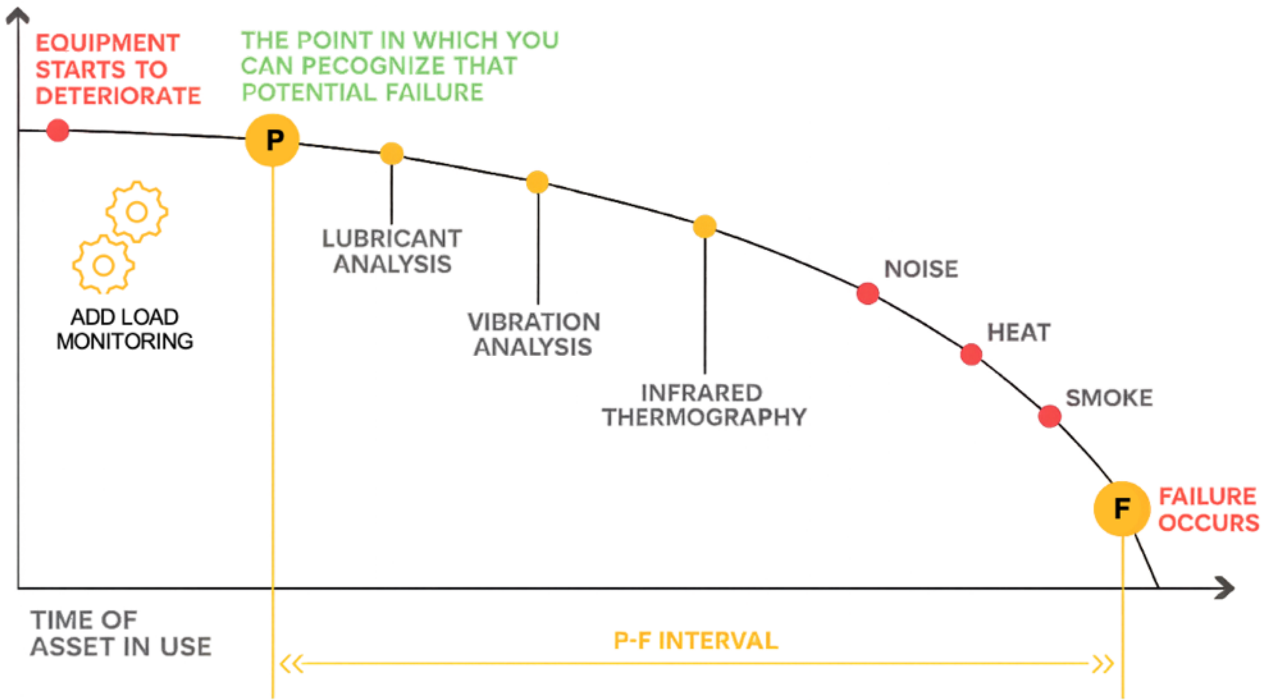

Figure 2: Load sharing on the P-F curve.

That action might be an early field service visit to a specific unit. It might be a derate recommendation to the operator, reducing torque to bring the overloaded planet back within design limits, buying time for a planned uptower bearing swap rather than a full gearbox replacement.

The alternative, undetected progression through the P-F curve, ends in (catastrophic) failure, contamination of the lubrication system, emergency crane, and replacement cost in the hundreds of thousands.

EUR 585,000

Cost per gearbox replacement

93.5%

Of gearbox failures from bearing and gear wear

Smart operation: turning a failure into a managed event

When torque or load sharing rises above a certain threshold, the turbine does not need to stop. This is the fundamental insight that changes the economics of planetary monitoring and the narrative for customers.

A planetary stage with identified load sharing inequality needs to be addressed. But as GearUp identifies the problem months in advance, a controlled response is possible. By derating output to approximately 1/LSII of nominal power (for example, 90 percent of rated output when LSII reaches 1.1), the actual load on the overloaded planet is brought back within design limits and Life consumption returns to the design rate; while the turbine keeps generating, indicated in the table.

Scenario	LSII	Power	Life Consumption	Outcome
Undetected or late detection	1.1	Full	Approx 1.5x design rate	Sudden unplanned stop, secondary damage risk
Early detection with derate	1.1	90%	Design rate	Orderly progression to planned maintenance

The difference is not just energy yield. It is the difference between an emergency crane call at 2-3x normal rates, in uncertain weather, with possible lubrication system contamination versus a planned uptower bearing swap during a low-wind window.

On a 5 MW turbine, four months of derated operation at 80 percent instead of zero represents EUR 200,000-400,000 in recovered revenue. That single avoided emergency event pays for the sensor system many times over. And a service team gets months instead of days to respond, while the turbine keeps generating.

€200k-400k

recovered revenue from 4 months of derated operation vs. emergency stop

How to start: low level entry point

As a new technology needs convincing, thrust and proof, Sensing360 has been developing GearUp, the fiber optical load sharing measuring solution since 2019 in close cooperating with leading wind turbine gearbox manufacturers with both test, factory and up-tower retrofit installations.

The system consits of a easy-to-install retrofit sensor strip to be installed within 2 hours and connects to a S360 edge box at the turbine. It requires no design change to an existing turbine and different models are possible; 24/7 monitoring or a traveling unit as handheld check.

Data integration is flexible, from complete sensor-to-advise via our S360 cloud till directly incooperating our data feed into any monitoring or SCADA system; with inbetween API options.

Implementation pathway

Adding load to monitoring is new and needs convincing and proof, therefore we offer dedicated single or multi turbine prototype installations by our trained team, without taking all the acquisition cost of the hardware before knowing it works!

Figure 3: Example GearUp strip installation up-tower