TECHNICAL WHITE PAPER

Vibration Monitoring and Protection in Large Rotating Machinery

Fixed monitoring, condition monitoring and machine protection with the CEMB TDSP system

Document objective

To provide a practical technical overview of the vibration quantities to be monitored, the most suitable transducers and the functions required from a fixed protection and diagnostic system for rotating machinery used in power generation.

CEMB TDSP protection and condition monitoring system.

Executive Summary

Vibration monitoring, integrated with the main operating parameters, remains one of the most effective methods for ensuring the operational safety of rotating machinery and optimizing maintenance activities. Continuous monitoring makes it possible to detect early-stage degradation, reduce the risk of sudden failures and review maintenance intervals according to the actual condition of the machine.

In large machines for power generation, the choice of measurement quantity depends substantially on the bearing type and on the dynamic behavior of the machine. Relative shaft vibration is particularly significant on sleeve bearings; absolute bearing-housing vibration is instead essential on rolling-element bearings. In the most critical cases, combining the two measurements increases both protection and diagnostic capability.

> **Key message**
>
> The installation of a fixed monitoring system is economically justified even if it prevents just one major failure during the life of the machine. Its value increases further when the data are used for predictive maintenance, trends, root-cause analysis and safe management of transients.

Contents

- Why vibrations should be monitored continuously.
- Which quantities should be measured: relative shaft vibration, absolute support vibration and the combination of the two.
- How the TDSP system processes signals for protection, diagnostics, thresholds and start-up ramp management.
- Operational benefits for safety, plant availability and maintenance.

Technical Reference

This document refers to the approach of the ISO 20816 family of standards for the evaluation of machine vibration. The figures included in this white paper are illustrative technical diagrams and do not replace the requirements of the standard or the machine manufacturer's specifications.

1. Why fixed monitoring is strategic

Large rotating machines often operate under demanding conditions, with high plant downtime costs and significant consequences in the event of failure. In this context, fixed vibration monitoring is not only a diagnostic tool: it is a component of the machine protection system.

Continuous measurement makes it possible to correlate vibration trends with speed, load, temperature, process conditions and start-up or shutdown transients. Compared with periodic checks, fixed monitoring detects rapid variations and enables the automatic activation of alarms or trips when defined thresholds are exceeded.

Expected results

- Machine protection with reliable alarms and trips.
- Timely detection of deviations from the normal condition.
- Support for predictive maintenance and for reviewing maintenance intervals.
- Higher plant availability and reduced unplanned downtime.
- Objective data for analyzing unbalance, misalignment, thermal expansion, load-related phenomena and passages through critical speeds.

> **Selection criterion**
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> To protect the machine effectively, it is not enough to measure just any vibration. It is necessary to measure the quantity that best represents the dynamic behavior of the critical component: shaft, support, structure or a combination of them.

2. The key parameters to be monitored

The monitoring system configuration must be defined according to the machine type, bearing type, service criticality and protection and diagnostic objectives. The three most common configurations are shown below.

Quantity	Typical application	Transducers	Information obtained
Relative shaft vibration	Sleeve bearings	Contactless proximity probes, for example CEMB NC-8000	Movement of the shaft relative to the bearing housing; useful for orbit and radial displacement.
Absolute support vibration	Rolling-element bearings or rigid structures	CEMB TA-100 accelerometer or CEMB T1-40 velocity sensor	Movement of the support relative to the ground; useful for overall levels and support protection.
Combined measurement	Critical large rotating machines	Relative probes + absolute transducers	Comparison between internal machine phenomena and phenomena amplified or generated by the structure.

2.1 Relative shaft vibration

Relative shaft vibration represents the movement between the shaft and the bearing. It is the most significant measurement for machines with sleeve bearings, because the shaft rotates supported by the oil film. The elasticity and damping of the film can attenuate the signal transmitted to the outside of the housing, making absolute housing vibration alone less representative of the actual shaft movement.

For this application, CEMB offers the NC-8000 proximity transducer, designed for contactless measurement of relative shaft vibration and adaptable to the main sleeve bearing configurations.

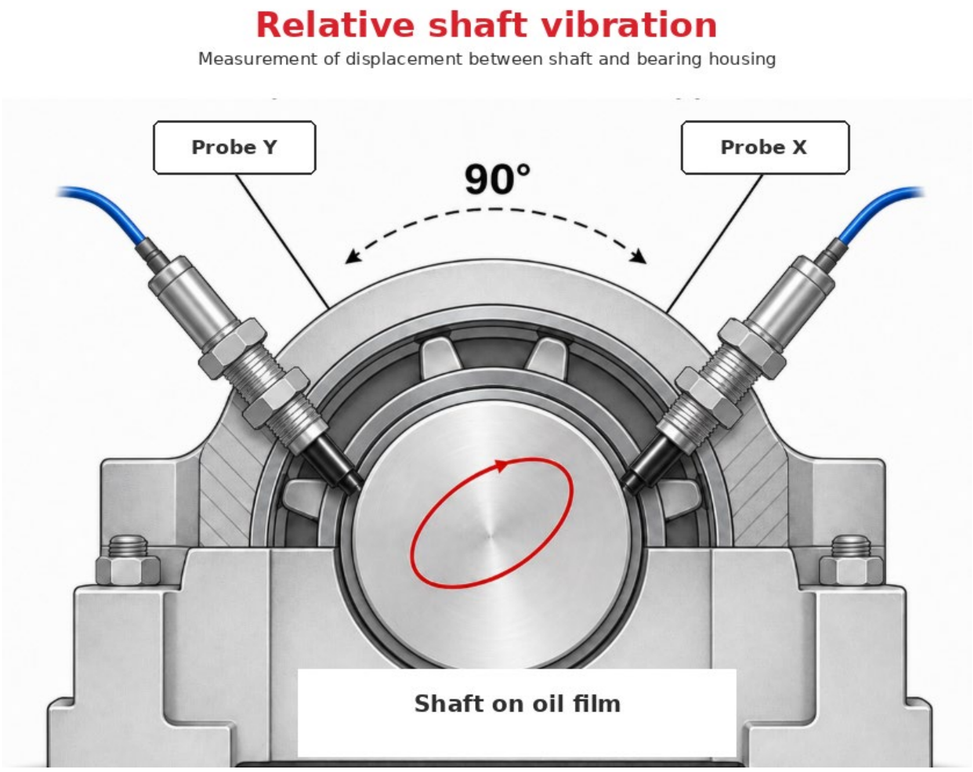

Figure 1 - Example diagram for measuring relative shaft vibration with two probes at 90 degrees.

Using two radial transducers positioned at 90 degrees provides better machine protection when the main vibration direction is not known in advance. The dual measurement is also essential when the shaft orbit in the radial plane needs to be determined.

2.2 Absolute support vibration

Absolute support vibration represents the movement of the support relative to the ground. It is the most significant measurement for machines with rolling-element bearings, where the mechanical connection between the shaft and the support is very rigid and oscillations are transferred directly to the support structure.

CEMB manufactures several absolute vibration transducers. Depending on the machine characteristics, the TA-100 accelerometer or the T1-40 velocity sensor can be used, selecting the quantity most consistent with the protection and monitoring requirements.

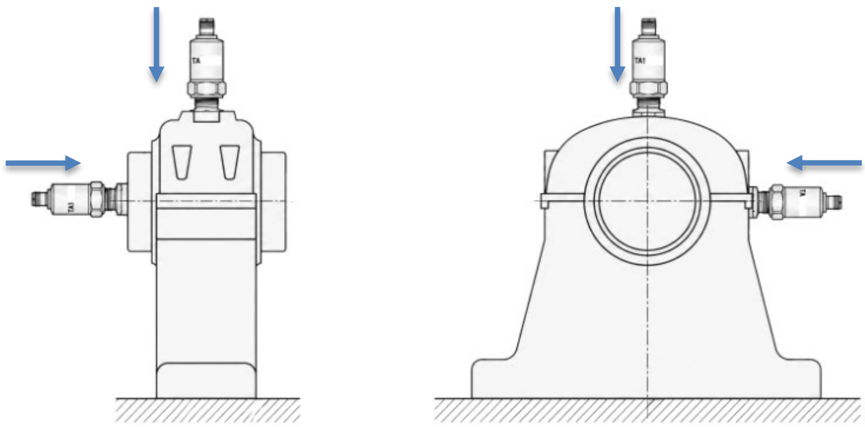

Figure 2 - Example diagram for measuring absolute support vibration in the X, Y and Z directions.

Measurement in the three orthogonal directions makes it possible to describe the behavior of the support comprehensively and to detect vibrations that may occur in different directions as operating conditions change.

2.3 Combination of relative and absolute vibration

On large rotating machines used for power generation, proximity probes and seismic transducers are frequently used together. The relative measurement highlights internal machine phenomena with greater sensitivity, while the absolute measurement makes it possible to assess the response of the support and load-bearing structures.

Comparing the two signals helps distinguish vibrations generated by internal forcing mechanisms, such as unbalance or shaft-related phenomena, from vibrations generated or amplified by the foundation, the support or the connected structure.

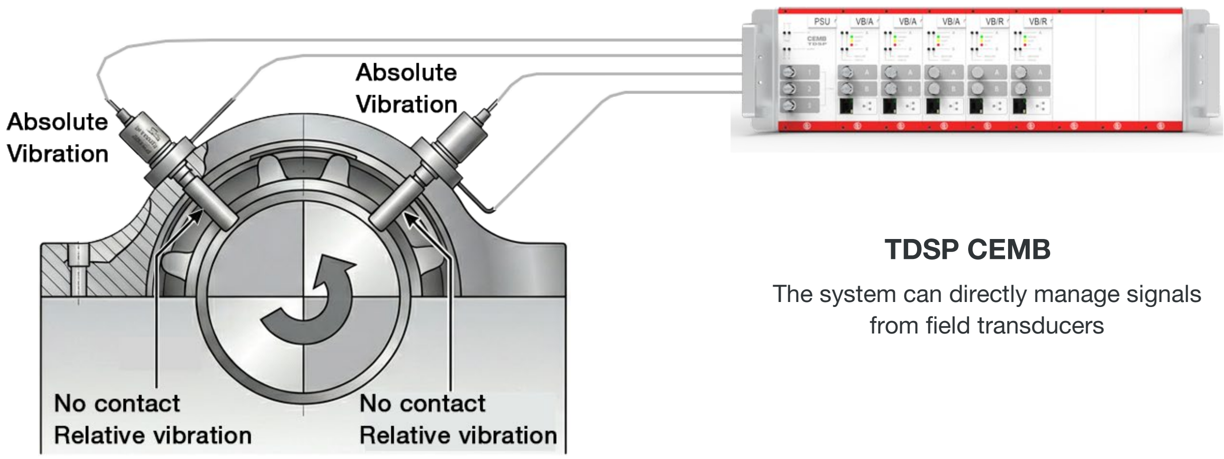

Figure 3 - Example diagram of combined relative shaft and absolute support vibration measurement.

3. Signal processing with the TDSP system

The CEMB TDSP machine protection and condition monitoring system continuously processes vibration signals and provides the information required for safe machine management. Its modular structure allows the system to be configured according to the number of channels, the type of transducers and the required alarm logic.

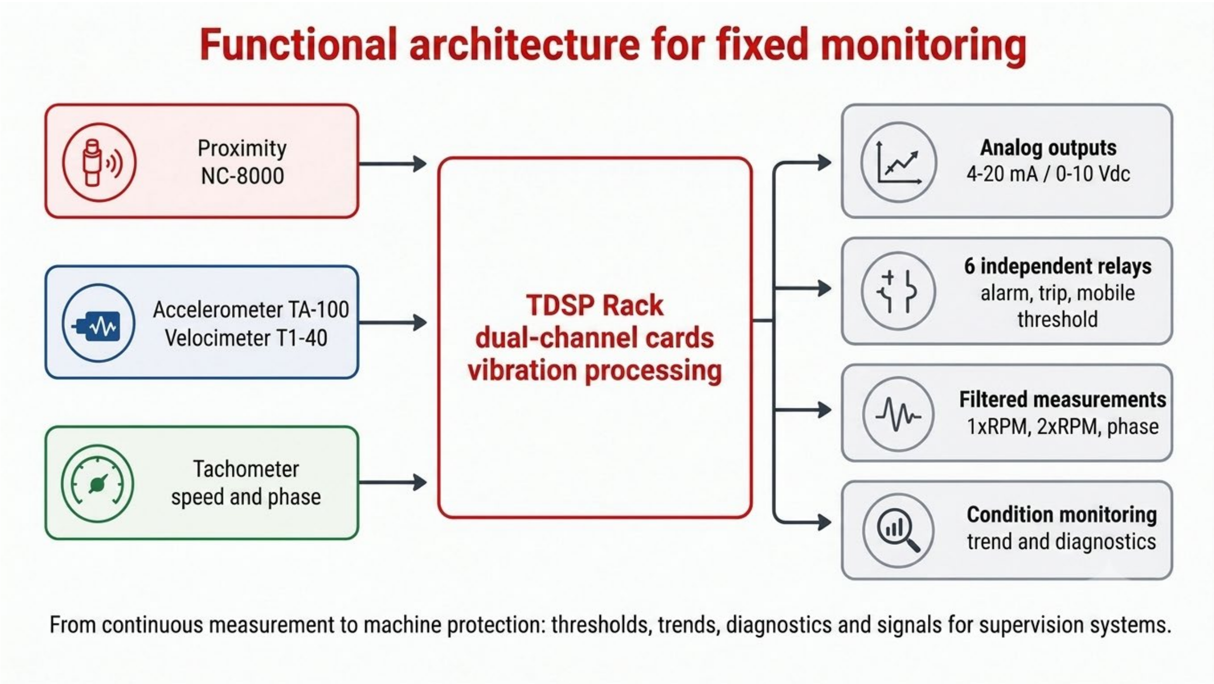

Figure 4 - Functional architecture of fixed monitoring with the TDSP system.

Dual-channel cards and output signals

The TDSP modular rack consists of dual-channel cards. Each card provides analog outputs and digital signals for integration with supervision, data acquisition and plant protection systems.

- Two analog outputs per card, configurable as 4-20 mA or 0-10 Vdc, useful for traditional acquisition systems or DCS.
- Six independent relays for sending digital signals to protection systems.
- One tachometer input for filtered measurements, phase and speed-based threshold management.

Threshold management: alarm, trip and adaptive threshold

The availability of six independent contacts enables condition-based vibration management. In a typical configuration, two contacts are assigned to alarm and trip thresholds, while an additional contact can be used for an adaptive threshold, set slightly above the actual operating value in order to detect degradation quickly.

The approach follows the two evaluation criteria referenced by ISO 20816: an absolute criterion, based on the vibration value, and a relative criterion, based on the variation from a previous condition.

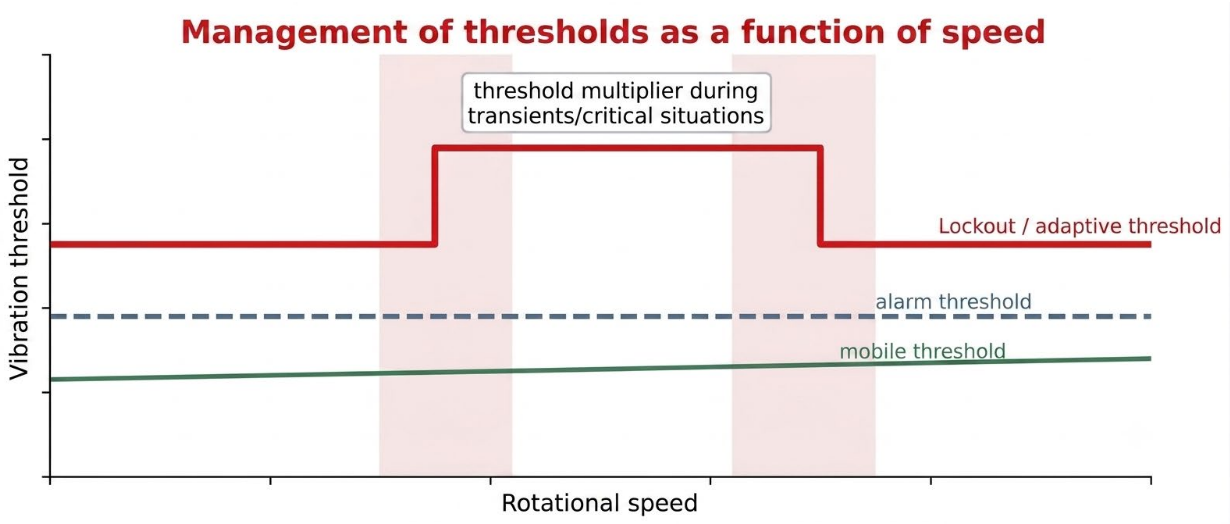

Figure 5 - Conceptual diagram of absolute thresholds, adaptive threshold and multipliers during transients.

Tachometer input and synchronous measurements

Knowing the rotational speed is the first step towards effective diagnostics. The tachometer input allows the total vibration value to be complemented by filtered components related to the rotational frequency and its main multiples.

- 1xRPM: component generally associated with unbalance.
- 2xRPM: component often associated with misalignment or phenomena related to assembly geometry.
- Vibration phase angle: useful information for confirming unbalance and interpreting behaviors influenced by load or thermal expansion.
- Instantaneous speed: basis for thresholds adapted during start-up ramps, shutdowns and passages through critical speeds.

Start-up ramp management

Large machines often operate above the first flexural critical speed. During transients, passage through critical speeds may require temporarily higher thresholds to avoid improper trips. The TDSP card allows speed ranges to be selected and a multiplier to be applied to the set thresholds, keeping protection consistent with the expected behavior of the machine.

4. Benefits for operation and maintenance

A fixed vibration monitoring system generates value when automatic protection is integrated with historical data analysis. The availability of trends, alarms, filtered values and phase information enables the transition from purely reactive control to management based on the actual condition of the machine.

Area	Operational benefit
Safety	Automatic action on alarm and trip thresholds, reducing the risk of serious damage.
Plant availability	Early detection of degradation and planning of interventions before failure.
Maintenance	Ability to review maintenance intervals based on trends and actual operating conditions.
Diagnostics	Analysis of 1xRPM and 2xRPM components, phase, orbit and comparison between relative and absolute vibration.
Integration	Analog outputs, relays and tachometer signals for connection to existing supervision and protection systems.

Economic value

In highly critical contexts, the return on investment can be achieved by avoiding even a single major failure. Continuous monitoring also reduces decision-making uncertainty and improves the quality of planned shutdowns.

5. Conclusions

Protecting large rotating machines requires correct, stable measurements that are consistent with the machine dynamics. Relative shaft vibration, absolute support vibration and their combination are the fundamental quantities for describing the condition of the machine and setting effective protection logic.

The CEMB TDSP system integrates acquisition, processing, analog outputs, protection relays, tachometer input, filtered measurements and speed-based threshold management. In this way, fixed monitoring becomes an operational tool for safety, availability and predictive maintenance.