Asset Performance Management
For electrical rotating machines and power electronics
gepowerconversion.com
A new way to work. Optimize maintenance schedules and reduce unplanned downtime with revolutionary monitoring of electrical rotating machines and power electronics.
Data Driven
Everyone wants to go straight to the end game: extracting valuable insights from your data. However, 85% of the effort is gathering, structuring, and normalizing the vast amount of data available from many different sources. As a result, many organizations can only analyze a limited data set after an issue has occurred, and not make holistic use of all the data available to obtain real-time indicators that could drive business efficiencies.

In addition many large organizations are the product of mergers and acquisitions, and as a result data capture, analysis and storage is carried out in entirely different systems and with different approaches across the organization. Extracting value and making comparisons using this data is a real challenge.

Reduce Downtime
Most industrial companies are used to employing planned maintenance techniques as a way of reducing failures and maintaining high availability. However, it has been demonstrated that the benefits of planned maintenance quickly reach a plateau, and so many organizations continue to explore alternatives.

While some equipment failure modes become more likely as equipment ages, most failures actually occur randomly and are independent of both time and planned maintenance. Our customers' reliability teams know this fact. They constantly strive to eliminate random failure, but struggle because of the lack of appropriate tools to mitigate the randomness. They’re often forced to rely on metrics like MTBF (mean-time-between-failures) which is a historical aggregate rather than a forward-looking indicator providing insights on a particular piece of equipment.

Optimize Cost
Without the ability to connect silos of information and analyze aggregated data across an organization many opportunities to identify pockets of inefficiency are lost.

Most operators lack the tools needed to evaluate the data and make balanced decisions. Organizations need to be able to evaluate the risk impact of changes to their maintenance spend and to track which asset strategies are operating optimally. Ultimately organizations need to know they’re making the best preventative maintenance choices for a given spend level.

Harmonize data from multiple systems and generate reliable predictions that reduce downtime and cost
A transformation in equipment maintenance with unique analytical techniques and support

Around the world over 40 million new motors are installed each year, driving everything from LNG plants to steel mills. Electrical machines are at the heart of the modern industrial world. The impact of unplanned downtime is estimated to be more than $30 billion every year.

At the same time the drive for energy efficiency is constantly increasing the number of variable frequency drives connected to rotating machines. For most GE customers this has become the standard solution in place of the direct on-line architecture.

We use our expertise in variable frequency drives and more than 100 years of engineering experience with motors, generators and control equipment, to bring together advanced High Frequency Sampling, Physics Based Analytics and Advanced Pattern Recognition with our domain and equipment experts. This depth of knowledge and capability means that the Power Conversion business not only helps identify future issues, but supports our customers to avoid or resolve these issues.
The use of Physics Based Analytics means that fragile vibration monitors are not required and a wider range of potential failures can be detected.

Edge analytics leverages the spare processing capacity in customer drives to pre-process data before sending manageable amounts of data to the cloud. All of GE Power Conversion’s HPCI drives can become seamlessly part of a capable analytical network.

Cloud based decision tools provide dashboards and insights at enterprise level and in detail, leveraging the data from hundreds of similar machines of the same type, in a secured environment. Basing analytics in the cloud ensures that only the very latest algorithms are deployed for faster, better, more accurate results.

Minimal hardware needs (one Visor Connect Box can monitor hundreds of motors) means deployment to every item of equipment is cost effective for the first time.

Minimal hardware, maximum results

ASSET PERFORMANCE MANAGEMENT ALLOWS MORE EFFICIENT, PREDICTABLE AND COST EFFECTIVE EQUIPMENT MAINTENANCE
Rotating machines fault mode detection

<table>
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<th>DETECTION METHOD</th>
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<td>PBA</td>
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</table>

| BEARING | Outer Race Defect | • | |
| Inner Race Defect | • | |
| Ball Defect | • | |
| INSULATION | Shorted Turns | • | |
| ROTOR BAR | Broken Rotor Bar | • | |
| MECHANICAL | Mixed Eccentricity | • | |
| Vibration Discrete Tone Identifier | • | |
| Vibration RMS | • | |
| Bent Rotor Shaft | • | |
| ELECTRICAL | Voltage THD | • | |
| Current THD | • | |
| >0 & <0 Sequence Voltage | • | |
| 0> & <0 Sequence Current | • | |
| Current Harmonics | • | |
| Energy Usage (Trend) | • | |
| Efficiency Estimation (Trend) | • | |
| TEMPERATURE | Bearing Temperature | • | • |
| Stator Temperature | • | • |

MOTOR / GENERATOR
MV/LV

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<tr>
<td>IND</td>
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PBA = PHYSICS BASED ANALYTICS
TEMP = TEMPERATURE
VIB = VIBRATION
IND = INDUCTION MACHINE
SM = SYNCHRONOUS MACHINE

Electrical Signature Detection provides a wider range of failure mode detection than conventional temperature and vibration monitoring
The GE Difference

At GE we have the unique ability to access high frequency data through our data acquisition devices (either drives or the RMDM box in the absence of a drive). Leveraging these devices allows us to look at a richer set of dynamic modes versus the SCADA/cloud data only. Using the same signals we use for drive control, our expertise enables us to cut through high frequency data noise using advanced signal processing techniques, allowing the extraction of the clean signals needed for fault analysis. GE’s unique experience and know-how of rotating machines engineering, manufacturing and servicing provides a deeper understanding of the physics behind the data.

Finding the True Positives

Monitoring systems can give one of four possible outcomes:

- **False Positive**: An alarm is raised when there is no impending failure
- **False Negative**: An asset fails, but no alarm was raised
- **True Negative**: No alarm is raised and no failure occurs
- **True Positive**: An alarm is raised and after a predetermined period of time a failure occurs or signs of impending failure are present

The starting point to determine whether an algorithm is performing well or not is defining the possible outcomes of that algorithm. To that purpose, the confusion matrix determines four possible outcomes for a binary test, plus a series of metrics associated to those outcomes.

### The Confusion Matrix

<table>
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<tr>
<th>Test Outcome</th>
<th>Positive Condition</th>
<th>Negative Condition</th>
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<tr>
<td>Positive</td>
<td>True Positive (TP)</td>
<td>False Positive (FP)</td>
</tr>
<tr>
<td>Negative</td>
<td>False Negative (FN)</td>
<td>True Negative (TN)</td>
</tr>
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### Simplifying the process: two key metrics

**True Positive Rate (TPR)**
Out of all faulty assets, how many were caught?

\[
\text{TPR} = \frac{TP}{TP + FN}
\]

**Positive Predicted Value (PPV)**
Out of all alarms, how many indicate faulty assets?

\[
\text{PPV} = \frac{FP}{TP + FP}
\]

**Avoided Cost of Downtime**

The **True Positive Rate (TPR)** is related to the avoided cost of downtime. Every asset that fails causes the customer to incur unplanned downtime to repair or replace that item, and to incur cost, both directly for replacement parts and labor and indirectly in terms of lost operating revenues.

**Cost of Replacement**

The **Positive Predicted Value (PPV)** measures the impact of replacing or repairing equipment as a result of an alarm when that equipment wasn’t at risk of failure. The higher the PPR, the more accurately the analysis is identifying future failure.

**Balancing Risk**

Every customer will have a view on their own level of acceptable risk versus the cost of asset replacement or inspection. Using the TPR and the PPR we define this optimal point for every customer and tune the analytics to deliver the optimum acceptable risk.

### Equipment Health Index

Once the system is set up and the optimal risk selected the various algorithms associated with the different failure modes will generate an Equipment Health Index (EHI). The task becomes connecting the real world experience to the algorithms to minimize false alarms and therefore help to minimize the maintenance cost for a given risk tolerance.

**Expert Review**

Subject matter experts in our managed services team monitor the data from the system to adjust the algorithms and alarm thresholds based on post event analysis of the equipment. The objective is to capture 100% of the instances where the algorithm didn’t behave as expected. This leads to continuous improvement of the response, specific to each customer’s process.

### The Real Difference

- Risk thresholds tailored to each customer’s situation
- Expert review of all alarms, driving continuous improvement
- Delivering expert decision making support that enables reliable, condition based maintenance
Asset Performance Management system architecture
**Simplicity**

Power Conversion’s Asset Performance Management (APM) for electrical rotating machines and power electronics, relies on the processing power of GE variable frequency drives to use them as Edge Analysis devices. We call this *Drive as a Sensor*. When a Power Conversion HPCI drive is present in the system it can be employed to deliver the sensing required to generate equipment health indices. Because of this APM is straightforward to install requiring minimal additional hardware. Often only one additional item of hardware is required, the Visor Connect Box (VCB), which provides a gateway for remote support and cloud connectivity.

**Visor Connect Box (VCB)**

The VCB is the solution to the need to provide secure remote access to the information generated by the drives and RMDM(s), connected by MODBUS to the VCB. With over 20 years of product experience the VCB is one of the most proven and trusted devices of its kind, and provides the connection to GE’s own secure service portal. Visor Connect is certified to Achilles level 1.

The VCB provides:

- Remote connectivity for service engineering
- Storage of all site relevant information
- 256GB of historical data (approximately 90 days) including analogue and digital time-series data
- Automated archiving
- Storage of drive trip notifications
- Automated service case management on system faults
- Up to three firewalls to isolate the VCB from admin and control networks
- Local analytics
- Remote software upgrades to the system

**Rotating Machine Diagnostic Module (RMDM)**

Where no Power Conversion drive is in use, as in the case of third party drives or in Direct Online machines, a Rotating Machine Diagnostics Module (RMDM) is employed to extract the required information to be able to execute the analytics.

The RMDM replicates the sensing and processing elements of a variable frequency drive in a stand-alone module. A single RMDM is capable of monitoring up to 20 rotating machines.

The RMDM takes periodic snapshots of high-frequency data which it compresses and uploads to our Cloud solution where it’s processed by our analytics engine.

**Managed Services**

Our services teams provide skilled, comprehensive technical backup, giving you timely response and domain expertise on-hand.

The *APM Data Analyst* team is responsible for monitoring the health of all assets under management and examining every alarm raised by the analytics.

The *Subject Matter Expert* team are experienced asset experts and field service engineers. They review alerts, applying process and product knowledge to configure the system to precise customer and class society needs, helping to continuously improve the system and remove anomalies.

The *Core Engineering* team is in charge of algorithm fine-tuning and incorporation of applications experience into the development of the system.
Four levels of service support

Detect
Equipment Insight to increase uptime and reduce opex through prognostics. We provide a mix of on-site and cloud based systems to monitor the health of your equipment and provide you with an Equipment Health Dashboard and managed services. With improved situational awareness customers get visibility of real-time equipment health and detailed insights from the engineering team on the alarms raised with recommendations for action.

Protect
In addition to the benefits of Detect you gain support not just for failure modes, but our experts will help identify and address performance deviations. This means that not only can we help increase availability and operational uptime, we’ll also be supporting you to increase productivity and/or quality by looking for those hard to find deviations from the norm that drive production losses. In addition we will help you to avoid or reduce unnecessary maintenance costs, lowering opex by optimizing inventory levels, collecting all the equipment information needed to undertake risk based maintenance operations.

Focus
Focus brings you all the benefits of the first two tiers and is designed to impact root causes of productivity, quality and reliability issues. So, with Focus you get enhanced technical support and on-call field service experts to help resolve issues on the ground. GE will undertake all routine maintenance of the equipment covered by the agreement. You decide the objectives, we provide the expertise and support to help you achieve them. Focus also alleviates the challenges of obsolescence. We will complete the studies and plan the strategy to cost effectively extend or manage equipment life. Cyber security is another problem area for most companies, one which potentially increases as the amount of data increases, so with Focus comes regular cyber security assessments.

Fix
The most complete service possible. You set the parameters. We agree a performance guarantee for the equipment and take care of everything related to the achievement of the performance. It’s that simple. All the maintenance, repairs, obsolescence issues, and inventory complexities that distract you from your core business... gone.
Flexibility in the level of support provided means organizations can get the right amount of backup for your needs.

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<th>Protect</th>
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<th>Fix</th>
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<tr>
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*INCLUDED IN FIXED FEE  ◊ SUPPLIED AS AN EXTRA FEE  ✓ CUSTOMER TO SUPPLY AS PREREQUISITE*
About GE Power Conversion

GE's Power Conversion business, a business unit of GE Power, applies the science and systems of power conversion to help drive the electric transformation of the world's energy infrastructure. It does so by making and delivering advanced motor, drive and control technologies that evolve today's industrial processes for a cleaner, more productive future. Serving specialized sectors such as energy, marine, renewables and industry, through customized solutions and advanced technologies, GE Power Conversion partners with customers to maximize efficiency.

For more information on GE's Asset Performance Management, please visit gepowerconversion.com or email powerconversion.apm@ge.com

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