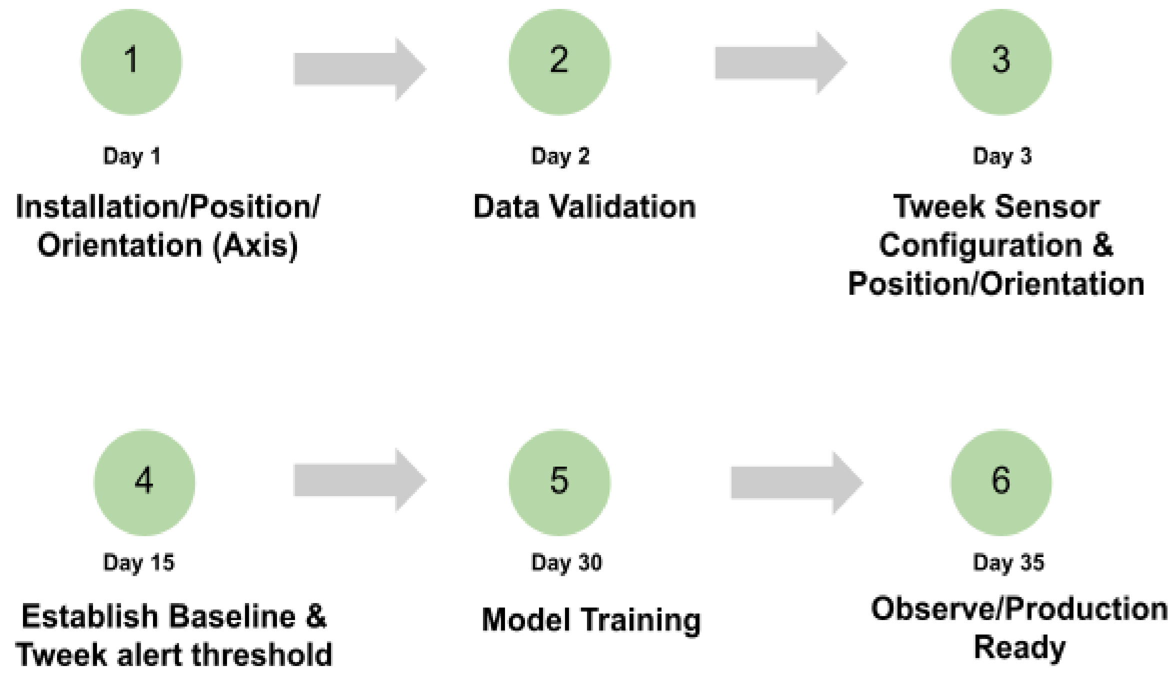
ioEYE Predict Implementation Guide

Updated: 22-Dec-2020

Onboarding Process Overview



STEP 1: Pre Installation

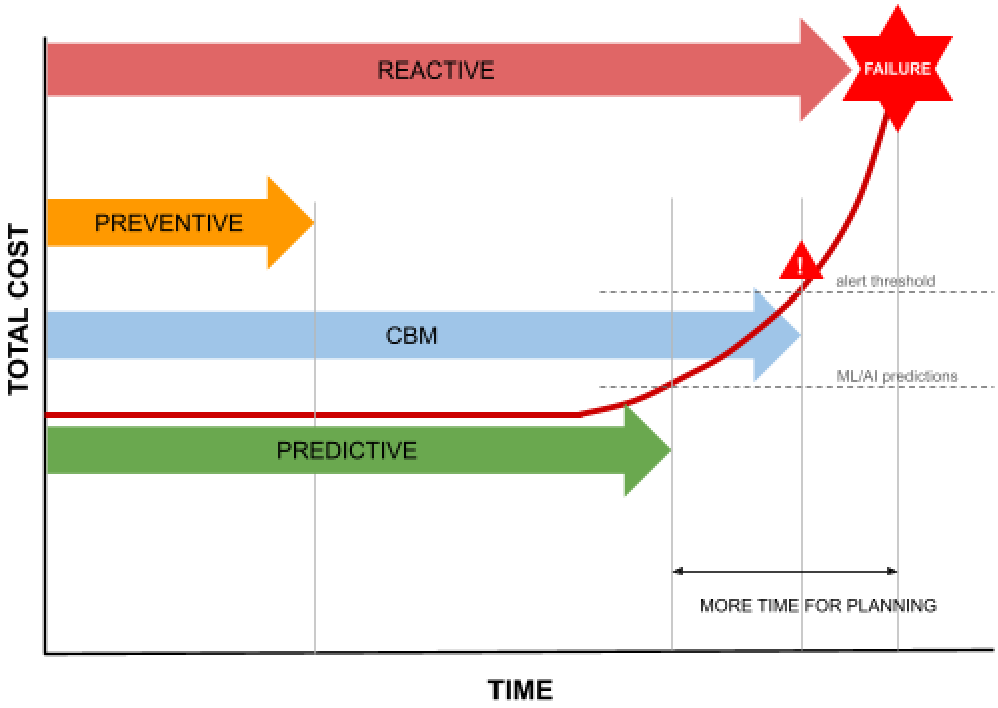
1.1 Overview

Maintenance has evolved from Reactive to Preventive to CBM (Condition Based Maintenance). Reactive Maintenance was only done when a breakdown happened. This led to unexpected downtime and high repair costs.

Gradually plants started to adopt Preventive Maintenance. Maintenance was done at set intervals to keep the machines in optimal working condition. It suffered from a lack of evidence or root cause justification. Most enterprises either extended or reduced the interval of maintenance without understanding the cost and risk balance. This led to the development of CBM.

In CBM the parameters that reflected the underlying asset condition were measured. If they were beyond their permissible limits, maintenance was carried out. It required highly trained manpower and was cost-effective for critical machinery only.

With the advent of IoT (Internet of Things), sensing technologies became cheaper. Cloud technologies allowed ML/AI to be run cost-effectively. CBM techniques augmented with these new technologies made Predictive Maintenance (PdM) possible at scale.

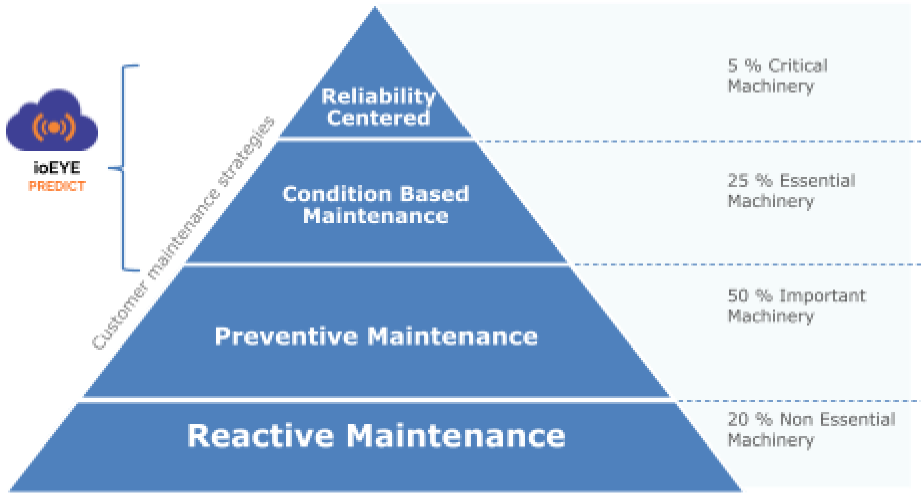


1.2 Deciding if PdM is the right tool for this equipment?

Create a plant-wide asset list and select them using the following criteria:

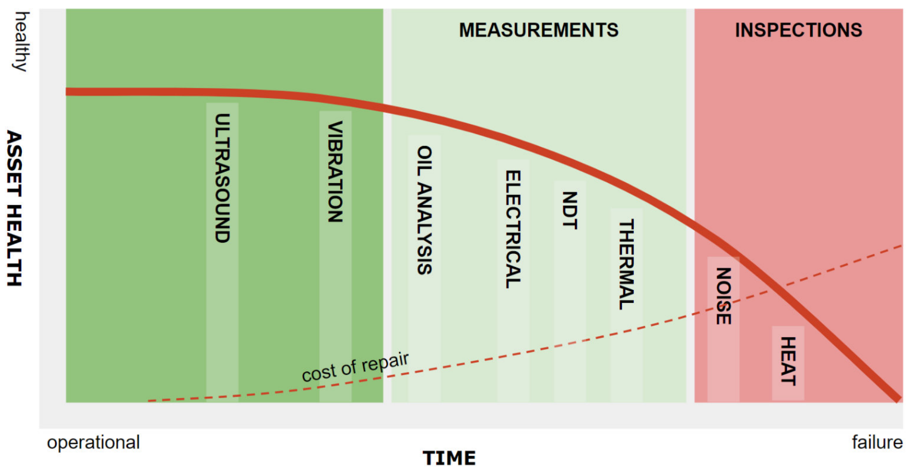
1. Assets that are critical to the operation and sudden breakdown can be costly or lead to safety issues.
2. Assets that have low MTBF than expected and have breakdowns of the following nature:
    a. Frequent.
    b. Costly to Repair.
3. Identify the root cause of each event and then only select events that were caused by fatigue/wear instead of sudden failure. Sudden failures are due to torsional or other stress and are difficult, if not impossible, to predict. They usually require a protective system instead of a predictive system to control them.
4. Identify the parameters that would reflect the underlying condition that caused the failure/wear event. These events are predictable and can be predicted from these parameters.

5. Select assets for which the total cost of failure for these predictable events (direct cost of repair + indirect cost of downtime) is at least 3x of the predictive maintenance system's annual cost.



1.3 What to Measure?

Measure parameters that are leading indicators to the underlying condition. As an example, vibration is a leading indicator of bearing failure while the bearing temperature is a lagging indicator of bearing damage. The temperature rises when the actual damage has already occurred.



The following measurements are widely used:

1. Vibration Measurement
   a. Unbalance
   b. Misalignment
   c. Looseness
   d. Rubbing
   e. Crack (Fatigue)

    f. Inadequate lubrication
    g. Bearing Defect - Journal
    h. Bearing Defect - Rolling Element
    i. Gear Defect
    j. Impeller/Pump Cavitation and Defects
    k. Fan/Blowers
    l. Pulley/Belt
    m. Electrical Motor
2. Infrared thermography
    a. Arcing/Electrical Issues
    b. Blocked Pipes and Valves
    c. Insulation issues
    d. Airflow/cooling problem detection.
    e. Belts, Pulleys, and Bearings in conveyor lines
3. Lube Oil analysis for wear detection in:
    a. Gearbox
    b. Bearing
    c. Engines
4. Ultrasound
    a. Electrical Arching
    b. Early bearing defect
    c. Lubrication issues
    d. Leakages in valves and steam traps
5. Dissolved gas analysis for transformers
6. Motor current analysis for issues like broken bars, air-gap eccentricity, etc.

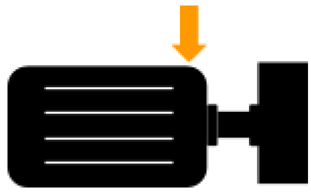
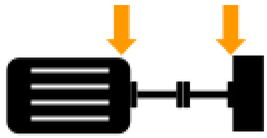
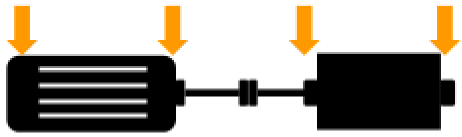
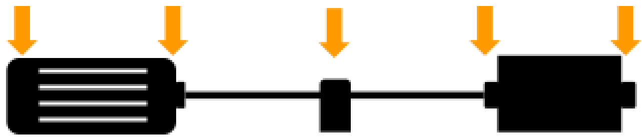
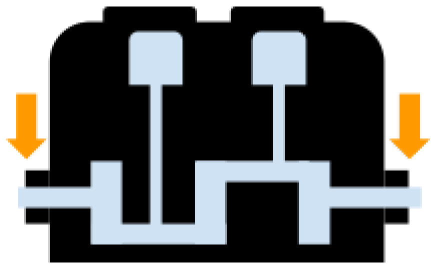
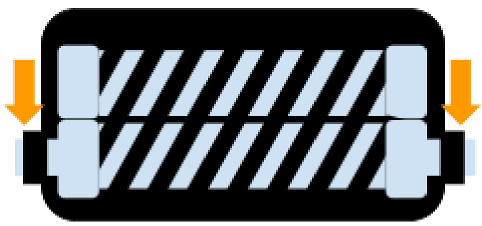
Problem	**ioEYE Predict Sensor**
Supply Side	ESA
Mechanical Imbalance and Misalignment	Vibration
Insulation Fault, Stator Electrical Imbalance	ESA, Magnetic Flux
Motor Broken Bars	ESA, Magnetic Flux
Bearing, Gearbox	Vibration
Early Stage Bearing Defects, Micro cracks, arching, lubrication and Leaks	Ultrasound
Mechanical Failure of Coupling and Load	Vibration

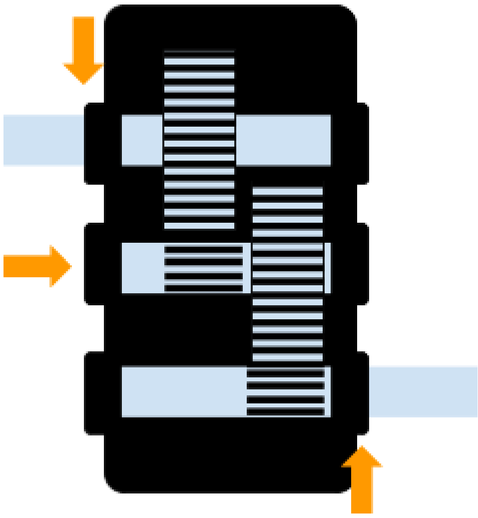
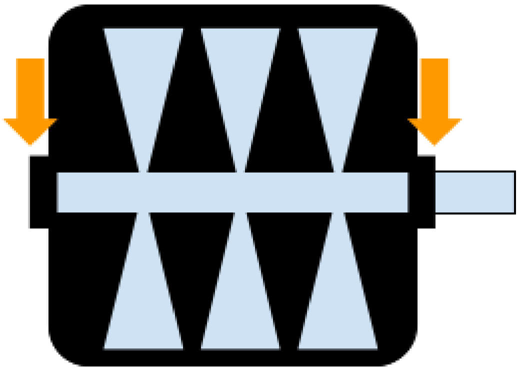
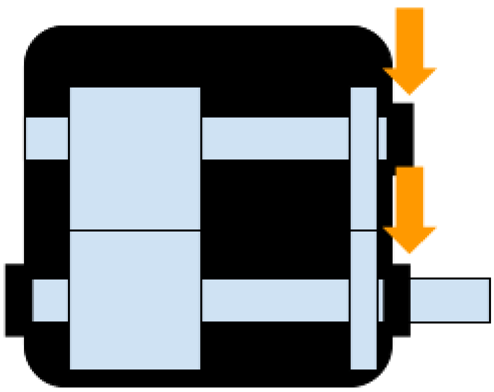
** ESA: Electrical Signature Analysis*

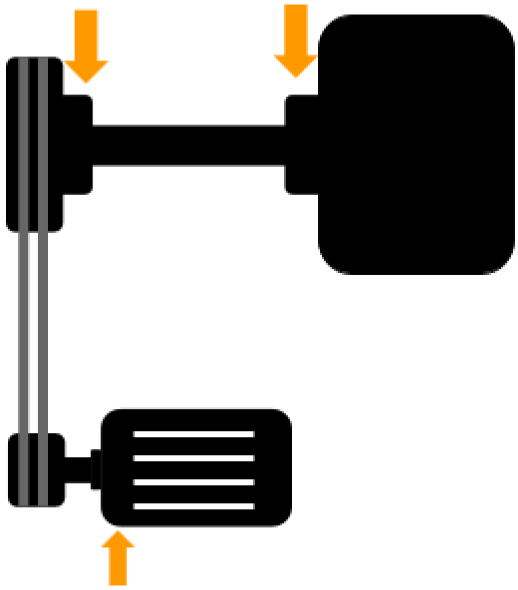
1.4 Where to Measure?

The perhaps is the most important decision. The spot where you make a vibration or acoustic measurement is called a **measurement point**. Select the measurement point as per the following guide:

1. The measurement point should be selected on a thick solid section of the machine. In most cases it is the bearing housing.
2. Do not select a measurement point that has paint, rust, or any material that can dampen vibrations, especially the high-frequency vibrations. The sensor should have direct contact with the metal housing.

1. Close Coupled Motors and Pumps/Fans On small equipment where the prime mover is directly coupled to the load (fan or pump) measure only on the motor bearing.	
2. Coupled Motors and Pumps/Fans **A.** On small equipment measure only on the motor and the pump/fan bearing. **B.** On large equipment measure on the MDE, NDE of the motor and pump/fan. **C.** For very large shaft, also measure on the PDE (Pillow drive end bearing).	A  B  C 
3. Compressors **A. Reciprocating and centrifugal Compressors**: Both ends of the compressor shaft. **B. Screw Compressors**: Both ends of the screw shaft. **C.** For large compressors, you can also measure vibration on the crosshead and the casing.	A  B 

4. Gearbox On bearing housing of each shaft.	
5. Blowers **A.** Centrifugal: Both ends of the shaft. **B.** Lobe: On both bearing ends.	A  B 

6. Chain and Pulley Systems	

1.5 Asset Information & Classification

The following asset data is required for the alert engine to work. You can use the "ioEYE Predict Asset Data Collection" spreadsheet provided by us to collect preliminary information:

Parameter	**Options**	**Description**
ISO 10816		
Foundation Type	• Rigid • Flexible	
Machine Type	• Pumps > 15kW with Integrated Driver • Pumps > 15kW with External Driver • Medium Size Machines 15kW < Power ≤ 300kW • Large Size Machines 300kW < Power < 50MW • Motor 160mm ≤ Shaft Height < 315mm • Motor 315mm ≤ Shaft Height	

Prime Mover (Motor) Information		
Motor Type	NA	
Electrical Supply Frequency	NA	
With VFD	NA	
RPM	NA	
Power	NA	
Mounting Orientation	NA	
Bearing Information		
Bearing Type	Roller, Journal	This should be captured at all asset measurement points.
Bearing BPFO		
Bearing BPFI		
Bearing BSF		
Coupling Information		
Transmission Coupling Type	Without Closed Coupling	
Closed Coupling Information		
Motor Directly Bolted To:	Centrifugal pump	Number of vanes
	Gear Box	Number of gear or screw teeth
	Fan	Number of blades
	Centrifugal compressor	Number of compressor vanes
	Screw/lobe pump	Number of teeth/lobes
Without Closed Coupling		
Coupling between motor and Driven component	Yes, No	

Driven component	Pump Fan Compressor Blower Spindle Gearbox Belt Drive* Chain Drive*	*Belt Drive and Chain Drive not shown if the answer to the above question is Yes.
Driven Component - Pump		
Bearing Type	Roller, Journal	
Pump Type	Centrifugal	Number of vanes
		The impeller is supported by Two Bearing, Overhung.
	Propeller	Number of vanes
	Sliding vanes	Number of vanes
	Screw/lobe	Number of teeth/lobes
	Piston	Number of Pistons
Driven Component - Fan		
Bearing Type	Roller, Journal	
The fan is supported by	Two bearings, Overhung	
Number of fan blades		
Driven Component - Compressor		
Bearing Type	Roller, Journal	
Compressor type	Centrifugal	Number of vanes
	Screw	Number of screw teeth or threads
	Piston	Number of pistons
Driven Component - Blower		
Bearing Type	Roller, Journal	
Number of blower lobes		
Transmission - Gearbox		

Bearing Type	Roller, Journal	
Number of speed changes		
Gear tooth count		
Transmission - Belt		
Input shaft speed		
Output shaft speed		
Rotation speed		
Transmission - Chain		
Input shaft speed		
Output shaft speed		
Tooth count		

STEP 2: Installation

1. It is recommended that you use either stud or epoxy mounting. Magnetic mounts are not recommended for permanent installations. The frequency measurement limits for various mounting options are:
    a. Magnet: 5kHz
    b. Epoxy: 6kHz
    c. Stud: 7kHz
2. Please follow the instructions mentioned in the sensor manuals.
3. If you have a large sensor installation you should name every measurement point and mark it with paint or stencil on each asset. You might also laser print measurement point labels and fix them on the large assets with a high number of measurement points.

STEP 3: Setting up Alerts

There are two alerts engines:
1. Threshold
2. Baseline
3. Benchmark Alerts - You should setup alert **as per general standards or Benchmark**:
    - Velocity Alerts based on the ISO 10816 (mm/s)
    - High-Frequency Acceleration Alerts (HFA)
    - Enveloped Acceleration Alerts (gE)
    - Ultrasound Level Alert (dBm)
4. ML/AI Alerts & Notifications

3.1 ISO 10816 Velocity Alerts

The velocity should be measured between frequency range **2kHz to 1kHZ (120 ≤ RPM < 600) for 10kHz to 1kHZ (600 ≤ RPM)**. ioEYE Predict will automatically apply the ISO 10816 threshold alerts based on the following inputs:

Parameter	**Options**
Foundation Type	• Rigid • Flexible
Machine Type	• Pumps > 15kW with Integrated Driver • Pumps > 15kW with External Driver • Medium Size Machines 15kW < Power ≤ 300kW • Large Size Machines 300kW < Power < 50MW

	• Motor 160mm ≤ Shaft Height < 315mm • Motor 315mm ≤ Shaft Height

3.2 High-Frequency Acceleration Alerts

Look at the acceleration time waveform and identify the highest amplitude peak, either negative or positive (this is true-peak acceleration). Amplitudes over 7 g's for ball bearings and 12 g's for roller bearings are a strong indicator the bearing is defective. It is very accurate on machines that do not produce a lot of high frequency energy during operation. Taking time waveforms with 1024 samples, the time sample must not be over 200ms (100ms is preferred for most machines). If the time sample is longer than 200ms, the anti-aliasing filters in the instrument will filter out the higher frequencies that defective bearings produce. This can become a problem on low-speed equipment because of the short time span for the time waveform compared to the long time span between the impacts caused by the rolling elements impacting bearing race defects.

IMP! Should only be used on spectrum data when the sample Fmax > 1kHz

Acceleration True Peak (g)	Ball Bearing	Roller Bearing	Journal Bearing
0-3	GOOD	GOOD	Na
3-5	SATISFACTORY	SATISFACTORY	Na
5-7	UNSATISFACTORY	SATISFACTORY	Na
7-9	FAULT	UNSATISFACTORY	Na
9-11	FAULT	UNSATISFACTORY	Na
11-13	FAULT	FAULT	Na

**Spectrum analysis should always be done to reject or accept this fault.*

3.3 Enveloped Acceleration Alert

These are applied on the enveloped acceleration (gE) trend.

Bearing Bore Size or Shaft Dia	RPM			
	< 500	500 - 1800	1800-3600	> 3600
20 - 150 mm	NA	NA	Alert: 4gE	Alert: 8gE

			Fault: 10gE	Fault: 16gE
50-300 mm	NA	Alert: 2gE Fault: 4gE	NA	NA
200-500 mm	Alert: 1gE Fault: 2gE	NA	NA	NA

**Spectrum analysis should always be done to reject or accept this fault.*

3.4 Ultrasound Level Alert

The Ultrasound RMS (dB levels), which represents energy in the measurement band, is usually a good indicator of the problem but trending both is always better. It is important to understand that when using overall measurements establishing a baseline is the most important criterion. Most alerts are set as a change from this baseline. It is also important that when you replace sensors they should have similar characteristics of SRN, Sensitivity, and Resonance Frequency. In case they vary there might be an abrupt change in the levels and baselining may have to be done again. This would lead to all historical data being rendered unusable.

Absolute change over baseline	**Fault Indicated**
8 to 10 dB	Poor lubrication or early bearing fault
10 to 15 dB	Stage 2 bearing fault
15 to 30 dB	Late-stage bearing faults
> 30db	Bearing failed

3.5 Change from Baseline Alerts (Beta)

The Baseline Alerts are only applied on the overall measurements that are trended. These alerts are produced when there is a % , logarithmic (dB) or absolute change from the baseline. There are two ways to identify the baseline:

- An average of a fixed period marked by the user as healthy data.
- An average of a x days period y days before the date of evaluation.
- A moving average of x days.

STEP 4: Analyzing Data

One of the fastest ways to derive value from your ioEYE Predict is to analyze the data. You can perform the following analysis on the data:

1. Overall trending
    a. Velocity, Displacement for defects in the low frequency (upto 1KHz).
    b. Energy Bands (Defect segregations and trending).
    c. Ultrasound (For lubrication and bearing health).
    d. Magnetic Flux (For overall motor health).
2. Spectrum
    a. FFT Analysis.
    b. Order Analysis.
    c. Envelope Analysis.
    d. Waterfall Analysis.
    e. Magnetic Flux Spectrum.

STEP 5: Leveraging ML/AI

The following ML/AI models are available:

- **Asset Overall Risk**: This is an unsupervised model that calculates risk of failure based on multiple features extracted from the overall and spectrum data of vibration and ultrasound. This gives a high level grey, green, orange and red indicator for the risk. The model has an automatic feedback chain that keeps improving the model over time without user intervention.

- **Fault Categorization**: This is a multi tier Model which is designed as an Active Learning system. In the first tier the model labels the data on a fault algorithm (Algorithmic labeling layer). This fault data is then fed to a neural network model (ML/Ai Model layer). Finally the user will be shown the fault and they can mark it as a fault or no fault (the supervision layer).

- **RUL (Remaining Useful Life)**: This ML/AI model that predicts the remaining useful life of bearing is in the experimental beta stage.

STEP 6: Measuring Performance

The best way to measure the performance of the system can be done in any of these ways:

1. Tracking the number of unexpected breakdowns and how this metric performs over time.
2. Number of faults detected and breaking them into % of false and actual alerts.
3. MTBF and tracking it over time and how this metric performs over time.