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1. Introduction

This sensor is designed to continuously monitor machine health and run time, helping to detect unexpected failures such as early bearing failure, unbalance, and misalignment. It is used across a variety of machines to identify and predict failures in rotating components.

Key Features

- **Performance:** It detects dual-axis vibration with a bandwidth of up to 4 kHz and provides high-accuracy measurements for vibration.
- **Data Output:** The device outputs actionable data, such as RMS Velocity, RMS High-Frequency Acceleration, and Peak Velocity, which is pre-processed from vibration waveforms within the sensor.
- **Design:** It is an industrial-grade sensor with a small form factor designed to fit into tight locations. It is manufactured with either stainless steel or aluminum housing.

2. System Requirements

To ensure the application runs smoothly, the following hardware and software specifications are required:

- Processor: **8** Core Processor (Intel i7 or i9).
- Memory (RAM): **32 GB** to **64 GB**.
- Storage: Dedicated storage starting from **1 TB**. (Storage capacity can be increased or reduced based on the number of sensor tags, data generation rate, and data retention requirements.)
- Operating System: Ubuntu Server **22.04 LTS** (Latest Stable Version).
  (Other compatible operating systems such as **Windows Server** or equivalent **Linux** distributions can also be used based on project requirements.)
- Internet Connectivity: Dedicated **500 Mbps** high-speed internet connection.
  (Lower bandwidth can be used depending on system load, data transmission frequency, and deployment requirements.)

3. User Roles and Assignments

Application Will provide the User Creation and Rights Assignment module. There will be operation users and Admin Users. Further Maintenance of the Application and Monitoring of any discrepancy in the data there will be Application User.

Application will be Capable of logging Application events and to notify any error to Application user following Functionality will be Provided as per user.

1. Operation User

Designed for day-to-day monitoring.

- Dashboard Access: Can view the dashboard and receive notifications based on prediction rules.
- Reporting: Can view reports and take records.
- Visualization: Can scroll through different equipment to visualize parameters and rules.

2. Admin Users

Includes all privileges of the Operation User with added control.

- Full Access: Access to all functionality available to the Operator User.
- Configuration: Can change parameters as per requirements.
- Data Access: Can view raw data.

4. System Architecture

The system uses a high-level architecture grouped into specific logical components to ensure seamless data flow from device to user, as shown in **Figure 1**.

4.1 Data Flow Overview

The data journey flows through the following stages:

i. Sensing Layer:

- **Vibration Sensor**: The sensor collects raw vibration and temperature data. It outputs this data via a wired RS-485 interface using the Modbus protocol.

ii. Transmission Layer:

- **LoRaWAN Converter:** An RS-485 to LoRaWAN converter is connected to the sensor. It reads the Modbus registers and transmits the data wirelessly over the LoRaWAN network.

- **LoRaWAN Gateway:** This device receives the wireless data packets from the converter and forwards them over the network (Ethernet/Cellular) to the central server.

iii. Processing Layer:

- **MQTT Broker:** Acts as the central messaging hub. The gateway publishes data to specific topics on the broker.

- **Backend Application:** Subscribes to the MQTT topics, receives the raw payloads, decodes the Modbus data, and applies business logic (alarms, thresholds).

iv. Storage & Presentation:

- **Database:** Decoded data and historical records are stored securely.

- **UI (Dashboard):** The frontend application fetches processed data from the database to display Live Graphs, Health Status, and Analytics to the user.

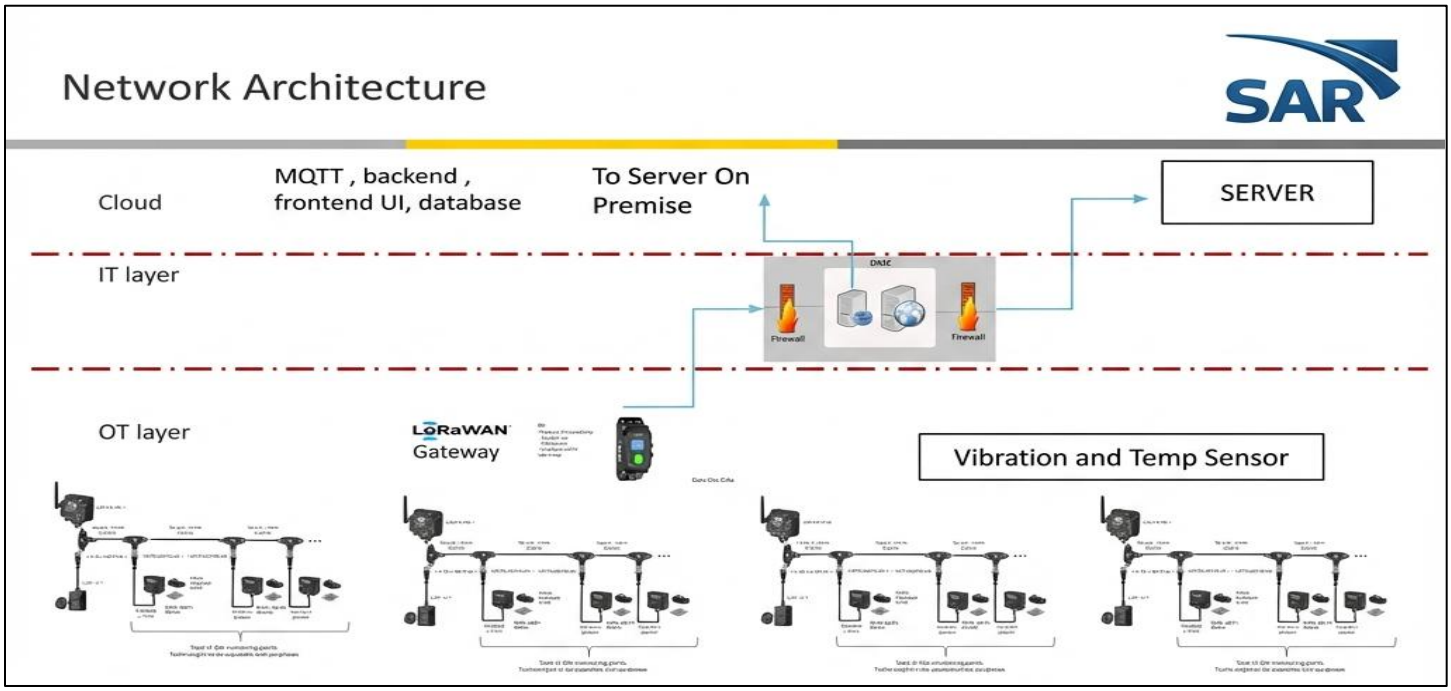


Fig.1: System Architecture

5. User Interface (Dashboard) Overview

A new dashboard interface has been designed to provide maximum visibility of machine health parameters and to enable easy and efficient analysis for the maintenance team. The layout is structured to present critical information in a clear, organized, and easily interpretable manner, supporting faster decision-making and proactive maintenance actions.

The dashboard consolidates real-time and historical condition monitoring data into a single view, allowing users to quickly assess equipment status without navigating through multiple screens. Key operating parameters, vibration metrics, fault indicators, and alerts are visually arranged to ensure that abnormal conditions can be identified at a glance.

The user interface is divided into logical sections such as navigation and controls, key parameters, fault indicators, alert notifications, data representation, and alerts summary. Each section is designed to highlight specific aspects of machine health, ensuring clarity and reducing the effort required to interpret complex vibration data.

The following figure illustrates the overall user interface of the dashboard and explains how different data elements are displayed and utilized for condition monitoring and maintenance analysis.

Fig:2. DASHBOARD IMAGE

Dashboard has been divided into multiple sections.

5.1. (#1) Navigation & Control Section:

This section is located at the top of the dashboard and allows the user to control data visualization and navigation.

Key elements available in this section include:

- **Line Selection:** Used to select the production line or equipment line.
- **Type Selection:** Allows selection of machine type (e.g., Hydraulic Power Pack Motor).
- **Home Button:** Navigates the user back to the main dashboard.
- **Time Range Selector:** Enables viewing of data for a selected time duration (e.g., Last 24 Hours).

- **Refresh Button:** Manually refreshes the dashboard data.
- **Auto Refresh Interval:** Displays the current auto-refresh interval (e.g., every 30 seconds).

This section helps users quickly switch between machines and control data visibility.

Fig:3. Navigation & Control Section

5.2. (#2) Key Parameter Summary:

This section provides instant health indicators using gauge meters for critical parameters.

Displayed parameters include:

- X-Axis RMS Velocity (mm/sec)
- X-Axis RMS Acceleration (mm/s²)
- Z-Axis RMS Velocity (mm/sec)
- Z-Axis RMS Acceleration (mm/s²)
- Temperature (°C)

These gauges give an at-a-glance understanding of machine condition.

5.3. (#3) Fault Indicators Section:

This section displays vibration-based fault diagnostics derived from signal analysis.

Fault types monitored include:

- Unbalance
- Looseness
- Misalignment
- Temperature Condition

Each fault indicator shows:

- Status (Healthy / Good / Fault)
- Visual confirmation using icons and color coding.

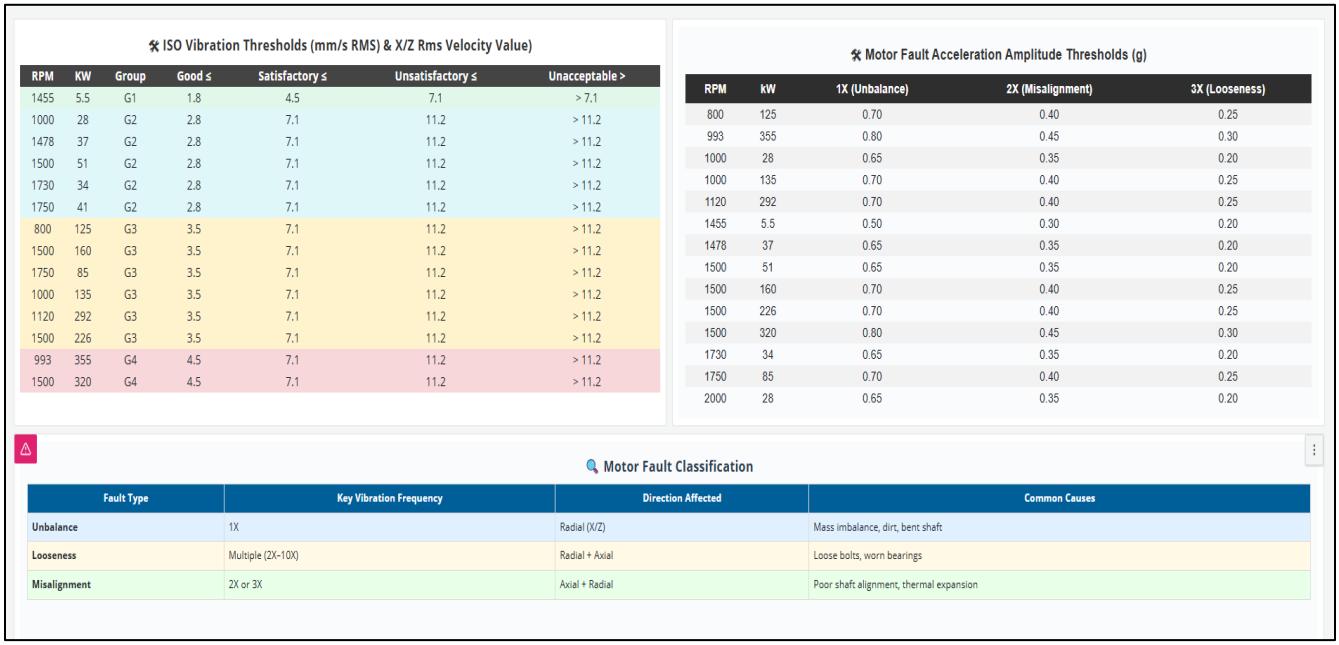
This helps maintenance teams quickly identify the nature of potential issues.

5.3.1 Fault Indicator Thresholds & Classification:

This section displays standard vibration and acceleration thresholds used to evaluate machine condition based on ISO vibration limits and motor fault frequency analysis.

- ISO Vibration Threshold Table defines acceptable RMS velocity limits for X and Z axes across different motor groups.
- Acceleration Amplitude Thresholds help identify fault severity related to unbalance, misalignment, and looseness.
- Fault Classification Table maps vibration frequency patterns to fault types, affected directions, and common causes.

These thresholds are used by the system to detect, classify, and generate alerts for machine faults.



🛠 ISO Vibration Thresholds (mm/s RMS) & X/Z Rms Velocity Value)

RPM	KW	Group	Good ≤	Satisfactory ≤	Unsatisfactory ≤	Unacceptable >
1455	5.5	G1	1.8	4.5	7.1	> 7.1
1000	28	G2	2.8	7.1	11.2	> 11.2
1478	37	G2	2.8	7.1	11.2	> 11.2
1500	51	G2	2.8	7.1	11.2	> 11.2
1730	34	G2	2.8	7.1	11.2	> 11.2
1750	41	G2	2.8	7.1	11.2	> 11.2
800	125	G3	3.5	7.1	11.2	> 11.2
1500	160	G3	3.5	7.1	11.2	> 11.2
1750	85	G3	3.5	7.1	11.2	> 11.2
1000	135	G3	3.5	7.1	11.2	> 11.2
1120	292	G3	3.5	7.1	11.2	> 11.2
1500	226	G3	3.5	7.1	11.2	> 11.2
993	355	G4	4.5	7.1	11.2	> 11.2
1500	320	G4	4.5	7.1	11.2	> 11.2

🛠 Motor Fault Acceleration Amplitude Thresholds (g)

RPM	kW	1X (Unbalance)	2X (Misalignment)	3X (Looseness)
800	125	0.70	0.40	0.25
993	355	0.80	0.45	0.30
1000	28	0.65	0.35	0.20
1000	135	0.70	0.40	0.25
1120	292	0.70	0.40	0.25
1455	5.5	0.50	0.30	0.20
1478	37	0.65	0.35	0.20
1500	51	0.65	0.35	0.20
1500	160	0.70	0.40	0.25
1500	226	0.70	0.40	0.25
1500	320	0.80	0.45	0.30
1730	34	0.65	0.35	0.20
1750	85	0.70	0.40	0.25
2000	28	0.65	0.35	0.20

🔍 Motor Fault Classification

Fault Type	Key Vibration Frequency	Direction Affected	Common Causes
Unbalance	1X	Radial (X/Z)	Mass imbalance, dirt, bent shaft
Looseness	Multiple (2X–10X)	Radial + Axial	Loose bolts, worn bearings
Misalignment	2X or 3X	Axial + Radial	Poor shaft alignment, thermal expansion

Fig:4. Fault Indicator Thresholds

5.4. (#4) Alert & Notification Section:

This section is dedicated to real-time alerts and system notifications.

Features include:

- Display of active alerts
- Fault detection messages

5.5. (#5) Data Representation:

This section provides detailed graphical visualization of sensor data over time.

Graphs available:

- RMS Velocity (X & Z Axis)
- RMS Acceleration (X & Z Axis)
- Peak Velocity
- Temperature Trend

- Statistical Parameters (Kurtosis, Crest Factor)

Graph features include:

- Time-based trend analysis
- Min, Max, and Mean values
- Threshold lines for warning and critical limits
- Comparison between X and Z axis

These graphs help users analyze machine behaviour, detect trends, and predict failures.

5.6. (#6) Alerts Box:

This section summarizes diagnostic conclusions based on vibration analysis.

Example information shown:

- Bearing Fault Status
- Health confirmation
- Last evaluation timestamp

This provides confidence that the system continuously monitors machine health.

5.7. Report Page:

The Report Page provides historical performance and condition data of the selected equipment for a defined time period.

- Displays threshold reference for temperature and vibration conditions at the top for easy comparison.
- Allows **date range selection** and equipment filtering for report generation.
- Presents **daily summarized values** including machine health status, runtime, temperature, vibration velocity, acceleration, and fault indicators.
- Fault status for **Unbalance, Misalignment, and Looseness** is clearly shown for each day.
- Reports can be **downloaded in CSV format** for analysis and record keeping.

This section helps users review machine condition trends and maintenance history efficiently.

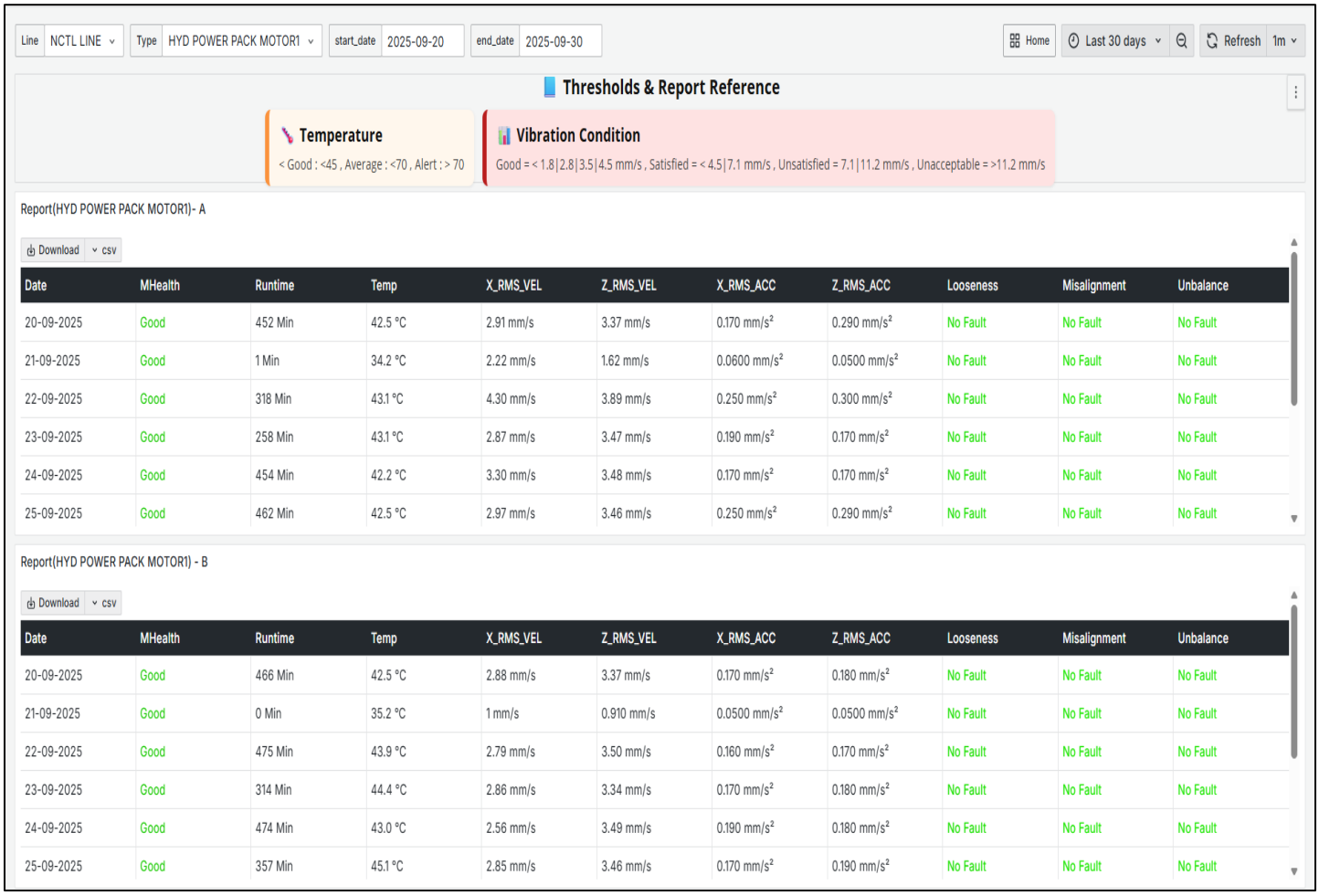


Fig:5. Report Page

5.8. Admin Page Overview:

The Admin page provides a real-time health summary of all connected machines on the selected production line.

- Displays **vibration and temperature status** for each motor.
- Shows **runtime, stop time, RPM, and power (kW)** details.
- Machine condition is clearly indicated as **Good / Normal** for quick monitoring.
- Includes controls for **report download, ISO threshold reference, alarms, time range selection, and auto-refresh**.

- Enables administrators to **quickly identify machine health and take action if required**.

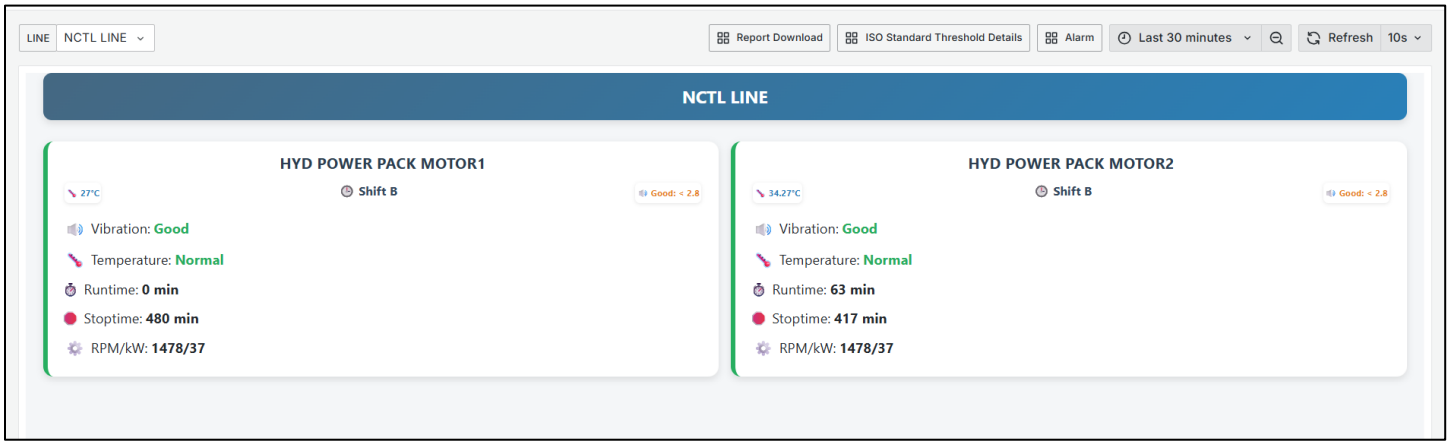


Fig:6. Admin page

5.9. Email Alert Notification :

When any abnormal condition or fault is detected in the system (such as Unbalance, Misalignment, Looseness, or Temperature breach), an automatic email alert is triggered.

- Alerts are generated based on **predefined threshold limits**.
- Email notifications include **equipment details, fault type, severity level, and timestamp**.
- Alerts are sent to **configured recipients** for quick action.
- This ensures **real-time awareness and faster maintenance response**.