element14
AN AVNET COMPANY

SMART MAINTENANCE: THE EVOLUTION OF PREDICTIVE MAINTENANCE (PDM)

WHITEPAPER

OVERVIEW

Industrial manufacturers manage complex processes and equipment daily, and maintenance is crucial for the efficient and safe running of the business. Maintenance professionals nowadays encounter multiple issues, including increasingly sophisticated equipment. Whatever the challenge, the primary problem is to maximise machine availability. Traditional maintenance programs fall short of such exacting needs.

Smart maintenance represents a radically new approach to the maintenance process. It can predict equipment malfunctions and optimise the management of resources to offer a solution to the ongoing problem. A Smart maintenance strategy can add exponential value to any organisation. Smart maintenance strategies leverage multiple technologies and maintenance techniques, including Predictive Maintenance (PdM). The digital transformation of PdM, also known as Maintenance 4.0, uses a broad range of connected and networked sensors and devices that are parts of the IIoT. Advancements in Machine Learning (ML) and ***Artificial Intelligence (AI)*** also play a vital role in producing Smart PdM solutions.

PdM is a notable area to help an organisation realise the value of its investments. According to industry estimates, manufacturing organisations without a PdM plan suffers 800-1000 hours of Downtime annually. Adopting PdM techniques may reduce unplanned Downtime by 60 percent and financial impact by 36 percent.

TYPES OF MAINTENANCE AND DIFFERENCES

A poor ***maintenance*** strategy can ruin a company's overall productive capacity. It is difficult to determine how frequently a machine should be switched off for servicing and weigh the risks of lost production time against a potential breakdown.

Maintenance strategies can be any of three categories, as shown in figure 1: Reactive Maintenance, Preventive Maintenance, and Predictive Maintenance.

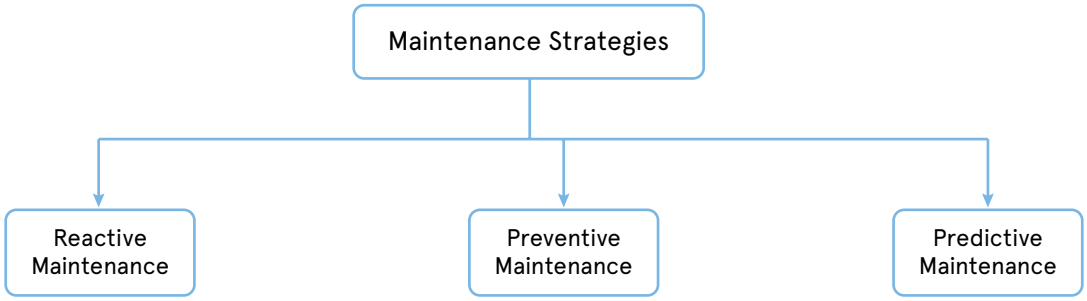


Figure 1: Classification of Maintenance Strategies

- ***Reactive Maintenance***: This is also called Run-to- Failure/ Runtime Failure maintenance. In this maintenance category, the repair of equipment or parts happens after the asset has failed to function.
- ***Preventive Maintenance***: This is also known as schedule or calendar-based maintenance; in this category, maintenance tasks occur during regular equipment operation to avoid unanticipated breakdowns and associated costs.
- ***Predictive Maintenance (PdM)***: In this category, technology-enabled maintenance connects the asset to a computerised maintenance management system (CMMS) via ***sensor*** data. You can directly monitor your asset performance during standard operation to predict failures and analyse all data collated from the sensors connected to assets. This data enables you to predict the failure time of your asset and enables your maintenance team to rectify an issue before a failure happens, as shown in figure 2. Predictive maintenance will help your organisation optimise its strategy by conducting only the necessary maintenance activities.

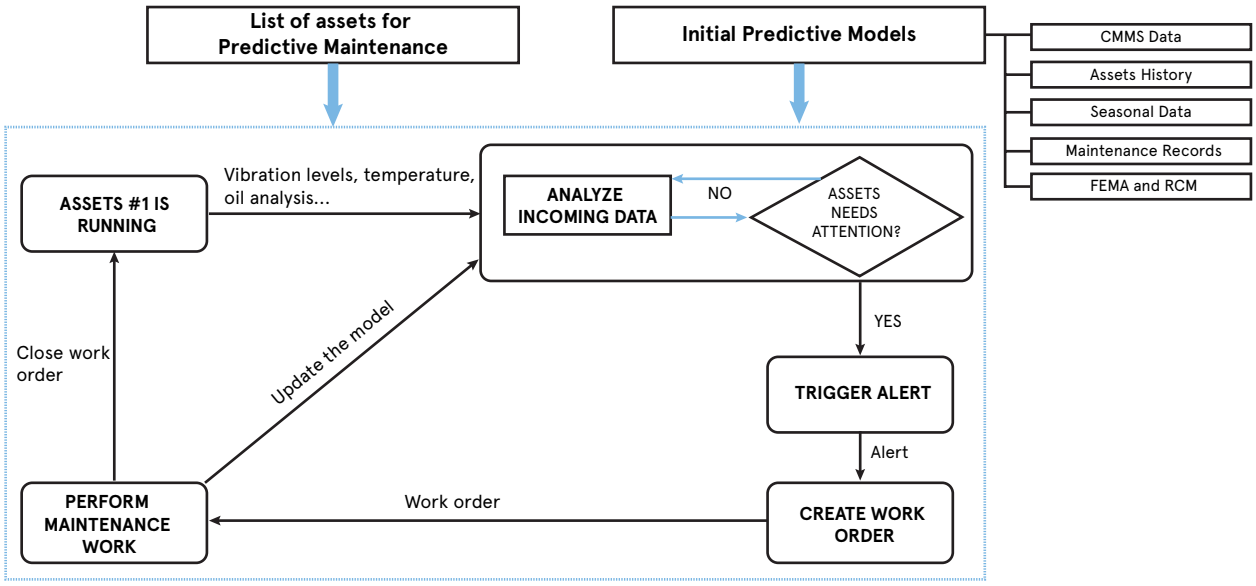


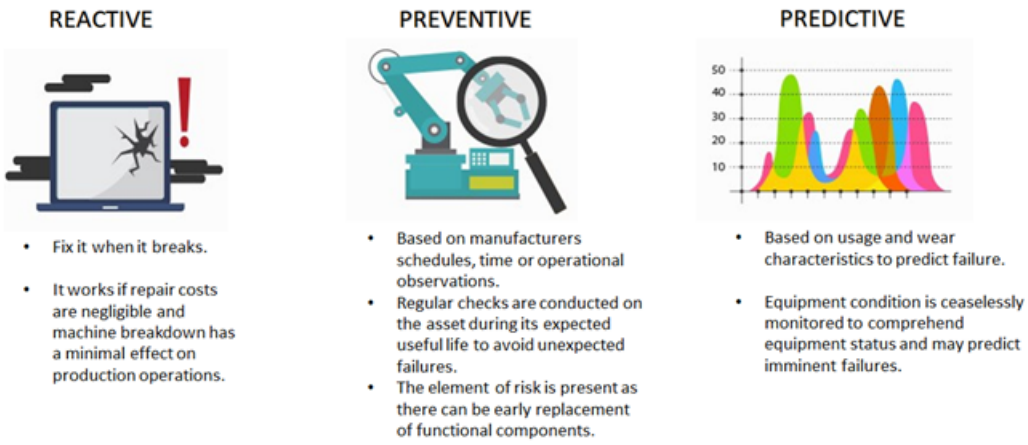
Figure 2: Workflow of predictive maintenance

Predictive maintenance assumes that, if input variables are known, it is possible to predict the failure of a machine component in the future. The part can be replaced with a new one just before it fails. PdM started as a visual inspection method and evolved into automated procedures. These automated procedures use advanced signal processing techniques based on ML, fuzzy logic, neural networks, and others. If paired with integrated sensors, predictive maintenance allows you to reduce machine downtime and maximise component lifetime with a positive impact on productivity, spare parts inventory management, and maintenance costs. The process of PdM includes prognosis and diagnosis activities. Prognosis predicts the faults due to natural wear, and diagnosis examines the variation between expected and observed parameters so that you can evaluate working conditions if particular failures happen.

DIFFERENCE BETWEEN REACTIVE MAINTENANCE, PREVENTATIVE MAINTENANCE, AND PREDICTIVE MAINTENANCE

Benefits of predictive maintenance:

PdM demands constant monitoring of system operating performance and mechanical conditions of assets. Repairs, if any, are occasional and lead to optimised investments. We will now deep dive into nine key benefits



1. **Accounts for actual conditions and applications:** The Maintenance of any equipment depends upon its condition and performance in its actual working environment and real-world applications. A generic schedule from statistical averages may not be suitable for your facility. For example, a manufacturer may instruct the replacement of a particular pneumatic system every 1,000 hours. However, this instruction is not applicable if the system suffers from dust exposure and other environmental degradation. Integrating the pressure data into a PdM enables you to accurately determine when the filters will be sufficiently clogged to change them before the total system fails.
2. **Early fault detection:** A key benefit of predictive maintenance is detecting an impending failure that may pause your production schedule. For example, a PdM plan involving regular temperature profile assessments of your equipment may reveal an abnormal rise in the operating temperature in recent months. This overheating problem, if not solved, may lead to quicker degradation of the wiring. The early alert will enable you to switch out the problem part to avoid a catastrophic failure. This alert also results in reduced Downtime.
3. **Less downtime and improved reliability:** PdM reduces Downtime as Maintenance happens only when required. Predictive maintenance and its supporting tools are at the heart of reliability. The combination of monitored equipment and helpful information filtered from data will help you recognise maintenance needs when they arise.
4. **Better performance and reduced cost:** It is vital to perform essential maintenance tasks on time. Timely maintenance ensures that the production line equipment will continuously operate at peak performance. PdM involves maintaining equipment when needed, not after the escalation of a problem. This maintenance has positive implications for costs, such as reduced downtime and power requirements.
5. **Extends equipment life:** PdM increases your equipment's useful life. It also increases the reliability of the machines, making it possible for you to wait much longer for needed refurbishment or replacement. Attending to problems at their nascent stage extends the motor's life span. A motor with ten years of functional life expectancy can see its life span extended by monitoring its condition.

Predictive Maintenance Tools and Techniques

Predictive maintenance (PdM) tools and techniques allow you to schedule repairs to your equipment. The popular predictive maintenance techniques are:

Condition Monitoring: You can use condition monitoring to analyse maintenance requirements. Downtime, unnecessary practices, and asset failures can be avoided. The breach of certain thresholds initiates maintenance in condition monitoring. The process may commence if there are indications of impending failure. Industries practice these main condition monitoring methods:

i. ***Temperature and thermography:*** Cameras are integral to the thermography process. For equipment appraisal, the camera captures infrared radiation. Assets emit this infrared radiation. A temperature variation identifies a potential problem and initiates maintenance. Thermographic analysis detects disconnections, wear, rusting, and delamination invisible to the naked eye. This technique finds use in electrical connections and systems, discharge patterns, roof maintenance, fluid analysis, and discharge patterns.

ii. ***Vibration analysis:*** Sensors, in vibration analysis, detect vibrations caused by degraded asset components. Vibrational changes produced by the equipment are subject to broadband vibration analysis and shock pulse analysis techniques. These methods help to find the flaws present in the parts. Vibration analysis tests component alignment and detects imbalances, clearances, resonances, and gear failures for rotating equipment and machines, such as compressors, water pumps, and engines.

iii. ***Motor circuit analysis:*** The electric signature analysis technique in the motor circuit analysis method determines the motor's overall health. Motor circuit analysers easily find faults in electric motors and their components. This analysis works on both AC and DC motors, and you can use it in online mode (when the motor is running) or in offline mode (the time when the motor is de-energised). Motor circuit analysis can ascertain issues related to incoming power, analyse motor electrical circuitry, analysis of mechanical motor components, gears, and motor mechanical couplings.

iv. ***Ultrasonic Analysis:*** In ultrasonic analysis, ultrasound detects high-frequency (30-40 kHz) sounds and analyses them by changing them into audio and digital data. Technicians perform an in-depth vibration analysis of the defective equipment to locate the cause of the issues. You can use ultrasonic analysis to detect leaks, and cracks, inspect electricals, test valves, and optimise lubrication practices.

v. ***Laser-shaft alignment:*** Bad equipment installation practices cause mechanical failures. Misaligned shafts result in bearings failures. Laser-shaft alignment examines shaft alignment to verify correct installation and thus prevent future performance issues. The technique identifies defects in the surface and subsurface of several materials.

vi. ***Oil analysis:*** You can use this method to analyse a lubricant oil's condition. Your factory equipment may deteriorate due to wear particles, viscosity contamination, and water contamination in lubricants, thus inducing failure of function. Typical oil analysis applications include compressors and gearboxes.

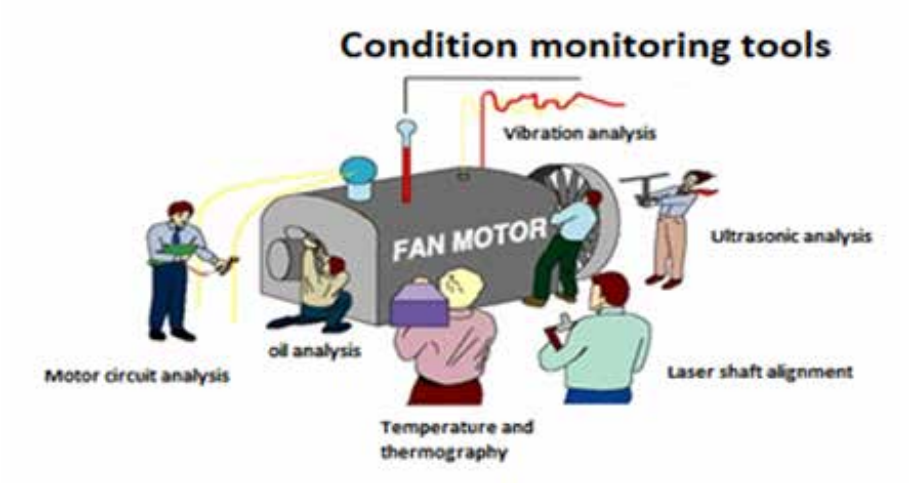


Figure 3: Methods of condition monitoring

IOT ENABLEMENT – CONNECTIVITY:

The abundance of IoT PdM system components allows the use of the process in a broad span of factory and production environments. IoT PdM Sensors can measure temperature, fluid levels, humidity, and proximity, amongst other criteria, making IoT PdM applicable to all types of manufacturing equipment.

How are IoT PdM systems organised?

The system starts at the field level, with industrial equipment incorporating PdM sensors. There is a medley of sensors, each type measuring some criterion of the equipment. The aggregator (gateway) accepts the information sent from the sensors.

A simple local IoT PdM comprises sensors (gather information) and gateways (process data and transmit it comprehensively to monitoring devices). The information is analysed, and the maintenance staff manually fixes all issues.

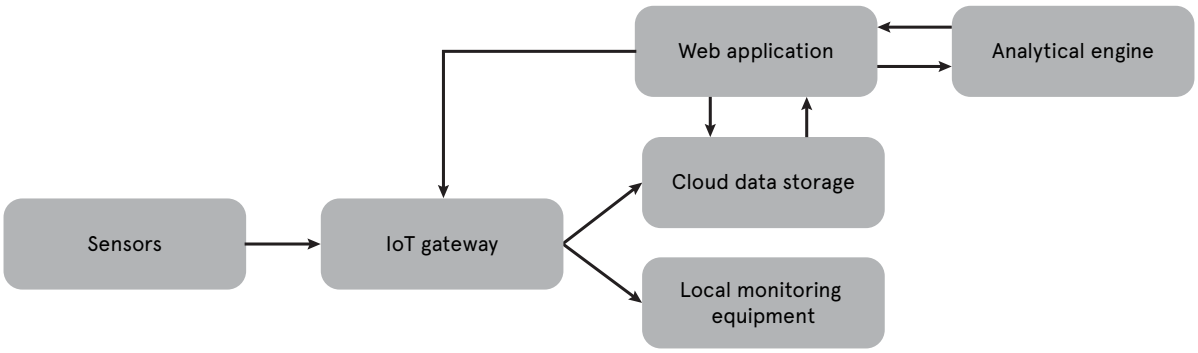


Figure 4: IoT predictive maintenance equipment flow

Multiple sensors are sometimes needed to cover all possibilities related to equipment failure. For example, adding a water-cooled motor to the IoT PM system requires at least one level sensor for measuring the liquid contained within the pumps. A vibration sensor is necessary to ascertain any anomaly (if any) present within the bearing system, and a single vibration sensor to detect any voltage problem.
The next stage in an IoT system is data aggregation in gateways. These gateways perform two principal functions; they gather and process raw data collected from sensors and transfer the processed data to cloud storage or monitoring devices.

Sensors are simple data-gathering devices. They have limited functionality. Compared to sensors, gateways are comparatively sophisticated. Sensors make possible particular remote tuning and reverse connectivity options.

PdM offers many options for data analysis and remote control. Cloud migration allows you to link your on-premises devices to a web platform having a specialised web application.

IoT PdM Web application

A sophisticated but easily usable web application can comfortably control your IoT predictive maintenance system. Large manufacturers and global companies use comprehensive IoT PdM applications as the simple user experience of such a system justifies the high costs involved with its implementation.

A basic web application offers the following features:

- ***Data aggregation***: The gateways process vast quantities of raw information sent from the sensors. This information subsequently moves to cloud storage. The storage connects big data warehouses with ML algorithms. The algorithms continuously improve and update the application.
- ***Illustration of trends***: Faults in equipment have ties to on-site production processes. Failures are usually the culmination of a long chain of interconnected factors. You can use the IoT PM application to create tables and charts illustrating statistics sourced from sensors automatically. These arranged data highlight trends in malfunctions, revealing the actual nature of problems on-site.
- ***Report creation***: The data gathered from gateways can be processed, analysed, and organised into reports. These reports must be readable for a faster operator response.
- ***Alerts***: Before being sent to the application user, all potential harmful tendencies and dangerous signals must be discovered and highlighted clearly.

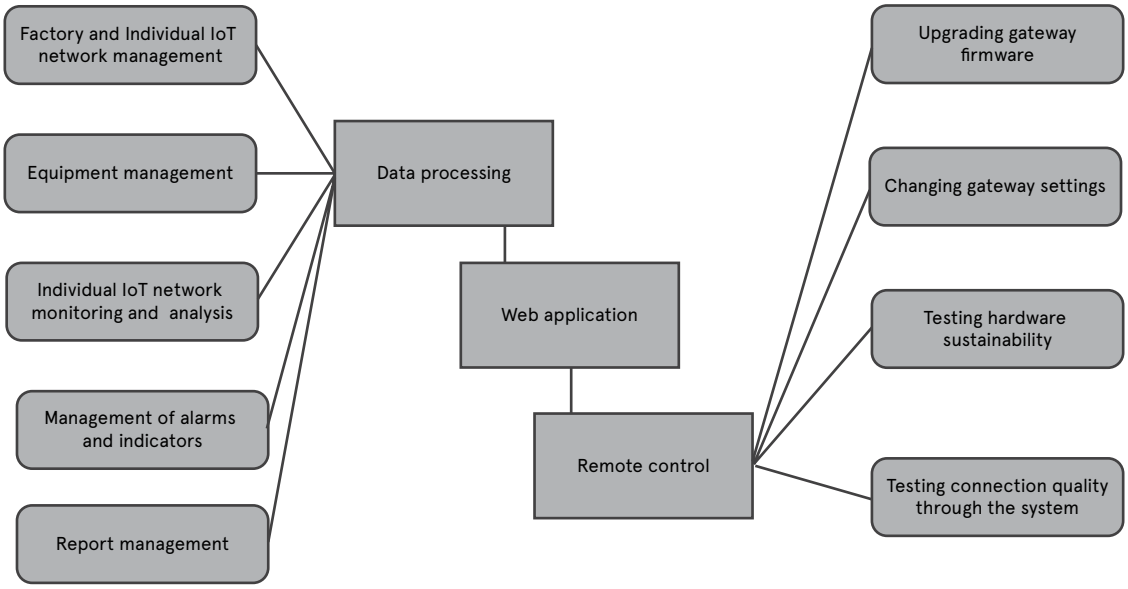


Figure 5: IoT PdM web application structure

PROCESSING INCOMING INFORMATION

You can quickly process information if you use an IoT PM Web application. Users can access a web application anytime and anywhere if they have an internet-connected device with a web browser. As a user, you enjoy the following options:

Factory running individual IoT network management

Companies running an IoT predictive maintenance application are mostly large multi-location enterprises. It is thus essential to have local IoT network management and factory management in place.

Equipment management

Since equipment maintenance is the core task of the IoT PdM system, the user must have granular control over equipment functions.

Individual IoT network monitoring and analysis

The analysis and monitoring of local IoT network data is vital for mapping the current condition of a business. Local network monitoring can help discover failure trends and factory-level problems.

Management of alarms and indicators

The user must receive vital and urgent messages as soon as the IoT PM Web application analyses information and identifies the trends.

Report management

Reports are readable and allow you to obtain a usable picture of a company's equipment situation. An IoT web application generally features standard overview reports (based on hard-coded rules) and advanced reports that cover historical data analysis. Cross-comparing various trends and data channels obtain additional industry-relevant insights.

Remote control

Inadequate equipment capabilities strongly restrict the actual scope of remotely controlling the IoT PdM system. Most sensors are primitive devices that can only communicate with gateways in a one-way fashion. Furthermore, the specifics of gateway architecture forbid the creation of software that can change sensor settings.

IoT PdM remote control options are usually limited to checking connection quality and gateway management. Remote application control uncorks multiple features, including gateway firmware up-gradation, changing gateway settings, and testing hardware sustainability. You can use the IoT system to improve connection quality and solve potential connectivity issues.

DATA ANALYSIS – EDGE & CLOUD COMPUTING WITH AI/ML

Adopting ML into PdM can ease many challenges that accompany maintenance activities, including unpredicted failures. ML integration will optimise maintenance work and avoid fatal consequences during unexpected downtime periods. The integration between ML and PdM can be classified into two classes: Supervised and Unsupervised.

In the Supervised class, information is available in the system database for failure prediction, whilst in the unsupervised class, information concerning maintenance requirements is absent. The system database contains high-level information concerning processing equipment. The system uses grouping and co-relation methods to identify the characteristic groupings within the processing data and then predicts ways to understand them. The nature of the maintenance policy influences the selection between both classes. For example, the supervised class can fit specific applications where it is possible to predict failure events between two maintenance cycles. Alternatively, another approach can be adopted, such as the unsupervised class.

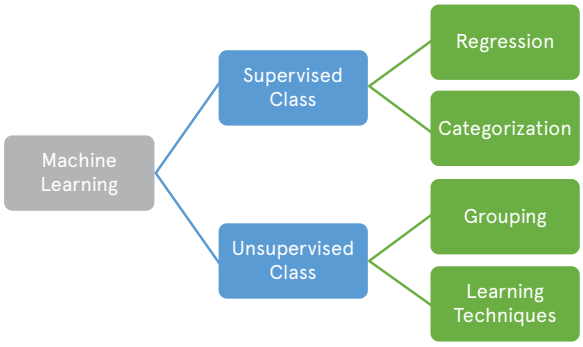


Figure 6: ML classes in PdM

How can ML be implemented?

PdM uses a data streaming mechanism from machine instrument devices (pressure, temperature, etc.) to determine the up-normal condition in machine behaviour and then predict the possibility of defectiveness during a particular timeframe. You can do ML modelling according to the following phases:

Data Collection

In the first phase, smart sensors collect data from possible failing parts inside the operating machine. You can achieve better results if you use a data set in the overall process. The data set demonstrates the machine's condition and behaviour during its lifecycle and captures the potential failures. Scientists can use data to develop PdM models.

Data Analysis

Combining the data streaming process with machine processing settings (such as set points, configuration, and historical data) achieves higher data prediction accuracy and better representation. These details collude from different sources, e.g., the enterprise management system.

Data Modeling

A comprehensive analysis of data streaming reveals the dependencies. Data modelling performs technical propositions related to possible failure indications and creates specific behaviours for the anticipated failure.

Data Prediction

Data modelling primarily detects failures and builds ML algorithms as the foundation for predictive models. The various steps in data prediction evaluate failure detection accuracy before the prediction models are finally approved.

PRODUCTS AND SOLUTIONS

Farnell offer a wide range of exciting products of predictive maintenance solutions that allow the user to monitor the health of various types of equipment. This equipment condition monitoring enables you to predict equipment failure. You can thus perform the necessary actions to avoid unplanned Downtime.

BANNER

STARTERKIT91200-CM-A - Banner Engineering - STARTER KIT, Condition Monitoring System is a cost-effective, end-to-end solution to integrate IIoT into the most common applications. The product makes it easy to monitor machine vibration and temperature, tank fill levels, system pressure, and temperature and humidity throughout a facility. It includes DXM1200 Gateway, AT&T Cellular Connection, and Cloud. It has a Local ISM radio band of 900 MHz frequency for up to 50 times more range than Bluetooth. And it also Connects as many as ten sensor nodes to scale and adapt the solution for specific needs.

Part number: STARTERKIT91200-CM-A

OMRON

The K6CM is the latest motor condition monitoring device that can quantify the status of three-phase induction motors. It has in-built EtherNet/IP & Modbus TCP communication to remotely monitor motor current, vibration & temperature, or insulation resistance depending on the model selected

Part number: K6CM-CICB200

OMRON

ZX series smart Sensors are Laser sensors with a built-in Amplifier. It has a CMOS Laser Sensor with a resolution of 0.002 mm, which is suitable for simple measurements.

Part number: ZX-TDA41 2M

KEMET
a YAGEO company

Vibration sensor made with proprietary Piezo Ceramic Material with built-in Amplifier.

Part number: VS-BV203-B

KEMET
a YAGEO company

The Honeywell SMART Arc Position Sensor is one of the most durable, adaptable, lightweight, and non-contact position sensors, enabling absolute position sensing with enhanced accuracy. SMART Position Sensors provide a self-diagnostics feature and data gathering for enhanced reliability and closed-loop feedback control.

This simple, robust, arc position sensor offers an IP69K sealed package, eliminating mechanical failure mechanisms, reducing wear and tear, improving reliability and durability, and minimising Downtime.

Part number: SPS-A100D-HAMS

OMEGA

OMEGA® ZW-ED is a wireless sensor/transmitter system that provides web-based monitoring of temperature, humidity, and barometric pressure. The radio is an IEEE 802.15.4 compliant transmitter operating at 2.4 GHz and designed to transmit up to 1000 m* (3280') to a ZW-REC coordinator.

Part number: ZW-ED

OMEGA

The OMEGA® iTHX-SD transmitter lets you monitor and record Temperature, Relative Humidity and Dew Point over an Ethernet network or the Internet with no special software except a Web Browser. The iTHX-SD serves Active Web Pages to display real-time readings, display charts of temperature, humidity, and dew point or log data in standard data formats for use in a spreadsheet or data acquisition program such as Excel or Visual Basic.

Part number: ITHX-SD-5-5D | IBTX-D/N | ITHX-D3-2

Laird CONNECTIVITY

The Sentrius™ IG60 brings all of Laird Connectivity's industrial wireless and IoT capabilities into one unique solution. Based on Laird Connectivity's 60-series and BL654, capture data from legacy serial (RS-232, 422, 485) industrial devices or Bluetooth 5 sensors, add edge intelligence and send to the cloud with 802.11ac Wi-Fi and global LTE Cat 1 (3G/2G fallback) wireless connectivity.

Part number: 455-00113

Life Is On Schneider Electric

ClimaSys DT USB data logger. DTHLog. 32000 samples. Type of measurement: Temperature - 40 at 80 °C. +/- 0.3 °C. Humidity: 5 at 95 %. +/- 2 %. Sleep mode is adjustable between the 30s/60s/120s to prolong battery life. Sleep mode is disabled. Software name: EffiClima. Monitoring and setup data logger. Firmware update by USB. Start/stop magnet key. 1 lithium battery 3 V size: CR2032. Clip-on support. 45.5 g. 111 x 39 x30 mm. Translucid colour. Protection IP54.

Part number: NSYDTEF32T

FLUKE.

The Fluke Ti450 provides the most advanced image quality in this camera series, offering the versatility and features needed for a thorough inspection, troubleshooting, and maintenance.

Part number: FLK-TIS60+ 9HZ

FLUKE.

The Fluke-830 is a Laser Shaft Alignment Tool to precision-align rotating shafts. It uses a patented single laser precision alignment system that provides accurate and repeatable measurement results.

Part number: FLUKE-830

OMRON

Omron FQ2 series have an all-in-one vision sensor with a built-in processor in the camera unit. Contains high-power lighting. It can receive PLC commands and send inspection results and measurements to the PLC. Images can also be transferred to a computer. FQ2 series cameras are IP67 water-resistant, HDR imagery, real colour, and other great features.

Part number: FQ2-D31

Industrial Shields

Raspberry Pi Panel PCs are fanless aluminum-cased Raspberry Pi-based HMI Industrial solutions for monitoring and controlling your manufacturing lines, machinery, or installations. TOUCH PANEL, 10.1", RESISTIVE, 1280X720P; Meter Display Type: Resistive Touch Screen; Display Size:263mm x 174mm; Display Resolution:1280 x 720 Pixels;

Part number: 003002000100 | 003002400100

SIEMENS

The KTP400 Basic are touch panel with additional buttons for simple applications. It has high-resolution dimmable widescreen displays with 64,000 colours and a touch and button function. It can be interfaced with various PLCs.

Part number: 6AV2123-2DB03-0AX0 | 6AV2123-2GB03-0AX0 | 6AV6 647-0AH11-3AX0 | CM-BF537E | 6AV2124-1QC02-0AX1

Life Is On Schneider Electric

Magelis SCU small touchscreen operator interface controller (HMI) is supplied with 24V DC, has a 3.5" colour TFT LCD display and 128MB EPROM. It also has 16 digital inputs, 10 digital outputs, 1 host + 1 mini-B USB port, 1 RS232C / RS485 port and 1 CANopen port.

Part number: HMISCU6A5

MITSUBISHI

High-performance mid-range Graphic Operation Programmable Terminal (GOT / PT) touchscreen HMI - Mitsubishi Electric (GOT2000 series GT25) - 5.7" 640x480pixels (VGA) TFT 65536 (65k) color display with LED backlight

Part number: GT2505-VTBD

Industrial Shields

RDBOX PLC family are Industrial Arduino PLCs based on the most popular open-source Arduino development boards, offering high-quality and high-performance industrial PLCs solutions with the flexibility to various sorts of sensors, data, and communication choices.

Part number: IS.AB20REL.HF+ | IS.MDUINO.21+ | IS.MDUINO.38AR+

ABB

Pluto is a cost-effective, powerful, compact safety PLC for all machine safety applications. Totally 46 I/O: 24 failsafe inputs + 16 non-failsafe outputs/failsafe inputs + 4 individually failsafe relay outputs + 2 individually failsafe transistor outputs.

Part number: 2TLA020070R1700

SIEMENS

The 6ES7214-1AG40-0XB0 is a Central Process Unit with EEPROM memory, 100kb work, and 4MB load integrated memories. It presents maintenance-free backup, PROFINET interface, and interference immunity against high-frequency radiation per IEC 61000-4-6 standard.

Part number: 6ES7214-1AG40-0XB0

DELTA
Smarter. Greener. Together.

Delta's MH300 series is a new generation of high-performance and standard compact vector control drives that inherit Delta's superior drive technology—all in a compact drive that is reduced 40% in size.

Part number: VFD1A5MS43AFSAA

Life Is On Schneider Electric

Altivar 320 variable speed drive can feed single-phase synchronous and asynchronous motors. Its compact form factor allows vertical stacking of drives inside machine frames. It works at a rated power of up to 1.5kW / 2hp and a rated voltage from 200V to 240V AC. Its robust design with IEC 60721-3-3 class 3C3 coated printed circuit boards allows to extend machine availability in harsh environmental conditions, for example, at ambient temperatures of up to 60°C, without the need for additional cooling.

Part number: ATV320U15M2C

ABB

The EF96 is a self-supplied electronic overload relay, which means no extra external supply is needed. It offers reliable and fast motor protection in the event of overload or phase failure.

Part number: EF96-100

ABB

ABBs SACE Preventive Maintenance for Emax and New Emax low voltage circuit-breakers.

Part number: 1SDA059763R1

SIEMENS

Zelio Logic SR2/SR3 range has a Bluetooth interface which is suitable for use in industry and building/service sector. It supports a 10m operating distance. It weighs around 0.015kg.

Part number: SR2BTC01 | SR3MBU01BD | SR2SFT01

BANNER

The DXMR90 Series Controller is an industrial controller within the Banner DXM family of controllers that consolidates, processes, and distributes data using industrial or web services protocols.

Part number: DXMR90-X1

Life Is On Schneider Electric

XPSMC32ZC is part of preventing XPCMC's configurable safety controller range. It is a configurable safety controller. It is supplied with 24 V DC and has 32 safety inputs. It conforms to Category 4 maximum conforming to EN 954-1/EN/ISO 13849-1, PLE safety level conforming to EN/ISO 13849-1 and SIL 3 level conforming to IEC 61508.

Part number: XPSMC32ZC

Weidmüller

The MA15D1SI is an AC and DC power Surge Protector that protects electronic equipment and computer networks against the effects of noise pollution-induced in power supplies.

Part number: MA15D1SI

Honeywell

The 060-6827-04 is a 2.5mA/32VDC bridge-based strain gauge sensor In-line Amplifier with 18 to 32VDC supply voltage and NEMA 4 housing.

Part number: 060-6827-04

nVent SCHROFF

The die-cast aluminium enclosure IP-Pro Alu EMC from nVent SCHROFF offers robust IP protection up to IP67, is EMC shielded and is shock, vibration and weather resistant. It can be configured for electronics with standardised or customer-specific form factors. The enclosure can be complemented by the expertise of nVent SCHROFF, which includes innovative solutions for PCB fixing, cable management and optimized cooling concepts.

Part number: 26880002 | 26880005 | 26880014

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