Predictive Maintenance Solutions
White Paper

Starting Predictive Maintenance Small for a Sustainable Future of the Manufacturing Industry

<Vol. 4> Latest trends in maintenance and examples of introduction of predictive maintenance

Preface

Predictive Maintenance Solutions Vol. 4 is a white paper regarding predictive maintenance.

While the previous Vol.1 to Vol. 3 were introductions to the features of OMRON's maintenance innovation solutions, which are the means to implement predictive maintenance, Vol. 4 provides answers to today's needs for predictive maintenance from the viewpoint of OMRON based on its analyses of the latest trends in maintenance from a broader perspective.

Study on the introduction of IoT and remote operation is also accelerating at FA manufacturing sites as a result of advances in digital technologies and environmental changes due to the COVID-19 pandemic. Particularly, maintenance sites where condition monitoring is given great importance, supporting operations with digital technologies can be highly effective. Predictive maintenance utilizing digital technologies reduces the time for "maintenance activities", allowing for the creation of time for "improvement activities" to create added value. OMRON believes that creating a cycle where humans and machines keep evolving will enable a "sustainable future for the manufacturing industry".

OMRON has also predicted the future of maintenance from another viewpoint, the future predicting SINIC theory which is the compass of its business management. Predictive maintenance has a beneficial effect on today's maintenance as society pursues spiritual enrichment by keeping an optimal balance between "individual and society", "humans and nature", and "humans and machines".

Predictive maintenance solutions are available from various makers, but OMRON's is an end-to-end on-site solution that enables small start since it allows data collection to analysis and judgment with on-site devices. This is a solution only OMRON can offer because of its lineup of more than 200,000 control devices and manufacturing know-how accumulated at its own factories. This white paper also describes some examples of actual introduction of predictive maintenance we hope you to go through.

We would be delighted if this white paper inspires people working in the manufacturing industry to consider introducing predictive maintenance.

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To the Era of Predictive Maintenance

Migration to predictive maintenance is advancing in the manufacturing industry due to advances in digital technologies and environmental changes due to the COVID-19 pandemic. The following describes what predictive maintenance is, provides its overview and background on why its introduction is advancing.

What is predictive maintenance?

Unlike conventional preventive maintenance where equipment is maintained by following a planned schedule, predictive maintenance is a new way of performing maintenance where monitoring devices monitor the equipment condition in real time 24/7 to detect and solve issues before a piece of equipment fails.Various companies are starting to provide as many solutions, but from the viewpoint of system configuration, they are either a cloud computing system, where a specialized SE analyzes the measured equipment condition data on the cloud to judge anomaly; or an edge computing system where the measured data is judged on site. With predictive maintenance, zero downtime due to unexpected post-periodic maintenance equipment failure is becoming realistic.Furthermore, It is also expected to reduce excess part replacement costs of preventive maintenance, resolve labor shortage, etc.

Background for the advancement of predictive maintenance

Global COVID-19 pandemic

Drs. Michael P. Brundage and Brian A. Weiss of the National Institute of Standards and Technology (NIST) of the USA point out in a report that due to the global COVID-19 pandemic of 2020, many factories are in need of establishing a factory operation system that allows them to continue manufacturing with fewer people while maintaining the required productivity as they have to reduce in-person work by relocating and reducing personnel.
In the report, they propose the use of Prognostics and Health Management (PHM) as a way to resolve this challenge. PHM is the generic name for new technologies and methodologies that aim to resolve management challenges, such as achieving zero downtime and controlling quality deterioration by detecting equipment failure and identifying the failure location, performing diagnostic tests, estimating remaining life, etc. Predictive maintenance is also a PHM technology.

Increased importance of PHM technologies

If in-person work is reduced by relocating and reducing personnel, the frequency of equipment maintenance may decrease. However, if the maintenance strategy is optimized by utilizing PHM, the equipment maintenance efficiency may be improved even with reduced personnel. For example, an automated monitoring system allows maintenance personnel to work on other tasks. Improving data analysis allows to reduce various maintenance workflow task times such as that of root cause analysis. Better failure prediction from data allows to reduce over-maintenance or under-maintenance, helping optimize the maintenance schedule. PHM helps to reduce the time and cost of maintenance by monitoring production in real-time, providing operation history of equipment and facilities, and predicting potential future failures. In 2016, American manufacturers reported an expenditure of 50 billion USD in maintenance, which represents a significant portion of their total operating costs. PHM can increase the equipment availability and reduce failure while maintaining the manufacturing process quality. By using PHM technologies effectively, manufacturers can decide the appropriate levels of reactive, preventive, and predictive maintenance to employ throughout their facilities. A small improvement in the implementation of PHM will help optimize these strategies, reducing unnecessary downtime, and saving expenditures.

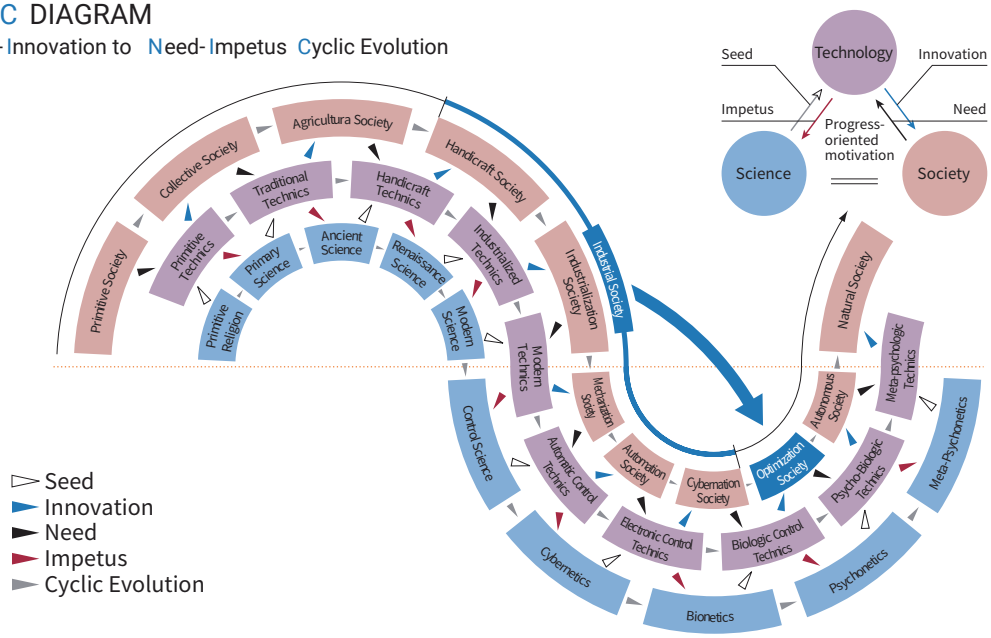
References:*Prognostics and Health Management to Improve Resilient Manufacturing*, Michael P. Brundage & Brian A. Weiss, October 23, 2020
https://www.nist.gov/publications/prognostics-and-health-management-improve-resilient-manufacturing

Predicting the future of maintenance from the SINIC theory

Let's change the viewpoint a bit and predict the future of maintenance based on the SINIC theory, the compass of OMRON's business management. The "SINIC theory" is a future prediction theory presented at the International Future Research Conference in 1970 by Kazuma Tateishi, the founder of OMRON. Presented in the midst of Japan's rapid-paced economic growth, before PCs and the Internet even existed, the theory draws a highly accurate picture of society up to the middle of the 21st century, including the appearance of the Information Society.
SINIC stands for Seed-Innovation to Need-Impetus Cyclic Evolution. According to the SINIC theory, science, technology and society share a cyclical relationship, mutually impacting and influencing each other in two distinct ways.In one direction, scientific breakthroughs yield new technologies that help society to advance.
In the other direction, social needs spur on technological development and expectations for new scientific advancement. Thus, both of these factors affect each other in a cyclical manner, propelling further social evolution.

SINIC DIAGRAM

Seed-Innovation to Need-Impetus Cyclic Evolution



Predictive maintenance applied to "optimization society"

In this theory, the present is defined as an optimization society. Optimization society is a society that pursues spiritual enrichment by keeping an optimal balance between "individual and society", "humans and nature", and "humans and machines". The introduction of predictive maintenance may be one of the trends to achieve that in maintenance sites. OMRON believes that introducing predictive maintenance by making full use of digital technologies will allow for "reduction in workload due to unexpected maintenance", "attention to the environment by reducing disposal", and "sustainable human and machine development" to help shape spiritual values such as the pursuit of spiritual wealth or new ways of living.

	Past (Up to 2005)	Present (2005 to 2025)	Future (From 2025 onwards)
Phase	Industrial society	Optimization society	Autonomous society
Society	A society that achieves material wealth through mechanization, automation and information	A society that pursues spiritual enrichment by keeping an optimal balance between "individual and society", "humans and nature", and "humans and machines"	A mature society that pursues wealth of the "spirit" where individualism coexists with cooperation to enjoy life's pleasures
FA manufacturing site	Factories focused on mass production by using PLC	Factories capable of high-mix low-volume production by using robotics and AI	Energy-saving smart factories capable of resolving labor shortage and detect defective products by using digital technologies
FA maintenance site	Reactive maintenance/preventive maintenanc	Predictive maintenance	Prescriptive maintenance

Issues of the Preventive Maintenance and Benefits of the Predictive Maintenance

Preventive maintenance, which has been the mainstream maintenance method, has various benefits such as its low initial cost and low technical barrier. However, it has many issues when the future sustainability of the manufacturing industry is taken into consideration, such as labor shortage, social challenges of skill transfer, and reduction of disposal as typified by the SDGs. The following sections compare the issues of the preventive maintenance with the benefits of the predictive maintenance.

Conventional preventive maintenance and its issues

In the manufacturing industry, many manufacturers use the so-called “Time Based Maintenance” method, which consists of periodic inspection and planned part replacement. Since parts are replaced periodically based on time, it has the benefit of not only reducing equipment failures to some extent, but also allowing for planned maintenance unlike a reactive maintenance performed after a failure occurs.Furthermore, to improve efficiency, preventive maintenance is combined with condition-based maintenance by a skilled maintenance engineer who at the time of a periodic inspection checks the equipment condition and judges whether or not to replace parts based on his/her skills and experience. Although preventive maintenance has improved over time, the following issues have arisen.

Increased replacement part cost

Increasing the maintenance quality increases the maintenance cost since the costs of parts, replacement, part stocking, and disposal add up to that of the replaced parts that have not broken yet.

Downtime prior to periodic inspection

Risk of sudden equipment stoppage (downtime) remains even if the frequency of periodic inspection is increased.

No time for other than inspection and maintenance

Since periodic inspection and maintenance are performed using limited human resources, they have no time for other value-adding work such as operational improvement.

Problems in transferring skilled maintenance engineers’ skills

Problems in transferring the skills and know-how of skilled maintenance engineers who perform inspection based on experience and intuition are that it takes time, or there are no successors due to labor shortage.

Reference: National Institute of Standards and Technology (NIST) survey results

The following shows estimated “maintenance costs”, “preventable losses”, and “benefits of advanced maintenance strategies” for the American manufacturing industry in 2016 drawn from the results of a survey by the NIST.

Costs and losses for the year 2016

According to “Economics of Manufacturing Machinery Maintenance” (June 2020) by Douglas S. Thomas and Brian A. Weiss, yearly equipment maintenance costs amount to 74.5 billion USD while preventable losses, with loss of sales opportunity as the main component, amount to 119.1 billion USD.In addition to the estimated perceived benefit of 73.8 billion USD, the introduction of predictive maintenance also generates invisible benefits such as quality improvement.

References:

NIST Advanced Manufacturing Series 100-34, *Economics of Manufacturing Machinery Maintenance*, Douglas S. Thomas, Brian A. Weiss, June 2020

https://www.nist.gov/el/applied-economics-office/manufacturing/topics-manufacturing/manufacturing-machinery-maintenance

https://nvlpubs.nist.gov/nistpubs/ams/NIST.AMS.100-34.pdf

■ Maintenance costs: 74.5 billion USD in total
- Machinery maintenance expenditures: 57.3 billion USD
- Additional expenditures due to faults and failures: 16.3 billion USD
- Costs for inventory: 0.9 billion USD

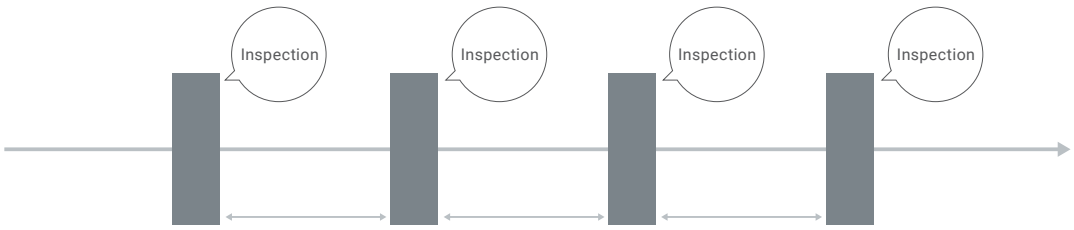
■ Preventable losses: 119.1 billion USD in total
- Due to downtime: 18.1 billion USD
- Due to defects: 0.8 billion USD
- Due to lost sales from delays and defects: 100.2 billion USD
- Estimated 16.03 injuries and 0.05 deaths per million employees

■ Perceived benefit of adopting predictive maintenance: 73.8 billion USD in total
- Downtime reduction: 6.5 billion USD
- Increased sales 67.3 billion USD
- Invisible benefits such as quality improvement

Predictive maintenance is the solution to preventive maintenance issues

Timing of inspection in predictive maintenance

Preventive maintenance (Time Based Maintenance)



In preventive maintenance, inspection is performed in a planned manner, independently of equipment failure.
“Time Based Maintenance” causes excess part replacement and inspection expenditures.

Predictive maintenance (Condition Based Maintenance)

In predictive maintenance, inspection is performed when a sign of failure is captured.
“Condition Based Maintenance” does not cause unnecessary part replacement and inspection expenditures.

Benefits of predictive maintenance

Reduction of excess part replacement costs

Since predictive maintenance is a Condition Based Maintenance, it can reduce the frequency of periodic inspections and excess part replacement expenditures. It allows for planning maintenance when monitoring devices capture signs of failure.

Reduction in risk of equipment downtime

If monitoring devices can capture signs of failure, improved productivity can be expected since the possibility of curbing unexpected post-periodic inspection equipment stoppages (downtime) increases significantly.

Maintenance efficiency improvement with limited human resources Ability to create surplus time

The frequency of periodic equipment inspection decreases since equipment is monitored 24/7 by monitoring devices, improving maintenance efficiency even with limited human resources. This enables the creation of surplus time that may be used for other tasks such as improvement activities.

Maintenance of skilled engineers even with little experience

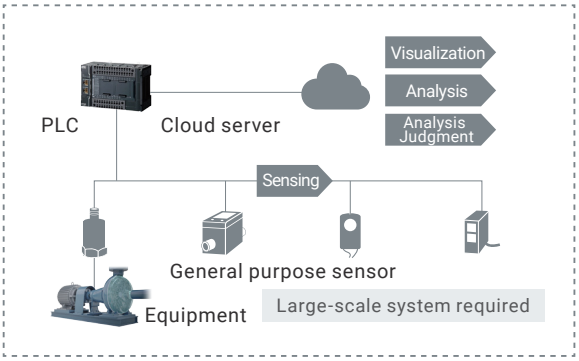
Since equipment condition is quantified by monitoring devices utilizing digital technology, clear criteria can be prepared so that maintenance engineers with little experience can also provide maintenance similar to that of skilled maintenance engineers.

Lowering the hurdle to introduction by allowing small start

OMRON's End-to-end On-site Predictive Maintenance Concept

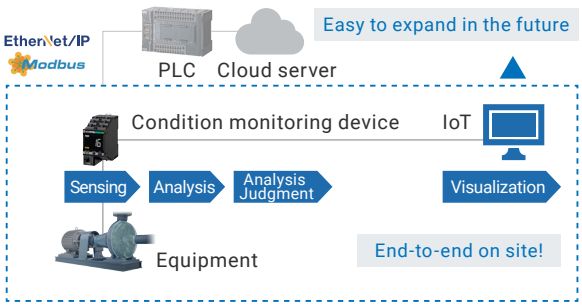
There are two major reasons why the introduction of predictive maintenance is slow although its benefits are understood. The first is its huge initial cost and manpower including the building of skills and know-how, and the second is that its return on investment is not so obvious. OMRON's condition monitoring devices allow for small start with little manpower and little cost since they do not require system design and data analysis as they collect, analyze, and judge data on site. In addition, small start allows confirmation of its return on investment at an early stage to make a decision on its full-fledged introduction. OMRON's condition monitoring devices allow for small start with little manpower and little cost since they do not require system design and data analysis as they collect, analyze, and judge data on site. In addition, small start allows confirmation of its return on investment at an early stage to make a decision on its full-fledged introduction.

FROM Predictive maintenance system utilizing PLC and cloud



Hurdle to introduction is high because of technical and organizational barriers; requires difficult analysis as well as IT/OT integration.

TO End-to-end on-site predictive maintenance system utilizing OMRON's condition monitoring device



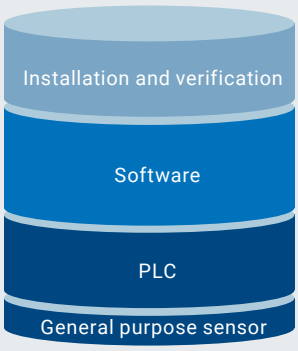
Hurdle to introduction is low because analysis to visualization is completed in the maintenance site. Furthermore, expansion for deployment is also easy. On-site verification of the return on investment serves as a strong argument for full deployment.

Image of costs to introduce predictive maintenance utilizing OMRON's condition monitoring device

OMRON's suggestion is to start small with an application with high failure frequency

Company A : Cloud system

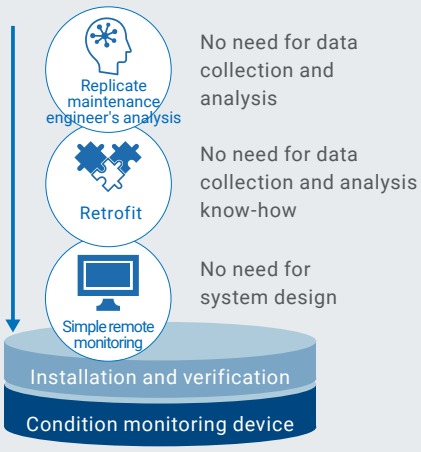
The amount of data becomes huge, making analysis difficult.Requires cooperation among Production Dept., Information Dept., subcontractors, etc., increasing the costs of both manpower and operations (costs of communication, license, etc.).



Company B : PLC-based system

General FA device configurations require technical prowess to combine sensors and PLC, or increased costs if outsourced.

All-in-one, three functions in on-site components to enable an easy start



OMRON : Condition monitoring device system

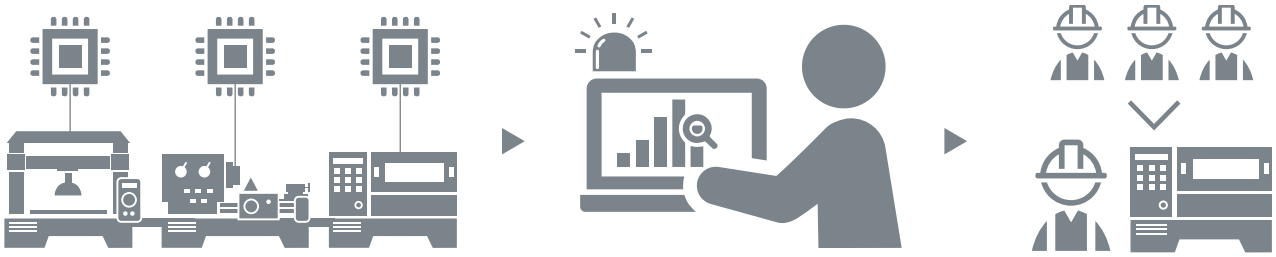
All remote maintenance functions in one device. OMRON's solution can be started small at a site level for a particular application with high failure frequency such as fan and pump motors.

Making it possible with OMRON's predictive maintenance

Maintenance innovation by "condition monitoring" compatible with the new normal

The social trend of DX by technological innovation is rapidly accelerating as a result of restrictions on movement due to the COVID-19 pandemic. Following the above-described end-to-end on-site concept, OMRON promotes condition monitoring based on the new 3 GEN principle, which remains true to the original but is refurbished to fit the needs of today: properly monitoring and analyzing GENbutsu (actual things) using data, understanding and assessing the GENjitsu (reality) from remote locations, and working at the GENba (actual site) when appropriate. With advanced component-level on-site condition monitoring, OMRON offers solutions that you can easily get started tomorrow.

Predictive Maintenance- take action when necessary



Equipment monitoring
Digitization

Abnormality Alarm
Remote Monitoring

On-site maintenance
Maintain as necessary

Extra value brought about by OMRON's maintenance innovation solutions

Benefits of predictive maintenance and results of maintenance are generally quantitative, such as prevention of losses due to downtime or cost reduction due to improved maintenance efficiency. However, the "end-to-end on-site" concept, which is a feature of OMRON's condition monitoring devices, generates values closer to site engineers. They may also generate the following extra values important to the company management.

Safety

Automating the maintenance at risky locations such as inspections at places of high altitude, high voltage, or high temperature allows for reducing the risk of employee accidents. OMRON's condition monitoring devices enable maintenance automation as they can be installed at anytime by retrofit.

Education

Skill transfer is an important point in a company's capability.With OMRON's condition monitoring devices, technical training can be performed efficiently as they digitally reproduce the skills of skilled engineers.

Trust

Delay in production and/or delivery due to production line stoppage, accident and/or disaster such as fire and poisonous gas leak lead to the loss of trust of neighbors and society as a whole.Constant remote monitoring by OMRON's condition monitoring devices allows for early detection of anomalies.

OMRON's Condition Monitoring Devices Introducing Predictive Maintenance in Three Steps

STEP1 "Easily" select the target of monitoring from application examples

Building a large system by installing an excessive number of sensors is inefficient from the viewpoint of both cost and manpower. Starting by setting priorities and narrowing down the targets to monitor is more effective.Application examples are available on OMRON's website. Use them to easily select your target of monitoring.

STEP2 "Easily" install the dedicated sensor to the existing equipment

Sensors can be installed with minimum effort, without the need for time-consuming and costly major remodeling.

Groups of on-site retrofittable sensors

Current sensor

Installable by clamping, without disconnecting the existing wiring.

Vibration sensor

Installable by using a magnet or glue, without modifying the equipment.

Temperature sensor

With a magnet, installable to the existing equipment by just placing it on.

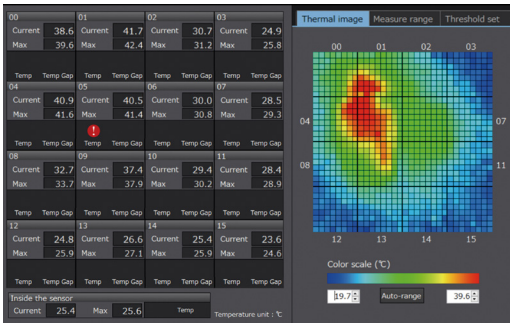
STEP3 "Easily" visualize using the dedicated tool

The collected data is analyzed by a proprietary algorithm in the component to output the results to a PC. A simple monitoring system can be built using a dedicated monitoring tool to easily monitor the equipment condition 24/7, either on site or remotely.

Automatic analysis of collected data by edge computing (within the condition monitoring device)

EtherNet/IP

Modbus



With support for industry-standard communication standard, can be easily connected to a PC or configured into a system.

With dedicated tools for setup and monitoring as accessories, can be easily started using.

Evolution of OMRON's condition monitoring device for a sustainable manufacturing industry

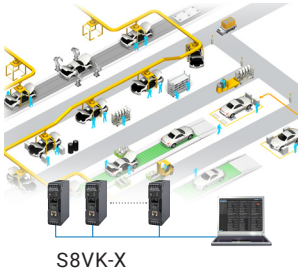
Today Small start of predictive maintenance in a specific application

OMRON proposes to start predictive maintenance small, from highly important pieces of equipment. Try different devices, services and support.

K6CM
motor condition monitoring device

K6PM-TH
Thermal condition monitoring device

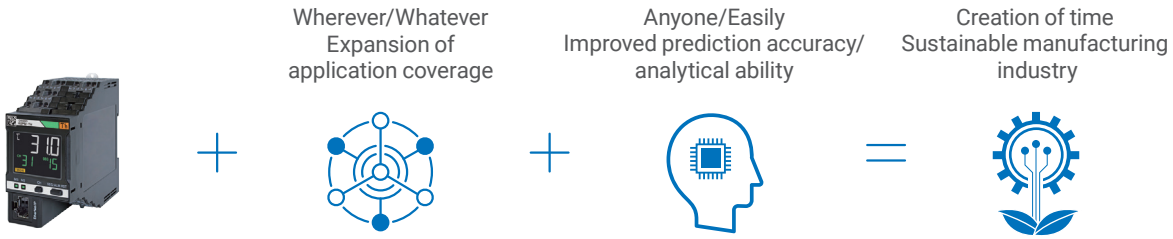
S8VK-X
Power supply monitoring device



K7GE
Insulation resistance monitoring device

Tomorrow Continuously create added value by using the time created

Introducing predictive maintenance into the entire factory while incorporating various technologies, such as DX and AI, contributes to keeping maintenance activities to a minimum and creating time for improvement activities (corrective maintenance/maintenance prevention) that generate added value to support sustainable manufacturing.



Examples of Introduction of Predictive Maintenance

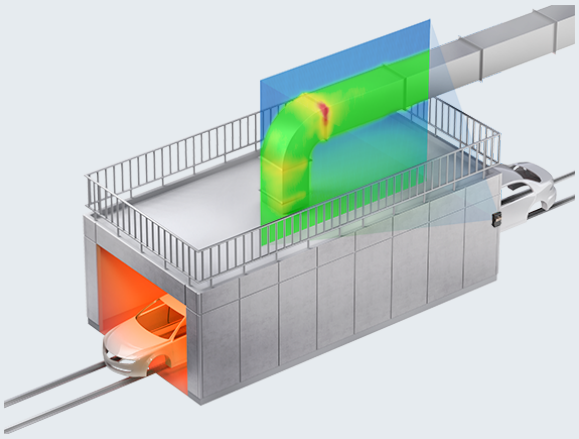
After releasing its first condition monitoring device in 2017, OMRON has also been expanding its product lineup. Used by more than 1700 companies, they are contributing to our customers' maintenance innovation. The following are examples of introduction explaining the background, introduction process, final decision, and the result of its introduction.

Automobile industry

Predictive maintenance against heat leak accidents due to cracks in the paint drying process air duct

Background of the issue

Advancing automation was making early on-site detection of anomaly increasingly difficult since some areas had no on-site personnel. Amid such circumstances, the process had to be stopped due to a heat leak from the air duct. The air duct carries hot air of 500 °C or higher. Therefore, any hot air leak may lead to serious accidents such as fires. Inspecting the duct as frequently as desired is not possible since it runs along the ceiling. The company was looking for a permanently-installable condition monitoring device capable of monitoring 24/7 to enable both improvement of maintenance efficiency and reduction of fire risk.



Application: Paint drying process air duct

Introduction process

A single condition monitoring device was installed on the existing equipment in operation to verify its effectiveness. The results were expanded across multiple factories.While each factory was pursuing their own study, a decision was made to introduce it as a remote monitoring system in a new factory being set up. A predictive maintenance system utilizing OMRON's condition monitoring device was introduced as part of the IoT implementation in the factory.Hereafter, their plan is to gradually introduce it to existing equipment in other factories while also assessing its effectiveness.

Effectiveness/Evaluation criteria

Since it can be started small and future expansion is easy, the company started by introducing it using the remaining of the IoT implementation budget for the factory under construction.If the condition monitoring yields real results, expansion will be carried out by securing budget as needed while more are installed.

Extra value

Fire may lead to inability of fulfilling the supply responsibility to consumers, or decline in the corporate brand image in association with its governance system. Condition monitoring is worth introducing also from the viewpoint of keeping the trust of neighbors, consumers and subcontractors.

1700 companies

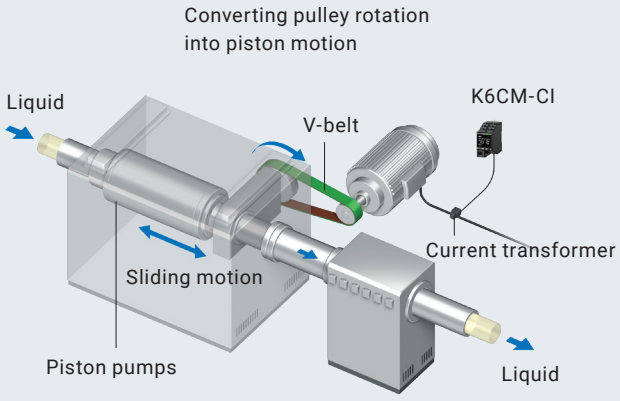
Number of OMRON's predictive maintenance customers

Food industry

Predictive maintenance against quality deterioration due to wear of the packing inside the homogenizer

Background of the issue

A homogenizer to homogenize fatty and liquid components is essential to guarantee quality. Deterioration in particular of the packing, a consumable inside the homogenizer, is an anomaly that affects quality but as yet cannot be detected in any way.For that reason, the company has been performing early periodic maintenance but since there was always the risk of quality deterioration in between periodic maintenance, as well as the issue of increasing maintenance cost, it was looking for a predictive maintenance solution capable of detecting condition changes quantitatively.



Application: Homogenizer

Introduction process

To resolve a company-wide issue affecting quality, a cross-organizational IoT team studied predictive maintenance solutions. OMRON's solution was deployed to each factory as the team saw potential in it. While production site personnel was busy with preventive maintenance amid labor shortages, condition monitoring with OMRON's predictive maintenance solution was achieved immediately by retrofit, allowing for easy effectiveness verification.

Effectiveness/Evaluation criteria

The adoption of OMRON's solution was decided based on three points: possibility of visualizing the deterioration status of the packing inside the homogenizer; the ability of handling at the edge level on site; and possibility of operating more economically than the cost of losses with preventive maintenance.

Extra value

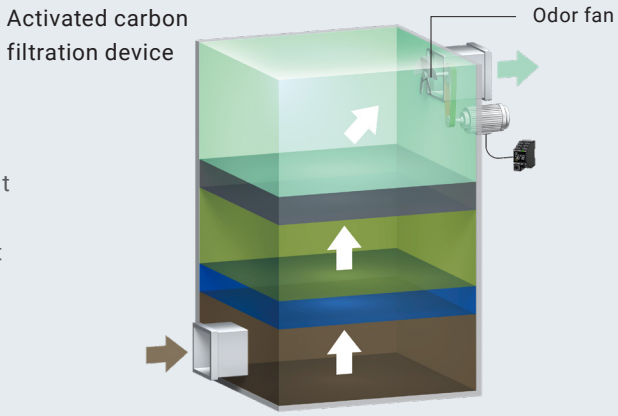
In the food industry, the quality of the food a company produces provides security to consumers and leads to improved corporate brand image.

Digital industry

Predictive maintenance against quality deterioration due to exhaust gas treatment device wear

Background of the issue

The company was looking for a remote predictive maintenance solution to implement a smart factory capable of dealing with the ever worsening labor shortage. They focused on the exhaust gas treatment device (scrubber) since according to their past quality trouble experience, it was the most important piece of equipment managed. They studied signs of failure of the cooling water circulation pump and air conditioning fan system which have great impact on production.They also looked for a solution that could be deployed to other pieces of equipment.



Application: Scrubber (exhaust gas treatment device)

Introduction process

The company easily confirmed its effectiveness since condition monitoring could be started also by busy on-site maintenance personnel just by installing sensors and turning on the power.Furthermore, normally, introducing a predictive maintenance system requires the design of the algorithm to detect anomaly. OMRON's end-to-end on-site solution also meant workload reduction for the new factory system integrator (SI).

Effectiveness/Evaluation criteria

Deciding factors for adopting OMRON's solution were: efficiency of verification due to its capability of installation by retrofit, and easiness of future expansion due to being an end-to-end on-site solution that reproduces the maintenance of skilled maintenance engineers.

Extra value

Avoiding unexpected production line stoppage and complying with the supply responsibility enabled the company to increase the trust of users and consumers.

1700 companies

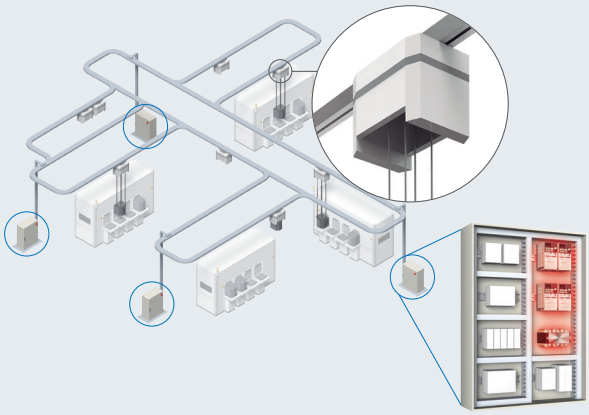
Number of OMRON's predictive maintenance customers

Digital industry

Predictive maintenance against unexpected stoppage in automated transport system

Background of the issue

Unexpected stoppage of an automated semiconductor transport system leads to a great loss of opportunity due to delay in the production schedule, delivery trouble, etc. After a system stoppage due to overheat protection as a result of a temperature rise in the automated transport system control panel, periodic temperature check by maintenance personnel was put into place as a temporary measure.However, the risk of unexpected stoppage remained as the control panel in the clean room could not be inspected as frequently as desired since it was very time-consuming. They were looking for a reliable solution capable of monitoring a large area 24/7 without any omission.



Application: Overhead hoist transport (OHT)

Introduction process

The facility design group launched a project to study OMRON's solution. They simulated an actual anomaly to evaluate the time from receiving an alarm from the condition monitoring device until the maintenance personnel arrive to the site to take measures. In the evaluation, they confirmed that the condition monitoring device provides sufficient detection accuracy and time to prevent unexpected stoppages. The results were also spread to other factories to study its introduction.

Effectiveness/Evaluation criteria

The customer was verifying many solutions simultaneously. They scored capital investment costs, data analyst training cost, risk of missed detection, etc. to make a comparison. OMRON's solution was adopted as they also considered the "ability to evolve into a sustainable maintenance activity in a short period of time", such as easiness to study and build a predictive maintenance system.

Extra value

Maintenance has relied on humans since abnormal conditions were determined based on know-how and intuition. However, the company found OMRON's solution valuable also from the viewpoint of skills and know-how transfer since with OMRON's algorithm, anyone who understands it can analyze and make judgments in the same way.

Why not try OMRON's predictive maintenance devices?

To monitor the condition of 3-phase induction motors and peripheral equipment

To monitor the temperature status of devices and equipment

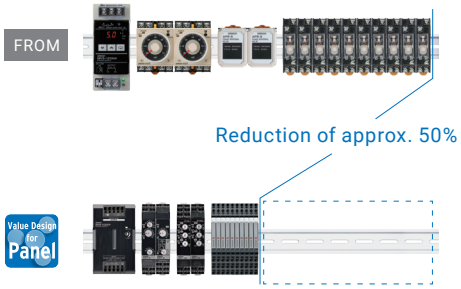
To monitor the trend of insulation degradation in motors

To monitor the voltage, current, and remaining life of switched-mode power supplies

For customers without space for installing a condition monitoring device

Panel Solution

OMRON's panel solution products allow for making the existing control panel compact and mounting the predictive maintenance device in the space made available.



Condition monitoring device to add

Push-in Plus terminal blocks make retightening unnecessary, reducing the inspection workload

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