Predictive maintenance as an intelligent service in Industry 4.0

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Abstract: *Current trend of digitization offers a whole new approach to providing maintenance services. From sensors to cloud, production data is a unique opportunity to declare a real added value for maintenance work. Predictive maintenance is one of the key elements of the Industry 4.0 concept associated with the emerging digitalization of industry. The purpose of predictive maintenance is to predict the status of production equipment and detect potential failure. Practical implementations of predictive maintenance are already found in a number of industrial companies, either in the partial form of maintenance according to technical condition, or in diagnostic maintenance, and in the form of actual equipment wear prediction and planned maintenance. Predictive maintenance extends routine health monitoring to look into the future of machines, offering options to increase efficiency and reduce overall operating costs. First part of this article presents the term of maintenance, its definition and role in the company. Also, various types of machinery maintenance types are presented. Next part of the article focuses on predictive maintenance.*

Key words: predictive maintenance, Industry 4.0, services, intelligent, CMMS

1. Definition of Maintenance

In literature there many different definitions about Maintenance: Swedish standard SS-EN 13306 define it as a "Combination of all technical, administrative and managerial actions during the life cycle of an item intended to retain it in, or restore it to, a state in which it can perform the required function" ((Maintenance Terminology, 2001)).

As maintenance evolved, its role in the company changed gradually. It used to be mostly about the need to repair damaged machines, but today, on the contrary, the need for prevention of disorders and accidents on the machinery is the most important aspect of maintenance, while ensuring their efficient, reliable and safe operation. Main maintenance goals are to achieve maximum productivity and further optimization performance of the machine and to ensure safe operation of the device at least throughout its life expectancy. Increase machine availability with minimal downtime, reduce downtime ideally to zero and the process of continuous improvement are methods of securing these goals. (LEGÁT, 2013.)

Over time, the idea and the need to create a department that will deal solely with the management and maintenance has evolved as a business philosophy. Like others, this department will use process management, planning, available information technology and other leadership tools such as teamwork, etc.

Maintenance has, according to terminology and standards, a direct link to reliability and thus to readiness, under which maintainability and maintenance is ensured. Reliability is evaluated by various indicators, maintainability is described by diagnostics, reparability and ease of maintenance, including lubrication, cleaning and adjustment. Maintenance supportability is then more likely to be maintenance management's ability to acquire and provide resources for the function of maintenance department and its activities. (Peter Poór, 2014)
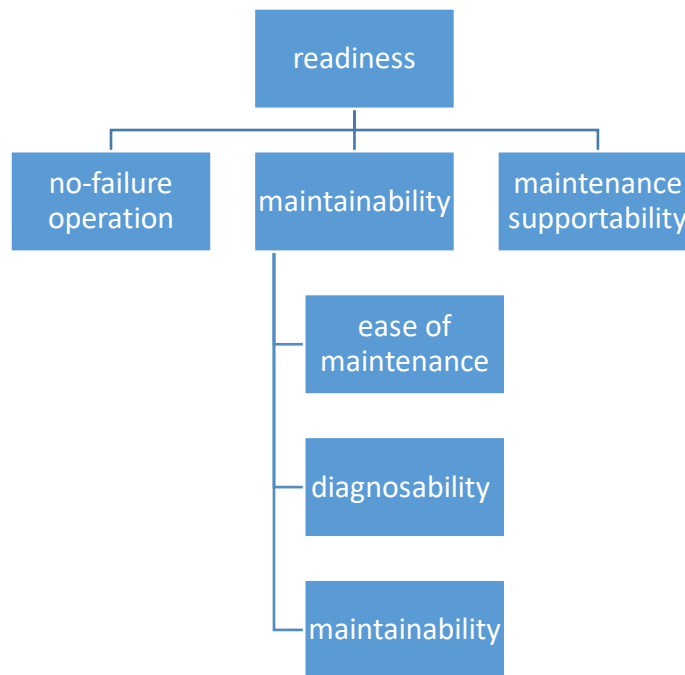
Figure 1: Reliability Relationships (Česká společnost pro jakost, 2014)

Maintenance is already associated with the time when people began to make tools. First, it was a necessity repair tool that has gradually evolved into the need to work with clean and functional tools. Up to World War II did not place any emphasis on maintenance, as the machines were oversized and thus virtually trouble-free, possible failures were handled operatively until they occurred. Until the end of the 1940s we are talking about the 1st generation, characterized by so-called after-maintenance failure or reactive maintenance. With increasing demand and mechanization of production during World War II, the machines became more defective and people began to monitor more closely and examine their lifespan, failure rate and downtime. We get to the 70's and the so-called 2nd generation characterized by preventive maintenance with regular inspections, inspections and repairs. John Moubray's third generation is the generation of predictive maintenance, when not only the need to plan and periodically check and repair the machine grew, but also to prevent machine failures by estimating its future status by tracking it or based on previous experience. It is the period of the greatest development of various failure analyzes and risks (Moubray, 1997)

In this article we are talking about the 4th Generation of Maintenance associated with the 4th Industrial Revolution and Industry 4.0.

2. Types of maintenance

The types of maintenance developed gradually depending on the circumstances. The oldest type is after maintenance failure, or reactive maintenance, whose advantage is the use of the machine's useful life. On the contrary, the disadvantage is unplanned breakdowns and possible long machine downtime. There are big financial losses and consequent costs of repair, purchase of parts, possibly safety risks associated with the disorder. This type is divided into immediate or delayed maintenance.

As the machines began to be larger and more complex, their operation became more expensive and a maintenance was developed with regular inspections and repairs, called preventive, which goal is to prevent the failure. Regular inspections and revisions need to be defined, either by frequency of disorders expressed e.g. time to failure, etc., or are specified by the manufacturer. Also basic perceptions such as hearing, sight and touch of machine operator are used, where he can guess from experience that there is something wrong with the machine. With increasing effort to prevent unexpected failures and optimize maintenance costs following two types of maintenance were developed, predictive and proactive maintenance (Dhillon, 2002).

The basic principles of predictive maintenance are diagnostics and condition monitoring equipment. By monitoring, long-term monitoring of certain machine parameters is considered and diagnostics, then a comprehensive evaluation of the condition of the machine and equipment. Because the machine it is not repaired at regular intervals but only if the repair is required by the technical condition, which we find out just by applying these principles. The basis is the right information in the right time for spare parts

to be ordered in time, machine downtime planned, secured personnel to repair or replace equipment parts. Not only will we increase the life of the machine and its safety, prevent accidents and accidents, but also optimize farming spare parts, especially to reduce the storage (Mobley, 2002)

Proactive maintenance goes even further and expands preventative maintenance. Its basis is the identification of the causes of failure by means of technical diagnostics. Proactive maintenance is defined as follows: Measurements that detect the initiation of degradation of the mechanism and thus allow the problem originators to be removed or controlled before each significant deterioration of the device condition. Proactive maintenance differs from preventive by staying maintenance needs on the current status of the device rather than on a scheduled schedule. Preventive maintenance is time-based (Fitch, 2013)

Reliability-based maintenance is "a procedure to establish maintenance requirements for any physical asset in its operational context." The reliability-oriented maintenance methodology addresses basic issues not covered by other maintenance programs. Recognizes that not all equipment in an enterprise has the same importance that the construction and operation of the equipment is different and that different equipment is more likely to cause a fault for different reasons. It also takes into account the fact that the facility does not have unlimited financial and personnel resources and needs to be identified and optimized (Jardine, 2006).

Total Productive Maintenance - TPM - is the state-of-the-art philosophy, organization of machine maintenance in the production process, with a significant share in increasing productivity and eliminating costs. It is a set of maintenance activities performed throughout the lifetime - the existence of machines in order to improve their accuracy, reliability, performance and efficiency as well as reducing all possible losses. It is part of the company's production philosophy, it includes all the departments of the company and represents the interconnection of maintenance and production with the technical security of the construction and technology (Sullivan, et al., 2004) The basis of the TPM philosophy is, on the one hand, to increase the efficiency of equipment and to reduce maintenance costs and losses due to downtimes, on the other hand, on the basis of good communication between the operator and the maintainer.

Two approaches must be accepted to achieve the ideal conditions:

1. Design of optimum conditions for human-machine system. To make the most efficient use of the device, it is necessary to know the ideal assumptions for the operation of each machine component as well as the values that represent the top performance of the machine. It is the duty of man in the man-machine system to maintain these prerequisites, the most important element in this system is still human. The system must be modified by him.
2. Improve the overall quality of the work environment:
   • changing the behaviour of people,
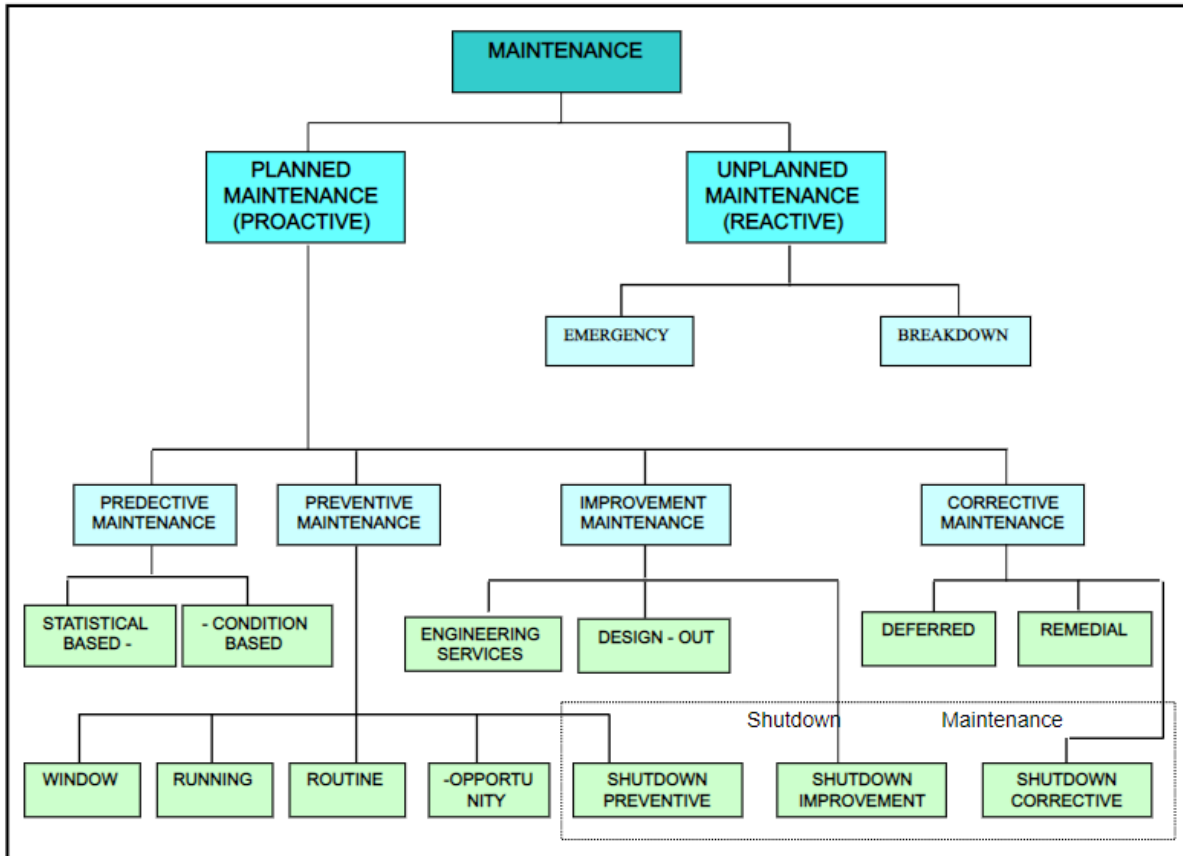   • change of equipment - the position of employees changes with it.

Figure 2: Types of machinery maintenance (Project Services Co. - Quatar, 2017)

Production machines, equipment and tools will always be subject to wear and the need for maintenance. From the first industrial revolution, the maintenance was done only when the machines stopped or they could not work, is the type of maintenance called Corrective Maintenance. A lot of parts are damaged by the application of strains and so it is possible to understand approximately their duration and so it is possible to fix, before the fault, maintenance intervals. In this way one company needs to find a trade-off between these types of maintenance: the fault should increase costs for delayed shipment, but, at the same time, too much maintenance means also big costs. In the last years, for these two reasons, the company aim is to introduce a maintenance strategy that can understand the need of maintenance before a breakdown. The arrival of industry 4.0 introduces and develops a lot different methods to do maintenance.

3. Predictive Maintenance

The current trend of digitization offers a whole new approach in providing maintenance services. From sensor to cloud, data represents a unique opportunity to declare a real added value for maintenance work. The term predictive maintenance with label 4.0 appears more and more on the market.

Predictive maintenance is not a new concept. Today, each maintenance technician understands that it is not enough to rely solely on reactive maintenance or implement a preventive maintenance plan (Koukolík, 2017) However, the introduction of a predictive maintenance program has had a number of pitfalls over the years, which are gradually being eliminated. Also, you need to remember the real consequences of the transition to predictive maintenance, where not every behavior of every machine makes sense to predict.

Predictive maintenance is an analytical approach that allows you to predict when production equipment fails and prevent timely and effective maintenance. However, it can go further and provide information, on the basis of it is possible to "tune" the device gradually and to reduce or even eliminate the failure rate. Preventive maintenance also includes factor evaluation affecting product quality and implementing measures to optimize it.

Predictive maintenance is based on the continuous integration of many internal data sources from sensors and sensors, control units, CMMS systems, maintenance reports, warehouse management or

ERP. Furthermore, it is possible to integrate information with this data on the external environment and external influences (such as weather, outdoor temperature and humidity, or operator experience and education). The subsequent analysis is based on a number of sophisticated statistical methods such as the Bayesian network, Weibull distribution, neural networks, linear and logistic regression, time series analysis, C5, CHAID, QUEST, Kaplan-Meier graph and Kohonen networks. (Dolphin Consulting, 2015) These methods can reveal hidden anomalies and tendencies to failures and determine which technologies and operational processes are at greatest risk of failure, finding problems before they actually happen, it allows less resources to be deployed more economically maintenance while maximizing the machine's operating time, improve quality, strengthen processes in the supplier system, and ultimately increase customer satisfaction. Organization using predictive analysis generally has a higher performance than those that rely solely on emotion and experience. Not only do they reach higher growth and more efficient cost management, but also take timely corrective action to reduce the risks they can threaten their plans.

Situation in Czech Republic is, that despite the frequent economic disadvantages and major pitfalls, companies are still making major corrections when a failure occurs, but preventive maintenance programs are equally widespread today. However, the predictive maintenance program itself is already declared by a decent 55% of survey participants. What is more interesting for further development is that there is a greater pressure on the company to introduce predictive maintenance. These tendencies are observed by 82% of the respondents, while half of them do not attribute this trend to new market sentiments, but rather attribute it to long-term developments (Smelík, 2017) Almost 40% of responses attribute the increasing importance of maintenance to principles of introducing so-called Fourth Industrial Revolution. And most of them think that it is most related to guidelines for introducing predictive maintenance.
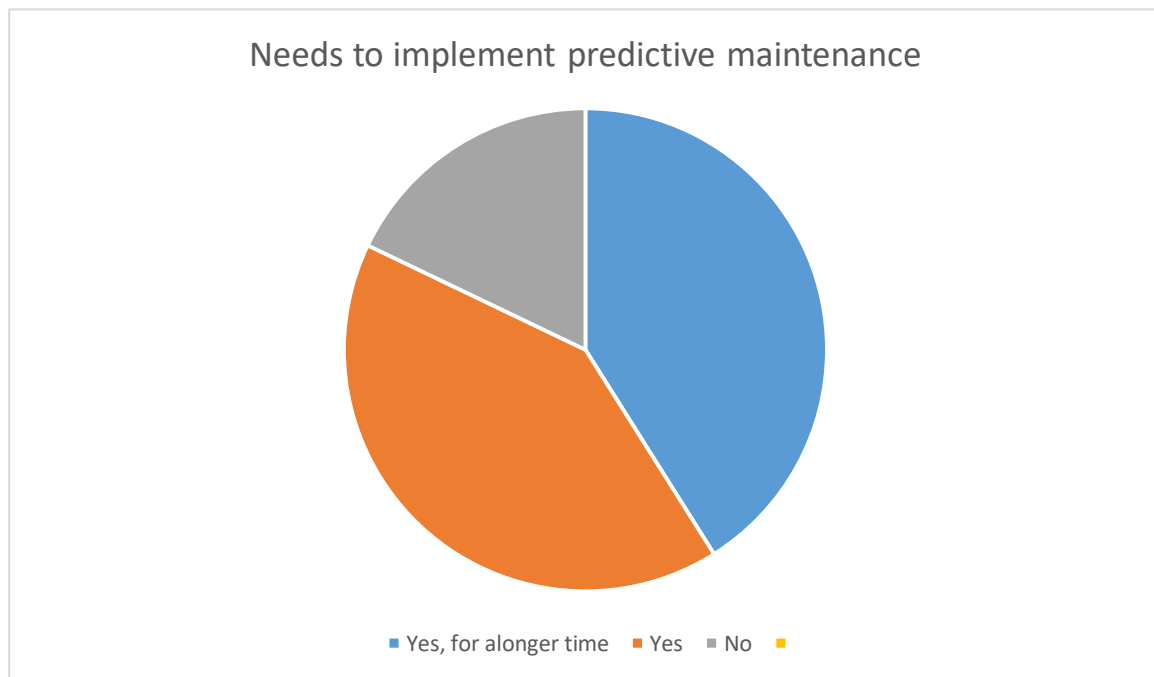

Figure 3: Needs to implement predictive maintenance (Smelík, 2017)

Most multinational enterprises that were instructed to prepare an Industry 4.0 compatible concept had to start with a project related to the implementation of predictive maintenance. A good predictive maintenance system can do without the support of an efficient information system, which is the backbone of all Factory 4.0 ideas. While IT department, production and maintenance personnel have been able to act relatively isolated while waiting for a breakdown, there is no such thing today. 65% of respondents agree that the further development of maintenance work is related to the development of collaboration with other departments, especially manufacturing and IT.
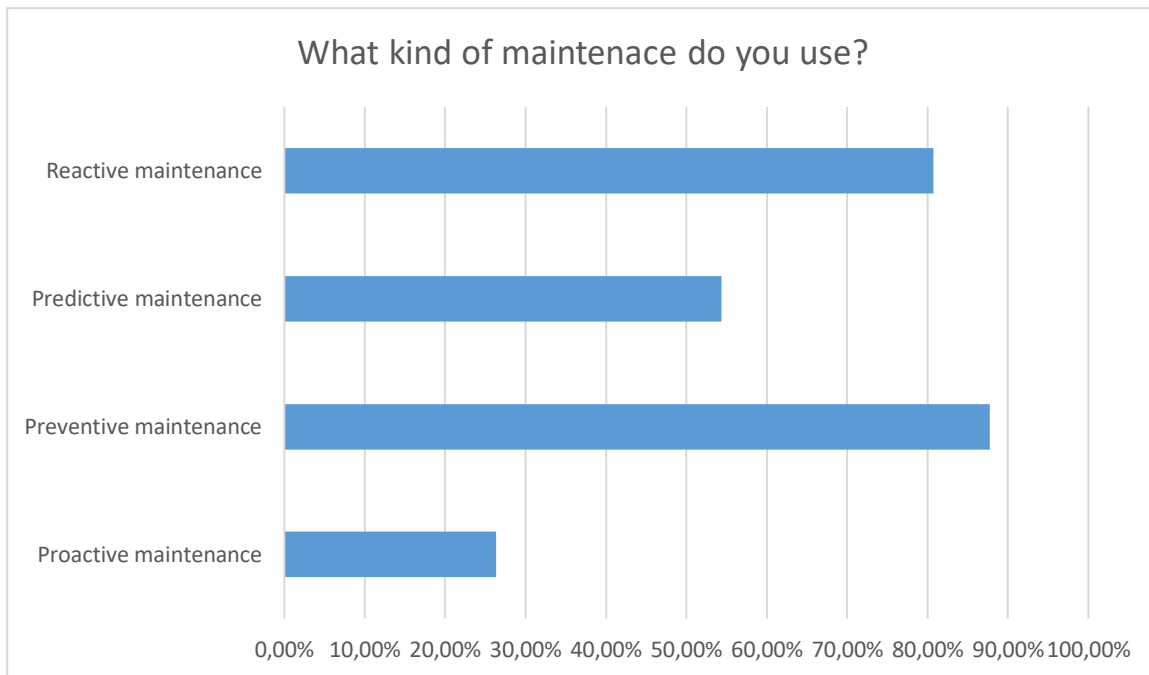
Figure 4: Maintenance used in companies (Smelík, 2017)

The concept of predictive maintenance is not an unknown, but it is often not allowed by current circumstances. The most common are logically the price and reluctance of leadership - which could often be merged. It is not only the expenses on implementing a maintenance system, but also its further operation, which, unlike the earlier, less frequent interventions, represents a different fixed cost item. However, a stop condition may occur for predictive maintenance due to inadequacy of the principle in terms of the complexity of production processes or the overall non-applicability in some enterprises.

If you manage to persuade the management about the indisputable benefits of introducing predictive maintenance and go through the difficult price bargains to buy the necessary equipment, the intention may fail elsewhere. Among the most common causes of failure to implement a predictive maintenance program is the lack of experienced staff. The problem here is often a simple calculation of how many employees are needed to produce one product, but in many cases the problem is also in the knowledge of the current maintenance area. Only by developing more sophisticated tools, employees who have previously focused on automation can have a partial advantage to eliminate the employee knowledge base. Where there is a lack of experienced staff who are able to evaluate the need for further interventions from the measured data, they must start building the knowledge base of the machines themselves.

Machine status monitoring, which allows data to be accessed simultaneously on the Internet, allows their users to increasingly use data collected directly from the manufacturer. It is not so unusual for machines together with sophisticated autonomous systems to predict maintenance intervals themselves. With the machine, there is no longer a need to supply preventive maintenance plans, but its system can draw attention to the actual need according to the production load itself.

The results of a recent IBM study have shown that companies using predictive maintenance tools have a tenfold return on investment - 20-25% reduced maintenance costs, 70-75% failure reduction, 35-45% downtime reduction and increased production by 20-25% compared to companies with traditional approach to maintenance. (Vrunda Negandhi, 2015)

3.1. Implementation of predictive maintenance

Although each company is different, the following overview describes a typical approach to implementing predictive maintenance (Selcuk, 2017):

1. Identify problem areas within production.
2. Quantify the financial impact of problems and potential the benefits of solving them.
3. Identify what data needs to be analyzed, what is available, and which will only need to be collected.
4. Estimate the cost of implementing predictive maintenance and compare them to financial benefits - Return on Investment (ROI).

5. If the ROI is positive, schedule the solution implementation in small increments with real business benefits.
6. Implement a pilot project - analyze part of the data, create models and predictions and verify their functionality.
7. Apply knowledge to production processes and procedures preventive maintenance.
8. Combine predictive maintenance data with other data in the company and use them as a basis for financial, manufacturing, business and strategic decisions.
9. Continuously extend the solution to all areas where it is its implementation economically advantageous.
10. Gradually build a positive attitude towards society work with data and information.

4. Predictive maintenance and use of CMMS

The emerging digitalization of industry brings the area of predictive maintenance to an opportunity for its much larger expansion. There are new sensors to assess the technical condition of machines with the ability to quickly exchange data with Internet repositories and process maintenance management software, increasing their installation into new machines directly to manufacturers, as well as securing machine data output to maintenance management software and Condition Monitoring (Ahmad, 2016) .

Maintenance management software is further adapted to work with a large number of on-line measured data from machines, their evaluation and prediction of future machine status (Poór, 2016). One of the positive factors is also greater popularization of predictive maintenance as one of the key tools for increasing the efficiency and productivity of manufacturing enterprises among managers who more than support their implementation. Incorporating appropriate predictive maintenance into a maintenance management system results in savings in machine maintenance costs and eliminates downtime and loss of customers or impacts on work and environmental safety or energy consumption.

The main functions of the maintenance information system include processing, visualizing, analyzing and archiving measured data. Automatic alarm generation when set limits and messages are exceeded in the form of SMS, e-mails and maintenance requests or work orders.

Other key components of a good CMMS with integration of predictive maintenance principles (Sláma, 2016):
1. Analysis of records on history of failures, their manifestations, causes and impacts in maintenance management information system
2. Selection of quantities indicating the degree of operation of the equipment and degree of wear of critical functional parts
3. Choice of on-line reading of values of these quantities or their interval erection
4. Choosing between evaluating results with your own trained or external specialist
5. Purchase of relevant equipment, installation of sensors, and connection of machines and configuration of information system.
6. Evaluation of acquired values and optimization of preventive maintenance plans.

5. Conclusion

With more and more industrial revolutions, production has evolved, and with it also maintenance. In the early days of production, the term maintenance meant the repair itself by the user, which through first specialized workers have developed up to the phase of a centrally managed department. After the third industrial revolution the separation of experts with mechanical, electrical and software maintenance, and various complex management approaches are being developed. These approaches combine maintenance after failure with maintenance preventive, predictive and proactive.

Upcoming Industry 4.0, predictive and proactive maintenance is much more important, also their methods, such as technical diagnostics. If with Industry 4.0 we plan that machines should communicate and accept the order themselves, it is necessary to use a large number of sensors to monitor the state of production itself.

Pressure on manufacturing companies is constantly rising. They must compete economic recession, rising raw material prices, restrictive legislation and many other factors. The main competitor, the advantage over cheap products from low cost human resources is quality and efficiency. Detailed data analysis helps to increase the operating time of the device, prevent production failures, improve product quality and reduce number of claims. Predictive maintenance is such a powerful tool to reduce costs, increase customer satisfaction and loyalty, thereby increasing profit.

Of course, introducing a predictive maintenance system will be easier in greenfield businesses, but trying to catch up with historical equipment is a stimulus to look for a room to move on to this maintenance system.

It is evident that many will still consider Industry 4.0 to be a populist term. On the other hand if something wants to feed on a wave of commercial interest, then that doesn't mean it's automatically useless. While there is no doubt about the increase in automation in the Industry 4.0 concept, there are still some who do not credit the same importance to maintenance. You can have as much production of robots as you want, but if nobody cares for them (with or without IT system), you will not be able to withstand this for a long time.

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