FEASIBILITY OF PREDICTIVE MAINTENANCE TECHNIQUES FOR THE INFRASTRUCTURE IN CV, EL, FM AND HE

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Abstract

Predictive maintenance is largely used in industry; this paper presents the maintenance strategy in which predictive maintenance is comprised and the type of maintenance to choose for a particular installation. It gives an overview of the most used predictive maintenance techniques in industry and presents the techniques currently used in some of the groups of the Technical Support department. It also gives some hints to which techniques could be implemented in the future.
1 INTRODUCTION TO MAINTENANCE AND MAINTENANCE PROCESS

The term Maintenance includes each and every action (technical, administrative and managerial) aiming at maintaining or repairing assets, so that it can continue to accomplish a given function. According to ISO 15288, through a maintenance process, the capability of a system to deliver services is measured, the problems are recorded and analyzed and suitable actions are taken. The input parameters are the status of the installation, its criticality and the available resources that are allocated in terms of man power (in-house or outsourcing) and budget. Taking into consideration these parameters, a strategy is defined and the precise actions and planning detailed. Key Performance Indicators and feedback from the field permit the search for the root cause of failures and for subsequent actions to improve the system’s capabilities.

1.1 Maintenance organization

In industry, the trend is towards the application of a method known as “Total Productive Maintenance (TPM) program”. The aim of this method is an increase of production, which for CERN would mean hours of physics, increasing at the same time the employees’ morale and satisfaction.

TPM shares objectives and means to achieve them with Total Quality Management (TQM). TQM is a wider concept that can include TPM. Both concepts highlight the need of a high and long-term commitment to the program by the management and the importance of empowering and training employees in relation to the installations they work. Benchmarking is used to assess performance.

As a summary, TPM is based on 8 pillars:

- Autonomous small maintenance by operators;
- Many and continuous small improvements in the company;
- Prepared in advance maintenance;
- Quality maintenance: passing from quality control to quality assurance and using predictive maintenance;
- Training: passing from only Know – How to Know – Why;
- Office TPM : includes improvement in CMMS, documentation, logistics, emergency stocks;
- Safety Health and Environment seeking at creating a safe workplace.

According to the European Standard EN 13306 there are two types of preventive maintenance: predetermined and condition based (or predictive) and two of corrective: deferred or immediate. In order to decide the type of maintenance best adapted to a particular installation, a decision logic tree is proposed by the Reliability Centered Maintenance (RCM) approach.

![Figure 1 – Maintenance process schematic diagram](image)
RCM recommends that when an installation is critical in terms of safety, security, health or environment or it can provoke a significant stop of production or a high economic loss, then, if it is technically possible, predictive maintenance should be applied.

2 PREDICTIVE MAINTENANCE APPLIED IN THE COOLING AND VENTILATION GROUP

At present, different predictive techniques are already implemented in the CV group.

In the critical cooling water stations, all filters are fitted with differential pressure switches; the status of these switches is monitored by the control system to determine whether a filter has reached a preset threshold and needs to be replaced or cleaned.

Leak detection systems are also fitted to most water cooling systems. They have two set points: the lowest sends a warning to the operator so that a search for the origin of the leak can be made and to make the necessary repairs. The highest set point stops the plant and closes the two main isolation valves to avoid or reduce flooding of crucial installations. The first case is covered by the CERN safety instruction IS37 which it defines as a Level 2 alarm.

Discordance detection occurs when values sent by the instrument are beyond expected values, i.e. temperature values higher or lower preset thresholds, on/off valves in intermediate position, etc.

Some techniques that could still be applied in CV are the monitoring of vibration measurements, ultrasonic noise analysis, infrared temperature measurements, gas leak detection for chillers’ refrigerant, lubricating oil analysis or software to analyze trends and particular events.

![Leak Detection Circuits Diagram](image-url)

*Figure 2 – View of the Water Leak Detection system in the SCADA for the underground cooling station at point 5 of LHC.*
3 SUMMARY OF THE MOST COMMON PREDICTIVE TECHNIQUES USED IN INDUSTRY

3.1 Vibration monitoring

Vibration monitoring is one of the most common predictive techniques. Accelerometers in the three axis covering the low and high frequencies (about 20 kHz) are installed in the vibrating object and by analyzing the variation over the time and through either mathematical models or empirical analysis, predict failures such as misalignment, imbalance, gaps, friction, etc. It can be useful in all rotating components such as fans, gear boxes, compressors and pumps, etc. The main drawback is that as for any other predictive technique, the warning is given once the failure has started. It is for the operator to decide the adequate thresholds.

3.2 Ultrasonic translators

Ultrasonic translators used to predict failure of moving equipment in industrial installations are based on the ultrasonic noise produced by machinery (in the range of 20 kHz to 100 kHz). The ultrasonic signal is converted into an audible signal (from 20 Hz to 20 kHz) by a process called heterodyning and can be heard through headphones, its intensity can be shown in a display and fast Fourier transforms can be realized to facilitate the analysis. The trained operator can detect variations of ultrasonic noise and find incipient failures. The main advantages are that ultrasonic noise is directional and therefore the source can easily be identified, there exists light and portable devices that can be used with a reasonable training and can solve problems in various fields such as leak detection, cavitation, worn or inadequately greased bearings, arcing or corona effect, etc.

3.3 Infrared thermography

Based on the principle that all objects emit infrared radiation, infrared thermography detects temperature of visible components that can then be compared with expected values (given either by the surrounding temperature or by normal values of the examined item). Problems such as unusual friction between mechanical elements or rust or loose fixations in an electrical connection generate a temperature increase and can be detected. Roof leaks, insulation failures on pipes, flow restrictions or air pockets in circuits, lack of tightness in valves or imbalance of heating circuits are problems that can be detected or analyzed by infrared thermography.

3.4 Lubricating oil analysis

By analyzing the used oil of machines, the lubrication capacity can be investigated and conclusions can be made on whether the oil is still useful or should be filtered, decanted or replaced. A regular check may indicate that the replacement intervals can be extended or shortened. Moreover, the number, size and nature of the particles in suspension can give some indication about unusual degradation of elements, i.e. water in the oil of a pump can indicate that the packing is failing.

3.5 Predictive maintenance in AC motors

Monitoring of electrical parameters such as power quality (voltage levels, unbalances or harmonic distortion) indicate the quality of the power to the equipment, show the behaviour of the motor to the applied loads and produces information regarding the health of the motor. Another parameter from which information can be obtained is torque. For motors submitted to constant load for example, the torque ripple can show defects in the load as cavitations, belt flapping, bearing faults, looseness, etc.

3.6 Software for trends and events analysis

Many physical parameters such as pressure, temperature, valve position, etc. are already available and even recorded in PLCs and SCADA systems but are not exploited for predictive maintenance. The behaviour of some parameters during and after determined events can be measured and conclusions on the working conditions of components and installations obtained, for example. During the startup of an air handling unit, opening the valve feeding the chilled water coil should reduce the air temperature inside the unit, on the contrary, there may be a problem with the valve, with the coil or in the capacity of the cooling system. Behaviour of parameters with respect to
manufacturer’s specification (for example, for a pump the working pressure and head must be in the curve given by the manufacturer) should be respected otherwise there may be a deficiency in the system. Dedicated software can help in the laborious analysis of large number of these parameters.

4 MAINTENANCE IN OTHER GROUPS OF TS

4.1 Predictive maintenance in the Electrical Service

The EL group performs most of their predictive maintenance within the scope of oil-immersed transformers. A thorough oil analysis is performed regularly and there are measurements of the dielectric breakdown voltage and the dissipation factor to check the insulating condition of the oil, the water concentration, acidity, flash point, viscosity, density, particle sizes and number, etc. There is also a search for furan derivatives, emanating from the decomposition of the insulating paper of the coil.

![Figure 3 – View of a possible hot spot in a Static Var Compesator by thermography](image)

In the HTA 18kV cells, spark detection by using ultrasonic methods is implemented and in the 400kV and 66kV parks, thermography is also utilized to search for faulty components (see Fig. 3).

Other techniques applied are the daily self-test of the UPS batteries or the measurement by protection relays of unbalanced currents in 18kV condensers caused by the degradation of internal elements. Replacement of these condensers is based on these measurements.

Techniques such as thermography could be further applied although in many cases the protection elements are a drawback for thermographic vision. Other authors propose full disclosure instruments to monitor power quality: disturbances such as impulses or transients, sags and swells can be a warning of deteriorating elements.

4.2 Predictive maintenance in the Handling Engineering

The use of handling equipment at CERN is discontinuous. Moreover, stringent tests are carried out to fulfil with the obligations imposed by law: according to the French “code de travail”, article R233-11, hoisting devices must be fully checked every twelve months or six months for those not installed permanently and bearing frequent change of location.

Nevertheless, for periods of continuous operation as it was the case during the construction of LHC, techniques such as thermography, ultrasonic measurements, vibration analysis and regular inspections of the wheels and runways can be applied to reduce breakdowns and the subsequent stop of activities.
4.3 Predictive maintenance in the Facilities Management

At present, there are not predictive techniques applied in FM. Most of the techniques described for CV could be applied as in many cases the nature of equipment is the same: pumps, motors, valves, circuits, fans, etc. In any case, as the FM equipment is in many cases not critical, a deep assessment has to be performed to evaluate if predictive maintenance is worthy in this case.

5 CONCLUSIONS

According to RCM, predictive maintenance should be applied for critical equipment when the appropriate techniques exist. There are still many possibilities to profit of the predictive maintenance techniques developed for industry and a trade-off analysis needs to be done on a case to case basis considering constraints such as budget, manpower, training, etc. and potential benefits.

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REFERENCES