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Implementing ESA

as Part of Your Predictive Maintenance Program

to Improve Electrical Reliability

William Kruger

Why Predictive Maintenance?

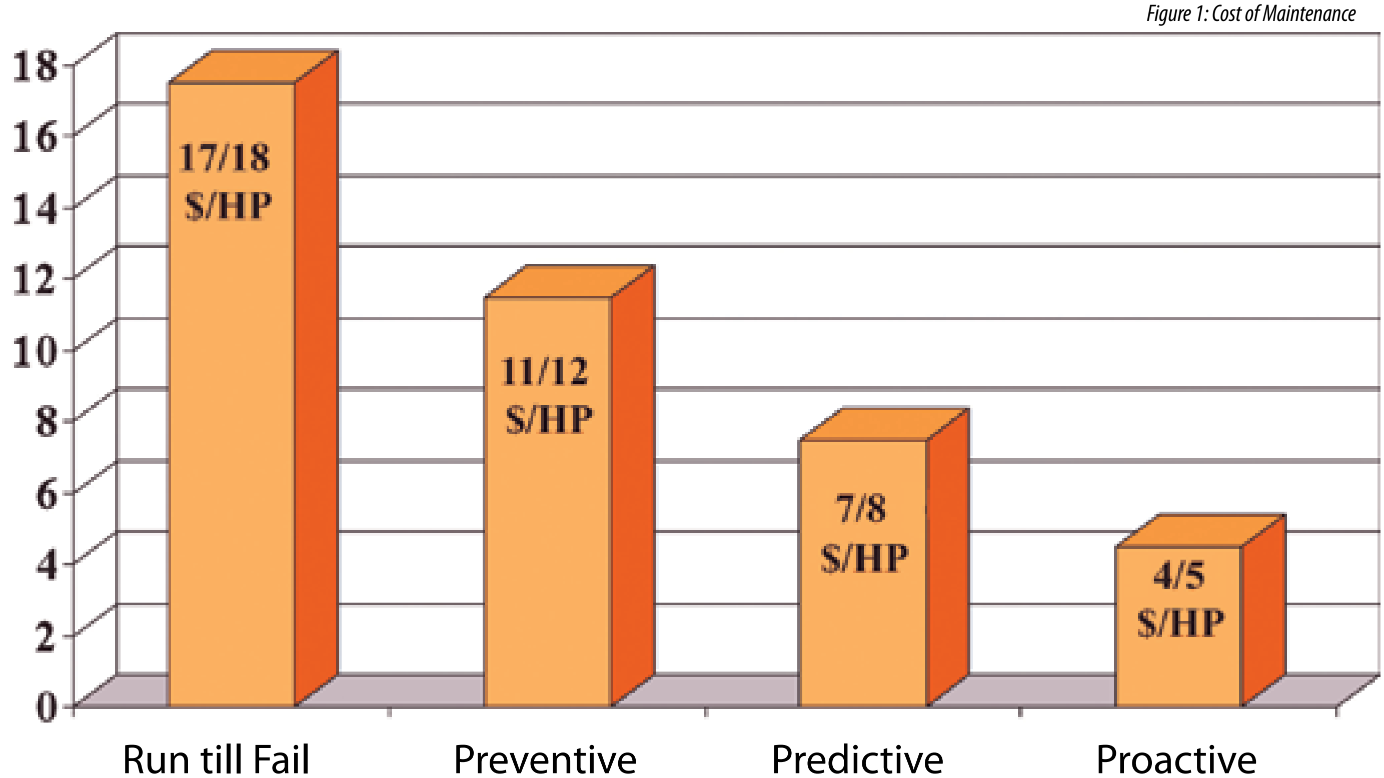
Predictive Maintenance (PdM) resulted from studies that determined that Preventive Maintenance (PM) programs are only effective for the 11 percent of machine failures that are age related. This means approximately 89 percent of machine failures are random in nature and time-based maintenance programs are ineffective on these random types of failures.

Multiple Technologies

There are many different PdM technologies, but the most successful programs use multiple technologies to provide the most information and consequently the highest probability of identifying a machine with a developing problem.

Some of the most common PdM technologies are machinery vibration analysis (MVA), infrared thermography, ultrasonics, oil anal-

Figure 1: Cost of Maintenance



ysis, motor circuit analysis (MCA) and electrical signature analysis (ESA). Common characteristic among the most successful PdM technologies are that they are easy to perform and provide non-destructive, repeatable measurements.

However, regardless of the technology being used, the most successful programs recognize that there are three phases in a successful predictive maintenance program:

1. Detection
2. Analysis
3. Correction.

Following is a brief review of the three phases of successful PdM programs.

Detection Phase

The detection phase is the most critical phase and the basis of most successful PdM programs. The main purpose of the detection phase is to identify "bad" machines or conditions that can lead to future machine failure. "Bad" machines are machines that are in a deteriorating condition.

Analysis Phase

Accurately determining the condition of the machine or more completely defining the cause of the change in the machine's condition is the main purpose of the analysis phase. The analysis phase involves taking additional or perhaps even different types or more in-depth data than the detection phase. This additional data may require more specialized techniques or technologies. It may require testing at different operating conditions or using completely different technologies.

Correction Phase

The main purpose of the correction phase is to determine the correct action based on the machine's condition change. This involves taking the action necessary to correct and eliminate the problem triggered by the change in the machine's condition. Additionally, the correction phase should verify that the corrective action did actually fix the problem(s). Alternatively, plant operations may dictate that the best action may be to simply continue monitoring at reduced test intervals.

Machine Selection

Selecting the machines that are going to provide the biggest payback from a PdM program seems obvious by classifying machines either by size or application. Most plants that have embraced predictive maintenance classify machines based on their application.

Critical Machines

Plants that classify machines based on application define critical machines as machines that are very critical to the plant's operation. In other words, if the machine shuts down, the entire process will stop. This, in many cases, results in lost production. Additionally, the product in process also may be lost. When classified by size, these machines are often the largest in the plant, usually greater than 300 HP (225 KW).

Semi-Critical Machines (Production)

Semi-critical machines are defined as machines that if shut down, will cause a partial loss of production. Losing these machines, although not causing a complete plant shutdown, may limit its output and therefore its availability. Some of these machines may have built-in spares or use two or three machines to operate at full unit capacity. These machines are medium-sized, typically 150 to 300 HP (110 to 225 KW).

Balance of Plant Machines (Non-critical)

These machines have little or no effect on plant production. These machines are usually the smallest in the plant, typically 5 to 150 HP (3½ to 110 KW) and spares are readily available.

Motor System

Any motor system has two subsections:

1) The electrical subsystem consists of the power coming into the plant, the plant distribution system and the electrical section of the motor.

2) The mechanical subsystem consists of the motor shaft and coupling, the driven machine and the process itself.

A fault anywhere in the motor system can prevent it from performing the intended function. This may result in reduced or lost production, excessive maintenance, or operational expenses. These two subsystems directly affect either electrical or mechanical reliability.

Electrical Reliability

Electrical power is one of the most important raw materials used in industry today. Not only must we have a continuous flow of power, it also should be clean and balanced. Yet, this important commodity is also one of the least inspected raw materials supplied to the plant.

Electricity is required in almost all areas of the plant to provide the driving force that either operates the equipment that produces the products or provides the services that the plant's equipment were built to perform. Electricity is a unique product in itself in that it requires continuous flow, cannot be conveniently stored and is normally not inspected prior to use.

Most people believe that electrical reliability ends with the successful delivery of power to the plant. But in many cases, the quality of the power supplied to the motor system may be the cause of a breakdown or failure. The result of poor "power quality" is usually long term and often overlooked as the source or contributor to the problem.

Power is normally generated far from the point of use, the reliability of the original generation is unknown and it is combined on the grid with many other generators. Many of the generating plants are smaller and privately owned. The power is transported through several different transformers and many miles of overhead and underground cabling before arriving at the plant. Many of these electrical distribution systems are owned, managed and maintained by several different entities. Once bad or "poor quality" power is placed on the grid, it cannot be removed or even rejected by the user.

Work to standardize and regulate power quality is in progress. Many states have their own specialized standards and regulations. However, generated power does not stop at the borders of the state where it is generated.

The detection phase is the most critical phase and the basis of most successful PdM programs.

Mechanical Reliability

Mechanical reliability has long been a subject of maintenance departments, and considerable improvement has been accomplished by understanding the importance and benefits of improving machinery balancing and alignment tolerances. The balance and alignment condition of a machine is measured and determined using mechanical vibration analysis (MVA). In many cases, machines exhibiting unacceptable vibration levels are removed from service and faults such as unbalance, misalignment, soft foot, mechanical looseness and other faults are corrected before mechanical failure occurs. Although MVA has proven very effective for identifying mechanical faults in the motor or the driven machine, it has proven ineffective in detecting the condition or quality of the power applied to the motor.

Additional limitations of MVA exist. First, it relies on measuring the motion of the machine's bearings or bearing housings to identify developing faults. The force generated during the early stages of most faults is insufficient to cause measurable movement. Secondly, faults that occur at locations remote from the bearings are usually undetectable with MVA. Faults in overhead fans or vertical pumps are normally undetectable using MVA. To identify faults on the entire motor system requires making multiple measurements at each bearing location. An average machine survey varies from 7 to 10 minutes.

If a motor burns up or if a breaker trips, technicians conduct electrical and mechanical inspections on the motor and the driven machine. The motor is then rebuilt or replaced and the whole process repeats. Faults that are caused by electrical problems, such as harmonic distortion, voltage unbalance, or any other electrical faults, are undetectable using MVA.

Electrical Signature Analysis

Electrical signature analysis (ESA) is a PdM technology that uses the motor's supply voltage operating current to identify existing and developing faults in the entire motor system. These measurements act as transducers and any disruptions in the motor system cause the motor supply current to vary or modulate. By analyzing these modulations, it is possible to identify the source of these motor system disruptions.

ESA measures all three phases of current and voltage at the motor controller while the machine is in normal operating condition. ESA performs a simultaneous capture of all three phases of voltage and current, performing a complete indication of the incoming power quality and motor power. It calculates motor efficiency and motor power factor. ESA also performs a Fast Fourier Transform (FFT) on the voltage and current waveforms.

Figure 2: Power Quality Table

ESA is proving to be a very effective technology for detecting faults anywhere in the motor system during the PdM process. The FFT allows ESA to identify all the mechanical faults that MVA finds in the motor, the driven machine and the process itself. It also provides better diagnostic capabilities for identifying and analyzing developing electrical faults within the motor electrical subsystem. In addition, it performs a complete power analysis to identify any power issues that can lead to premature failures in the electrical subsystem of the motor system.

The automatic analysis performed during the ESA process can be far more accurate than MVA since measuring the motor voltage and current allows for accurate determination of the running speed. This accuracy is usually within one or two RPMs. Additionally, ESA uses the motor current as its transducer and very small changes in any part of the motor system causes modulation of the motor current. This increased sensitivity allows for early detection of developing faults anywhere in the motor system. ESA has successfully detected faults in vertical pumps, overhead fans and loose bearing housing on machines driven by belts.

Summary

Successful implementation of PdM programs requires a thorough understanding of the PdM process and the efficient utilization of highly trained PdM personnel together with special and often expensive equipment. Reliability engineers agree that developing faults need to be identified as early as possible and ESA fulfills this requirement. As a detection tool, ESA usually identifies most mechanical faults in the motor system

Plant Name: **** Equipment:****
Coordinator: **** Analyst:****
Date: 06/24/2010 22:03:04
File name: C:\ATPOL DATA\ESA 6.1\EX3\EXERCISE 3_000(H1)

ALL TEST Pro OL 6.2 Analysis Results

PERFORMANCE SUMMARY

Bottom Line
_______ This induction motor is operating normally, no action is required.
_______ This induction motor exhibits suspicious operation, trending of the induction motor is warranted.
___X___ This induction motor exhibits abnormal indications, action is warranted, NOW.

Power Factor Commentary
___X___ Power factor exceeds 0.85.
_______ Power factor is below 0.85, see detailed report.

Current Commentary
_______ Current variation is within normal limits.
___X___ Current variation is beyond normal limits, see detailed report.

Voltage Commentary
___X___ Voltage variation is within normal limits.
_______ Voltage variation is beyond normal limits, see detailed report.
_______ RMS voltage differs from nameplate by more than 5%.

Load Commentary
___X___ Load on the induction motor is consistent with nameplate values.
_______ Load on the induction motor exceeds nameplate values, see detailed report.
_______ Load on the induction motor is less than 25%.

Phase Connection Commentary
___X___ Connections are normal.
_______ Voltage ground reference is NOT neutral.
_______ Loose connection.

Rotor Commentary
_______ Rotor bar health is normal.
___X___ Rotor bar health is questionable, see detailed report.
_______ Load is insufficient to determine rotor bar health, at this time.

Stator Commentary
___X___ Stator health is normal.
_______ Stator electrical health is questionable.
_______ Stator mechanical health is questionable.
_______ Turn to turn short.

Rotor/Stator Air-gap Characteristics
_______ Dynamic or static eccentricity indications do not exist.
___X___ Indications of static eccentricity exist.
_______ Indications of dynamic eccentricity exist.

Harmonic Distortion Commentary
___X___ There is no evidence of harmonic distortion.
_______ There is evidence of harmonic distortion, see detailed report.

Misalignment Indications
___X___ There are no indications of mechanical problems like misalignment or unbalance
_______ There are indications of mechanical problems like misalignment / unbalance. Perform vibr. survey to identify and correct the cause.

Bearing Commentary
___X___ There is no evidence of bearing problem.
_______ Indications of potential bearing problems, perform vibration survey to verify.

Figure 3: Motor System Analysis Report

before mechanical methods like machinery vibration analysis (MVA). Additionally, ESA accurately identifies electrical problems in the motor system that MVA or other PdM technologies cannot identify. In the analysis phase, ESA more accurately determines the system's rotational speed and more precisely identifies the mechanical and electrical faults that lead to reduced plant availability and uptime.

William Kruger joined ALL-TEST Pro, LLC as the Technical Manager in 2005. Since joining ATP, Bill has traveled the world teaching the Theory and Application of Motor Diagnostics, helping Fortune 500 Companies implement Predictive Maintenance Programs. With his combined work in the field as well as with ALL-TEST Pro, Bill has over 40 years of proven experience in the practical engineering and predictive maintenance field. www.alltestpro.com