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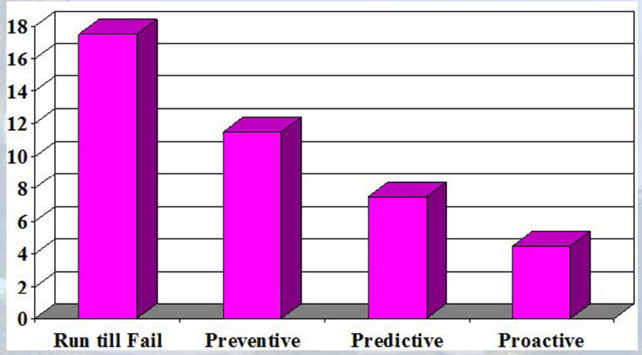
IMPLEMENTING ESA AS PART OF YOUR PREDICTIVE MAINTENANCE PROGRAM TO IMPROVE ELECTRICAL RELIABILITY

WHY PREDICTIVE MAINTENANCE?

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

In the early 1960's companies recognized that when rotating equipment began to fail, its operating conditions change. By routinely monitoring these operating conditions, an advanced warning of these changes provide the user with sufficient time to remove the degraded machine from operation, and perform the necessary corrective actions, before additional damage or even worse, a catastrophic failure occurs.

This maintenance philosophy has escalated since the early 1980's with the introduction of microprocessor-based data-collectors. Predictive maintenance uses various machine measurements to identify both the machines' operational and mechanical condition. Rotating machines' operating characteristics, such as temperature, pressure, oil condition, further loss of confidence or satisfaction in these programs, vibration and other performance indicators are measured and trended to identify machine deterioration. In some cases comparing these measurements to predetermined values can also determine the condition of the machine without trending. This led to rapid acceptance and implementation of predictive maintenance programs.



Many companies, with a large population of rotating equipment, have implemented PdM programs with varying degrees of success. Some estimates for management satisfaction of their current program are as low as 13 -15 %. Many managers feel that the results do not justify the means and that the amount of time spent administering programs far exceeds any resulting benefits. Additionally, any undetected machine failure or false calls create unnecessary and costly inspections and/or disassembly/assembly.

Ultimately, further loss of confidence often times results in lack of support or even, in extreme cases, the termination of the program.

The number of machines that are being monitored and the number of problems detected really doesn't measure the success of the program. Ultimately, it is the answer to the question: Is the program achieving its objective? Has the plant achieved more uptime? Has the program reduced machine failures? Has the plant reduced maintenance costs?

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MULTIPLE TECHNOLOGIES

There are many different PdM technologies and 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.

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Some of the most common PdM technologies are Machinery Vibration Analysis (MVA), Infrared Thermography, Ultra-Sonics, Oil Analysis, Motor Circuit Analysis (MCA), and Electrical Signature Analysis (ESA). The 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

The most common complaints of unsuccessful or faltering programs are failure to detect developing faults or recommendations of incorrect corrective action.

Failure to detect developing faults is often the result of spending too much or ineffective time in the detection phase. Ineffective time comes from taking a large amount of detailed data on "good" machines, but not having sufficient time to analyze the data. Gaps in coverage is often having insufficient work force to monitor effectively all machines in a timely manner or monitoring machines too often.

The second is the result of skipping the analysis phase attempting to determine the corrective action from the data collected to identify "bad" machines. Too many missed or incorrect calls will quickly reduce the effectiveness and confidence of any predictive maintenance program.

The trade-off is time or coverage. The more time spent per machine in the testing detection phase results in fewer machines monitored. To increase machine coverage requires additional work force or decreasing monitoring time per machine; or creating gaps in the machine coverage.

Most PdM programs focus on the mechanical aspects of the machines and operators have accepted the myth that electrical failures just happen, or worse, that the existing mechanical techniques can provide adequate warning to developing faults.

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

DETECTION PHASE:

The detection phase is the most critical phase and is the basis of most successful PdM programs. The main purpose of the detection phase is to identify "bad" machines or identify conditions that can lead to future machine failure. "Bad" machines are machines which are in a deteriorating condition. The detection phase, which is usually the data collection phase, involves periodically surveying the selected machines at periodic intervals. To maximize the detection phase, as many machines as possible should be surveyed, as quickly as possible. Therefore, the selection of the technology used during the detection phase becomes very important. The technology or technologies chosen for the detection phase should be able to identify as many of the machine's faults as possible, accurately define the machines condition and/or identify conditions that could lead to premature machinery failure.

The data taken during the detection phase is usually insufficient to provide anything other than a preliminary determination of the machine's basic condition. These measured values are trended or compared to data taken from similar machines, established standards, or a baseline to evaluate the condition of the machine. The main purpose of this data is to identify machines that indicate a change in condition, exceed established standards or exhibit conditions that can lead to failure.

Another important consideration of the detection phase is to identify a machine's deteriorating condition as early as possible in the failure stage. Since failures are random in nature in approximately 89% of machinery, early detection of a fault provides better insight into when corrective action is required. Early detection of a developing fault allows for more accurate tracking and trending as well as more time to prepare for the proper corrective action.

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Since most PdM technologies rely on comparing the measured data to the machine's previously measured data (during the detection phase), it is important to always perform the detection phase at the machine's same operating conditions each time. Consistency is often time more important than accuracy.

The information gathered during the detection phase may also help define any additional testing or technologies required to more accurately identify the machine fault during the analysis phase.

It is estimated that somewhere between 2% and 3% of the machines surveyed, in a mature program, exhibit any significant change during any detection survey period. Therefore, it is usually more time and cost effective to select the technologies that surveys the minimum number of data-points necessary, to identify a change during the detection process. Once a "bad or suspect" machine is identified during the detection process, then spend the time and resources necessary to accurately determine the machines condition.

(Note: the baseline is data taken from the same machine when the condition of the machine is considered to be in good operating 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 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 additional specialized techniques or technologies. It may require testing at different operating conditions or using completely different technologies.

Specific tests may be necessary during the analysis phase to determine if the condition change is the result of a change in the machine's operating condition or an actual change in the machine's condition.

Testing during the analysis phase may require testing of the machine during transient, start-up or even in a machine's shutdown condition.

During the analysis phase it should be determined if the change in data is the result of time, temperature, operating speeds, loads or the process. Does the condition improve or get worse with the operational changes? Are the observed changes intermittent or permanent?

However, if the plant site is remote or has other access limitations, then taking data that are more detailed during the detection phase will be justified. Many plants and sites use permanently installed monitoring systems for these remote sites.

CORRECTION PHASE:

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

Acceptable vibration levels, harmonic distortion, voltage or current unbalance, power factor or other performance measurement levels help determine the exact type of corrections and repairs.

MACHINE SELECTION

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

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Critical Machines

Plants that classify machines based on application define critical machines as machines that are very critical to the plants operation, if the machine shuts down the entire process will stop. This, in many cases results in lost production; additionally the product in process may be lost. When classified by size these machines are often the largest in the plant, usually > 300 HP (225 KW)

Semi-Critical Machines (Production)

Semi-critical machines are defined as machines that if lost 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 or (3 ½ to 110 KW) and spares are readily available.

MONITORING INTERVALS

There are no established generic monitoring intervals that cover all technologies, industries, or operations. Plant conditions, operating environment and commitments, selected technology and other plant considerations need to be considered.

Each technology generally provides recommended initial monitoring guidelines and test intervals. However, regardless of the technology, all machines should be monitored to some extent and a baseline should be established. Other considerations are the criticality of the machine, the cost of repair, causes, types and consequences of failures.

Critical machines are going to be the most frequently and extensively monitored, followed by semicritical and then the balance of plant machines.

Machines that operate in a dirty, harsh environment or undergo frequent start and stops should be monitored more frequently.

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 system from performing its intended function. This may result in reduced or lost production, or excessive maintenance or operational expenses. These two subsystems directly affect either the electrical or the mechanical reliability.

ELECTRICAL RELIABILITY

Most people believe that electrical reliability ends with the successful delivery of power to the plant. 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 should also be clean and balanced. Yet, this important commodity is also one of the least inspected raw materials supplied to the plant.

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Electricity is required in almost all areas of the plant to provide the driving force that operates most of 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.

The quality of the power supplied to the motor in many cases may be the cause of a breakdown or failure. The result of poor "power quality" is usually long term and is 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.

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, softfoot, 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 are that MVA 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 (ESA)

Electrical Signature Analysis 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 which performs a complete indication of the incoming power quality and motor power. It calculates motor efficiency and motor power factor. ESA also performs an FFT on the voltage and current waveforms.

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 of 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.

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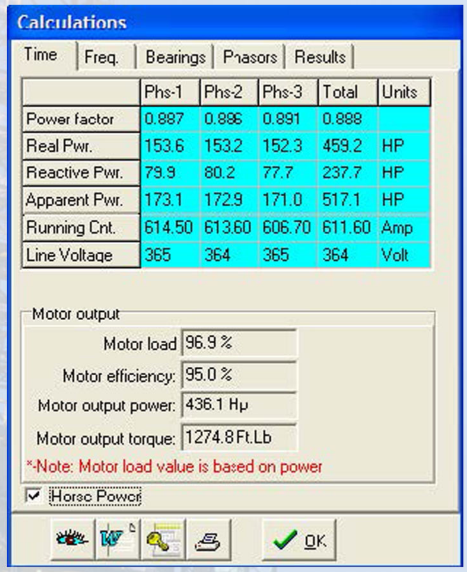
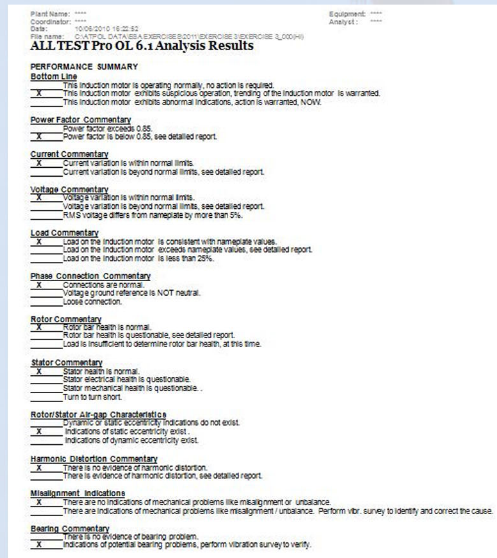
In addition, it performs a complete Power Analysis to identify any power issues that can lead to premature failures in the Electrical subsystem of the Motor system.





Plant Name: **** Equipment: ****
Coordinator: **** Analyst: ****
Date: 10/06/2010 16:22:52
File name: C:\ATPOL DATA\ESA EXERCISE S\2011\EXERCISE 3\EXERCISE 3_000(HI)

ALL TEST Pro OL 6.1 Analysis Results

PERFORMANCE SUMMARY

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

Power Factor Commentary
____ Power factor exceeds 0.85.
_X_ Power factor is below 0.85, see detailed report.

Current Commentary
_X_ Current variation is within normal limits.
____ 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
_X_ Rotor bar health is normal.
____ 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
____ There is no evidence of bearing problem.
_X_ Indications of potential bearing problems, perform vibration survey to verify.

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 RPM. 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 before mechanical methods such as 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 systems rotational speed and also more accurately identifies the mechanical and electrical faults that lead to reduced plant availability and uptime.

This is the first of a series of papers discussing implementing ESA as part of your PdM program. Each paper will discuss different electrical or mechanical faults and how ESA identifies these faults.