Solutions for Electric Motor Reliability

Save Money, Time & Manpower

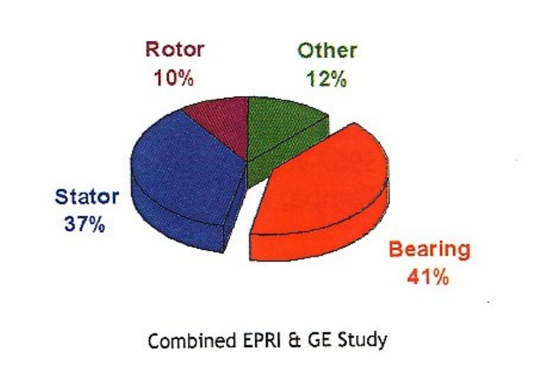
Reduce Unplanned Down time

POWERFUL MOTOR MANAGEMENT

Electric motors are key components in most industrial plants and equipment. They account for two-thirds of all the electrical energy used by industrial and commercial applications in the developed world with lifetime energy costs normally totalling many times the original motor purchase price. Clearly, industrial companies need effective motor maintenance and management strategies to minimize overall motor purchase and running costs while avoiding the pitfalls caused by unexpected motor failures.

How Do Motors Fail?

Often electrical defects are the root cause even when mechanical failure is the apparent cause. A study by Electrical Power Research Institute (EPRI) identified that a major source of motor failures where electrical.



Combined EPRI & GE Study

With electrical faults responsible for nearly 50% of all motor failures, taking a proactive approach to these problems becomes a necessity.

Your Solution is:

Enhance your motor maintenance program with the addition of Comprehensive Motor Analysis and use it for Quality Assurance, Trending & Diagnostics / Trouble shooting. Comprehensive motor testing provides more information on motors to evaluate quality after costly repairs, to store motor data for condition monitoring and to analyze data, define problems and isolate the root cause of each potential motor failure.

MOTOR FAULT ZONES

There are six areas of interest in motors known as **Motor Fault Zones** that must be looked at during a motor troubleshooting effort. Missing any of these zones could result in missing the problem and losing credibility of total trouble shooting procedure.

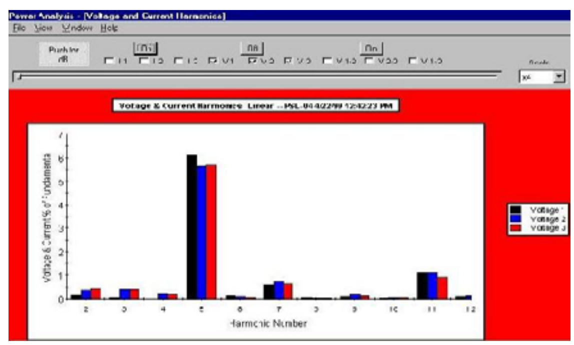
The six electric Fault Zones in motors are:

1. Power Quality
2. Power Circuit
3. Insulation
4. Stator
5. Rotor
6. Air Gap

POWER QUALITY

Power Quality: has recently been thrust in the limelight by utility deregulation and the popularity of AC and DC drives. With deregulation, competition among utilities has heightened the concern of penalties from high distortion levels. The variable frequency drives (VFD's) and other non-linear loads can significantly increasing the distortion levels of voltage and current. How can this distortion be minimized? What equipment is required, and is the concern purely financial or is equipment at risk?

First, let's understand what we are really talking about when we speak of power quality problems. Voltage and current harmonic distortion, voltage spikes, voltage unbalance and power factor are a few of the many concerns when discussing power quality. Although all of these are important, we will focus on just a few, beginning with harmonic distortion. High 5th and 7th harmonics indicate the presence of a 6 pulse drive influence on the distribution system. Each of the individual harmonics should be <3% of the fundamental per IEEE 519-1992.



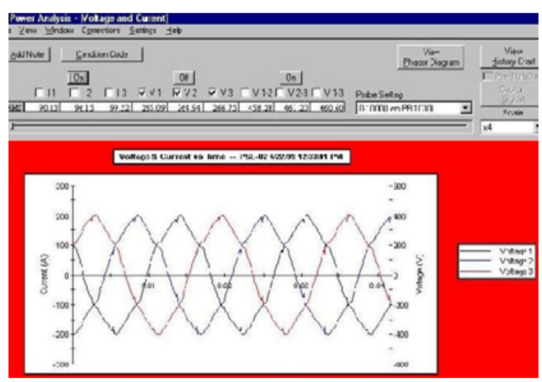
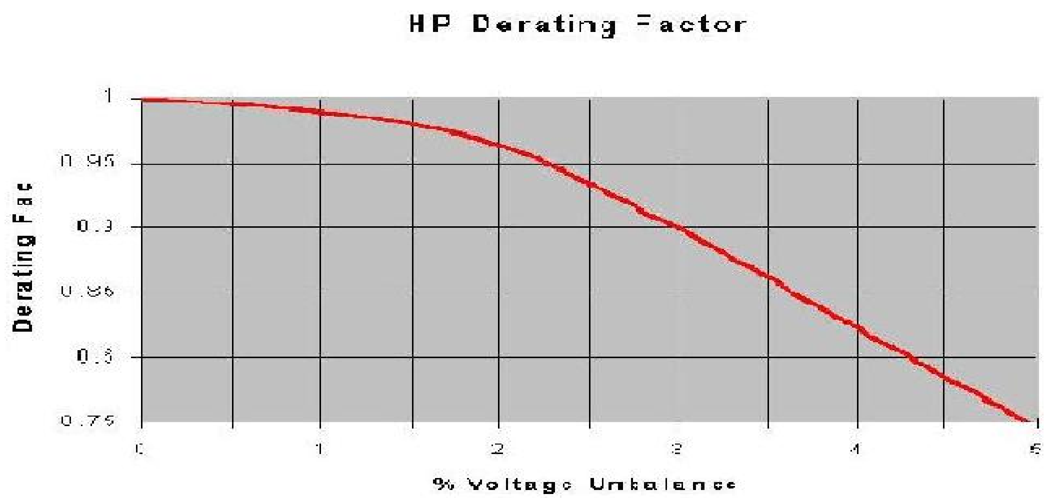


Figure 2 shows a fundamental 60 Hz voltage signal with 6 pulses occurring throughout each sine wave. This resulted from an unfiltered 6 pulse drive connected to the distribution system

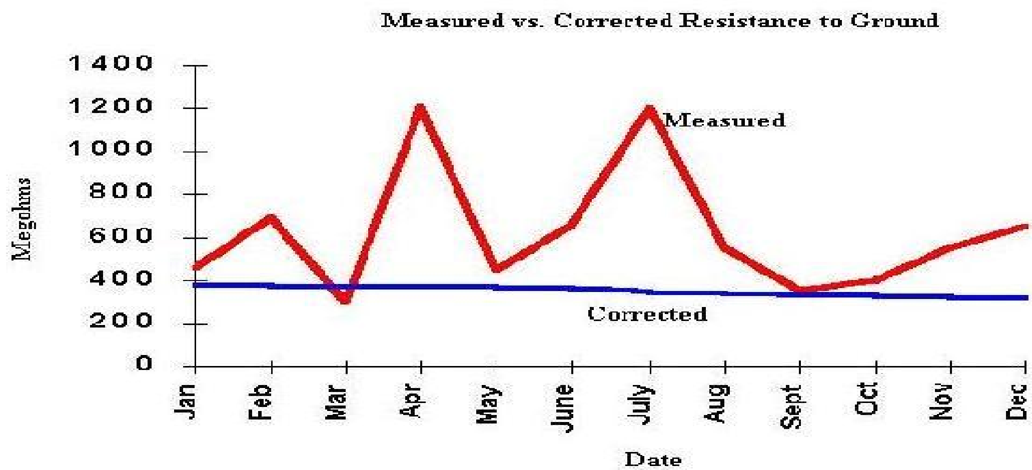
POWER CIRCUIT

The power circuit refers to all the conductors and connections that exist from the point at which the testing starts through to the connections at the motor. This can include circuit breakers, fuses, contactors, overloads, disconnects, and lug connections. A 1994 demonstration project on industrial power distribution systems found that connectors and conductors were the source of 46% of the faults reducing motor efficiency. Many times a motor, although initially in perfect health, is installed into a faulty power circuit. This causes problems like harmonics, voltage imbalances, current imbalances, etc. As these problems become more severe, the horsepower rating of your motor drops, causing temperatures to increase and insulation damage to occur. This motor is replaced many times and the failure cycle begins again. As seen in figure, high resistance connections resulting in voltage imbalances will reduce the horsepower rating significantly.

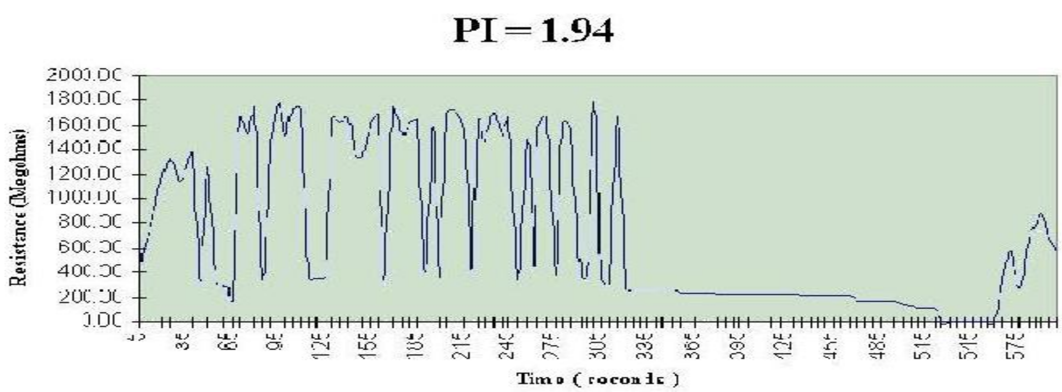


INSULATION CONDITION

Insulation systems today are better than ever and are able to handle higher and higher temperatures without significant reduction in life. However, we are still finding ways to destroy our insulation much earlier than should be expected. Keep in mind that although insulation is many times involved in a failure, this fault zone is heavily influenced by other problems. The power circuit for one can heavily influence the insulation. If a high resistance connection exists upstream of the motor, which develops better than a 5% voltage imbalance, and we continue to run the motor at its normal Hp rating, we will see a shortened insulation life. Was the insulation system the real cause of the motor failure or was it just a symptom? It is easy to diagnose the evident insulation failure as the fault mechanism but it will happen again with a different motor if the problem is not fixed. Simply megger testing with no regard to temperature will result in resistance to ground readings, which swing heavily from high to low readings, depending on the temperature of the windings. Temperature correcting the readings will
it will give a much better trend as seen in following Figure.



An insulation test that has fallen out of the spotlight is the Polarization Index test. Applying a constant DC voltage, in the form of a megger test, for a period of 10 minutes will result in a gradual increase in the resistance to ground (RTG) reading. This is a result of charging the insulation system, much like a capacitor, which causes a reduction in the absorption current. Per ohms law, I(current) = V(voltage) / R(resistance). Therefore, the reduction of this absorption current must result in an increase in the resistance. If we take the ten minute RTG and divide it by the one minute RTG, a value of 2.0 or higher is considered acceptable by IEEE. Unfortunately, motors with unstable insulation systems can give values close to or greater then a 2.0, but still be defective.



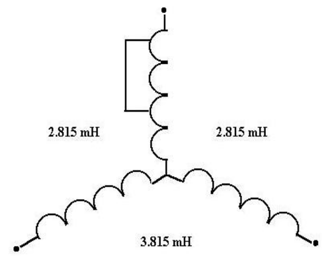
In Figure , when the ten minute reading (approximately 600 megohms) is divided by the one minute reading (approximately 300 megohms), the result is 1.94. This nearly meets the IEEE specification as a good insulation system, and would probably be accepted in the field. You can see, however, that this insulation system is very unstable. Always look at the PI Profile and not just the Index.

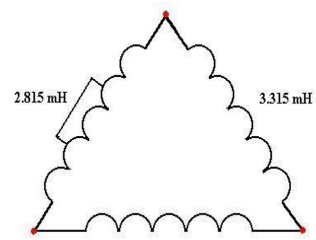
STATOR WINDING

Stator winding consists of the DC or 3 phase AC windings, insulation between the turns of the winding, solder joints between the coils, and the stator core or laminations. One of the common faults occurring with motor windings is a turn to turn fault. This occurs when the insulation between two turns in the same coil breaks down and reduces the coil's ability to produce a balanced magnetic field.

A turn to turn or a phase to phase short can occur many times without resulting in an immediate ground fault. Because of this, testing with just a megger for preventive maintenance or following a motor trip may not identify the fault. This could cause a small winding fault to develop into a major catastrophic failure. Permanent core damage may necessitate replacing an entire motor.

To more fully understand what the inductance readings are telling you, a simple understanding of the winding configuration can help. A "Y" configuration winding with a turn to turn short will result in two low inductance readings and one high inductance reading, when looking at phase to phase inductance. A delta configuration winding with a turn to turn short will result in one low inductance reading and two high inductance readings, when looking at phase to phase inductance.





ROTOR CONDITION

This refers to the rotor bars, the rotor laminations, and the end rings of the rotor. In the 1980s, a joint effort between EPRI and General Electric showed that 10% of motor failures were due to the rotor. The rotor, although a small percentage of the motor problems, can influence other fault zones to fail. When a motor is started with a broken or cracked rotor bar, intense heat is generated around the vicinity of the break. This can spread to other rotor bars and destroy the insulation around the nearby laminations. It can also effect other parts of the motor. What is just a few millimeters away from the rotor? The stator! Stator insulation can not hold up to the intense heat developed by the broken rotor bar and will eventually fail. Unfortunately, many times broken rotor bars are not easily seen without technology and it may be missed as the root cause of failure. This will result in a motor rewind, and replacement of bearings, but not a rotor repair. When the motor returns to service, it has the same problem all over again, just with new insulation to destroy.

One method of testing the rotor condition is the Rotor Influence Check (RIC™). What is a RIC? The RIC is a test performed on AC induction, synchronous, and wound rotor motors which illustrates the magnetic coupling between the rotor and stator. This relationship indicates the condition of the rotor and air gap within the motor.

Without historical data, a RIC must be performed to provide any information about the standard squirrel cage induction rotor. Faults such as broken rotor bars or damaged laminations can exist even if the balance of inductance is low. If you are basing the decision to perform a RIC only on how high the balance of inductance is on the baseline test, you could be overlooking late stages of rotor bar defect.

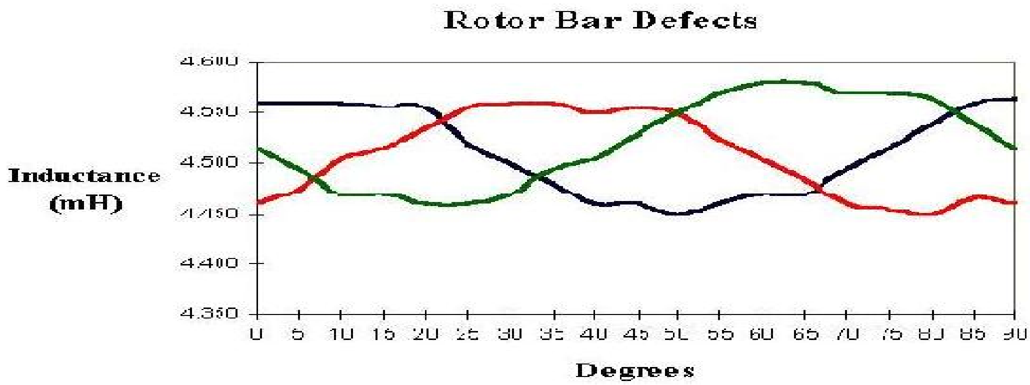
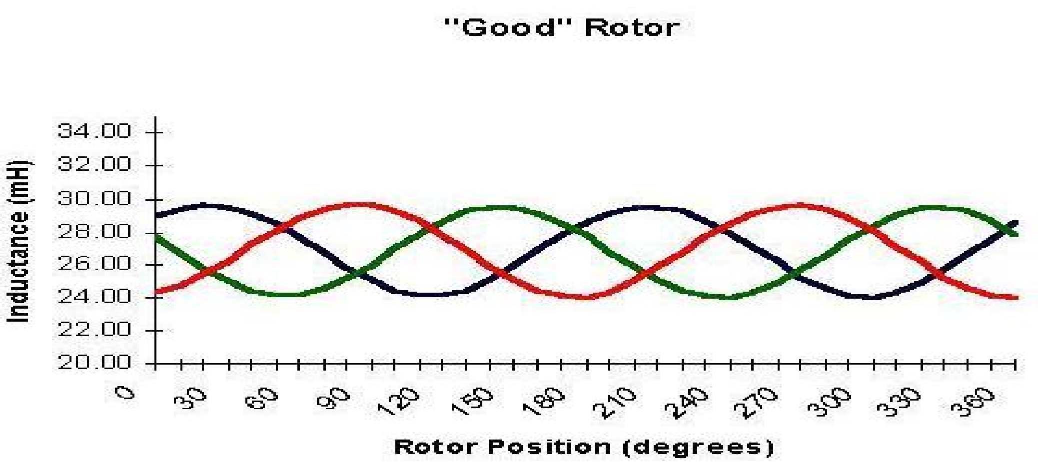
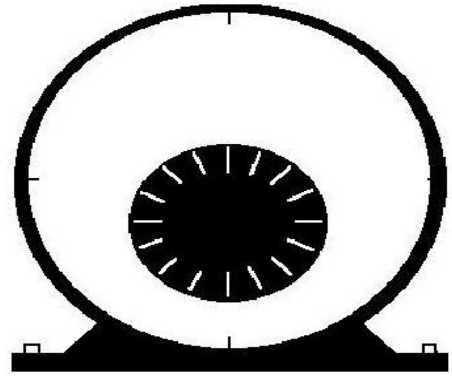


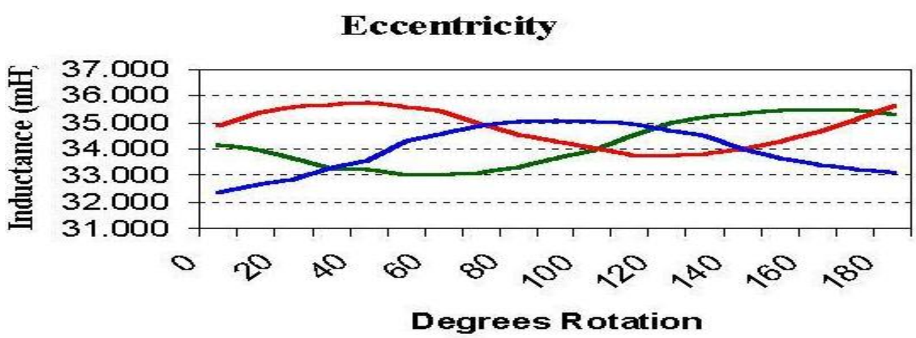
Figure shows the expected inductance changes for a rotor with broken rotor bars. Note the erratic inductance values at the peak of the sine waves for each phase. Broken rotor bars cause a skewing in the field flux generated by and around the rotor bars. A normal rotor would have no skewing or erratic inductance patterns, as seen in following Figure



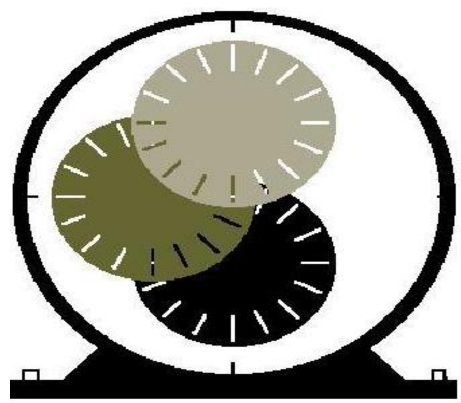
Rotor / Stator Relationship: This relationship references the air gap between the rotor and stator. If this air gap is not evenly distributed around the 360 degrees of the motor, uneven magnetic fields can be produced. These magnetic imbalances can cause movement of the stator windings, resulting in winding failure, and electrically induced vibration, resulting in bearing failure. A faulty relationship between the rotor and stator is also called an eccentricity.

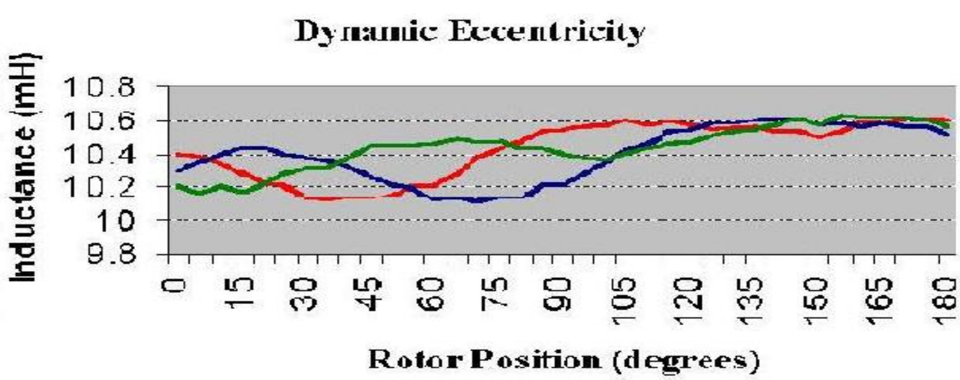
The first type is called static eccentricity. Figures show an example of what static eccentricity looks like, physically and inductively. This type of eccentricity is caused by problems like a misaligned end shield or the shaft sitting low in the bearing. The physical result is that the shaft is always in the same place out of the electric center.



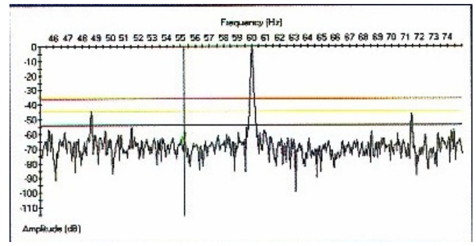


The second type of eccentricity is called dynamic eccentricity. This results when the rotor does not stay in one place but is allowed to move within the space of the stator as seen in Figure. The inductive result is the movement of all three inductance values up or down, depending on which phase is closest to the rotor at a given degree rotation. This is seen in Figure below

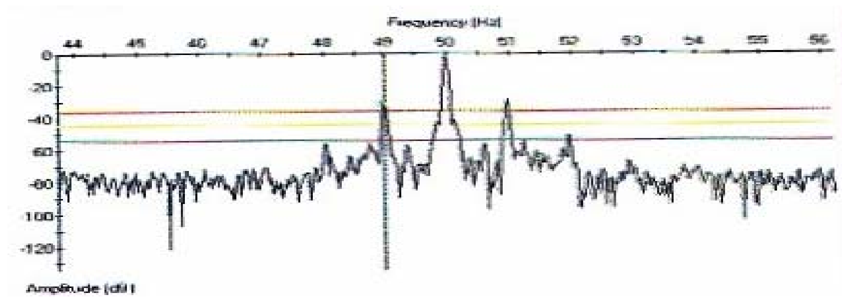




Current Signature Analysis (CSA) is a preferred predictive maintenance tool to identify damaged rotors and air gap eccentricity in induction motors. By performing a Fast Fourier Transform on motor current, the power cables can act as permanently installed test leads for predictive maintenance applications.

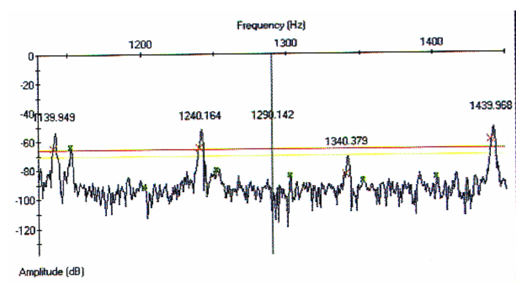


Satisfactory rotor



Damaged rotor

If the distance between the length of the stator bore and rotor is not equal through out the entire circumference, varying magnetic flux within the air gap creates imbalances in the current flow, which can be identified in the current spectrum. The effect of this condition is seen as multiple side bands of odd harmonics of the line frequency powering the motor.



Every day, predictive maintenance professionals are faced with difficult challenges. The tools you use and the support you receive can often determine failure or success. Successful strategies will be focussing on getting the clearer data from the field. Combining the capabilities of Off-line and On-line tests it becomes the single most powerful motor testing tool available. Every facet of the motor can be evaluated, from the power quality, power circuit and insulation to the rotor, stator and air gap. In conclusion we really can have a thorough assessment of the motor health and can confidently remark " **The Motor is Fine**".