IMPROVING MOTOR RELIABILITY THROUGH STATIC AND DYNAMIC TESTING

By Noah Bethel

Static motor testing is a well-known means to comprehensively test electric motors. However, if a motor cannot be shutdown, even the best static equipment becomes ineffective. Situations like these have fueled the popularity of DYNAMIC testing. But can dynamic testing be productive? One way to answer this question is to prove that a dynamic technology can detect known faults in actual motors. Another is to ensure that it effectively correlates with its static technology counterpart. This not only increases the confidence of the person testing, but also improves the accuracy of analysis.

The advantage of utilizing both static and dynamic technologies for improved motor reliability is tremendous. First and foremost, the combination of technologies enables a facility to test during any plant condition. Dynamic is used for the obvious: the collection of data under operation without the interruption of production. This allows a manager to make more informed decisions as to which motors to focus on during the turn around. Static testing facilitates quality assurance assessments, diagnostic testing on de-energized motors and comprehensive analysis during plant shutdowns.

The correlation of static and dynamic data was accomplished at Advanced Energy Laboratories. Advanced Energy is an independent laboratory equipped with the ability to test small to large hp motors, from partial to full load, while coupled to a dynamometer. Advanced Energy is renowned as the most accurate and reliable independent motor testing laboratory in the nation, providing information such as voltage, current, power, efficiency, torque and more, with great precision.

Two pieces of equipment were selected for the testing: the MCETM, a static Motor Circuit Evaluator, and the Emax, a dynamic Motor Analysis tester, both manufactured by PdMA Corporation. The motors to be tested were 20hp TECO motors manufactured in China. The following defects were installed:

- High Resistance Connections
- Stator Faults
- Rotor Bar Defects
- Static and Dynamic Eccentricity.

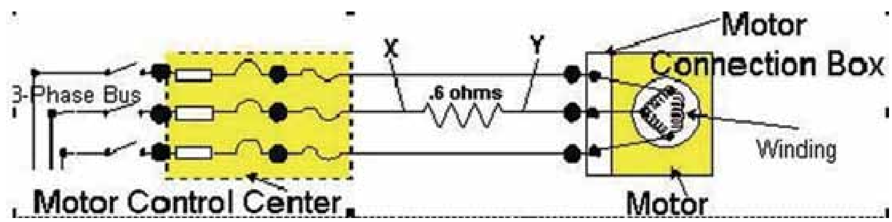


Figure 1

HIGH RESISTANCE CONNECTIONS

Static technology, MCE, identifies a high resistance connection by taking a resistance measurement of each phase and calculating a resistive imbalance. The MCE tests de-energized motors and therefore must send signals to the motor to gather information. As a result, the high resistance connection would have to be down stream of the test lead connections for the MCE to identify the problem. Dynamic test equipment, Emax, identifies a high resistance connection by taking voltage measurements of each phase and calculating a voltage imbalance. The Emax tests motors while they are running, therefore indicating changes in voltage that occur upstream of the test leads. By utilizing both technologies, MCEmaxTM, and connecting them at the same location, the entire power circuit from the transformer to the motor is tested for high resistance connections.

Engineers at Advanced Energy installed a .6ohm resistor in line with phase 2 as seen in Figure 1. A high resistance such as this could result from a loose connection, bad fuse, poor contact pressure, degraded contact surface or corroded materials.

The MCE testing at position X, upstream of the resistance, indicated a resistive imbalance greater then 10%, above the alarm set point. When the same test was run at position Y, downstream of the resistance, the resistive imbalance was less then 1%, well within tolerance. The Emax tested at position X, upstream of the resistance, indicated <1% voltage imbalance. This was also expected because the voltage drop due to the resistor doesn't occur until after the power signal goes through the resistor. The Emax tests performed at position Y, downstream of the resistance, showed voltage imbalance >2%, above the alarm set point. This imbalance, if left undetected, would result in the motor running with high negative sequence currents when near full load. These negative sequence currents could result in the motor overheating and destroying the insulation system. Based on the NEMA horsepower de-rating standards this motor should be reduced to 90-95% of full load to protect against insulation

continued on page 24

Improving reliability

from page 22

damage.

STATOR FAULT – (TURN TO TURN)

The MCE identifies a stator-winding fault by taking an AC inductance measurement of each phase and calculating an inductive imbalance. If any of the three windings produce a lower value of inductance, an unbalanced magnetic field is produced while the motor is running. The Emax identifies a stator-winding fault by taking voltage and current measurements of each phase and comparing the complex impedence values for each. If one phase is offset due to winding

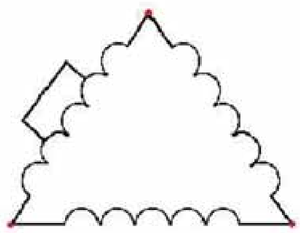


Figure 2

defects, it will result in a high impedance imbalance. By utilizing both technologies, winding defects can be identified at all stages of the motor life, including prior to installation, while operating, or worst case, after the motor has tripped.

During our research, 2 turns in phase 1 of the delta wound motor were shorted, as seen in Figure 2. A winding defect, if undetected, could very quickly result in catastrophic failure of the motor.

MCE tests performed before the turns were inserted indicated an inductive imbalance of 6%. After the turns were shorted, the inductive imbalance increased to an alarming 16%. Emax results had impedance imbalances greater then 20% with the turns shorted, far above the acceptance criteria.

ROTOR BAR DEFECTS

The MCE identifies a rotor bar defect through the performance of a Rotor Influence Check (RIC). A RIC test performed on AC induction motors illustrates the magnetic coupling between the rotor and stator. This relationship indicates the condition of the rotor and air gap within the motor.

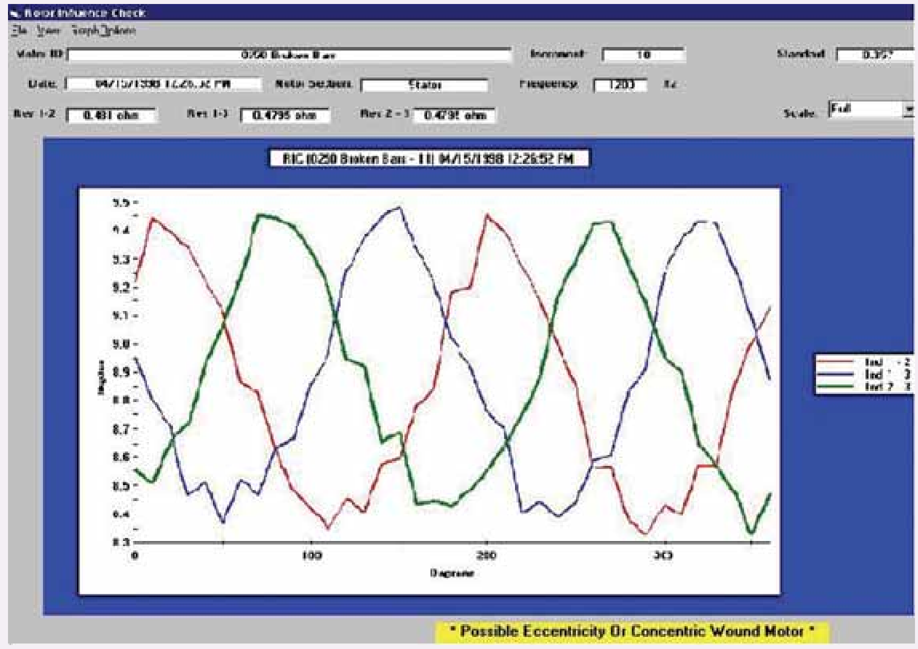


Figure 3
MCE - Note the erratic inductance values at peak of the sinewaves for each phase. Broken rotor bars cause a skewing in the field flux generated by all around the rotor bars.

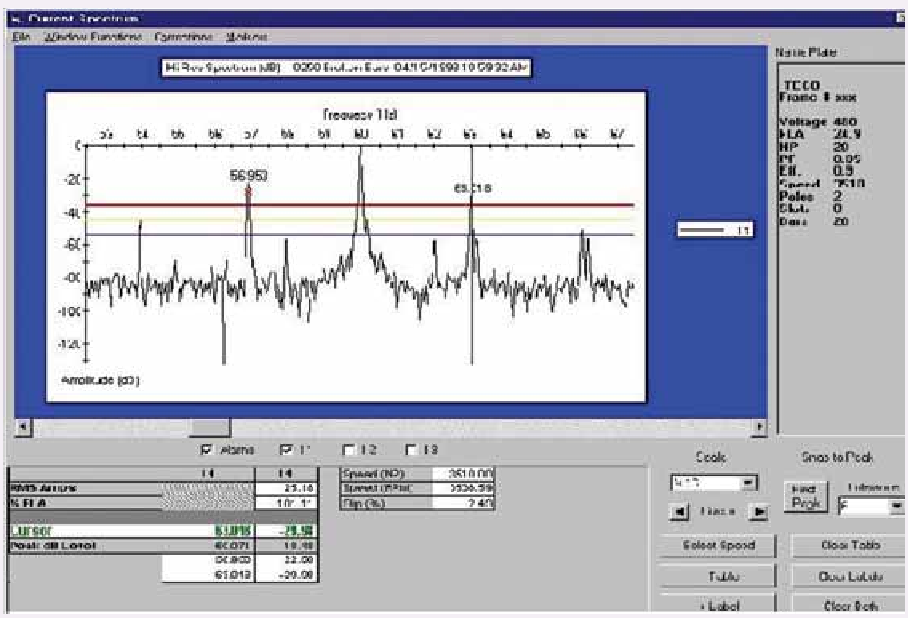


Figure 4
Emax - The difference in amplitude between the 60 Hz line frequency (LF) peak and the Pole Pass (Fp) sideband peak near 57 Hz is only 22dB. A healthy motor will have a 50dB or greater difference.

The RIC is performed by rotating the rotor in specific increments (determined by the number of poles) over a single pole group, and recording the change in inductance measurements for each phase of the motor.

The Emax identifies a rotor bar defect by comparing the Pole Pass Frequency (Fp) sideband to the line frequency. These frequencies are developed by collecting the three current signals, then running them through an FFT for high resolution spectral analysis. By utilizing both technologies, the confidence

Figure 5 (right)
MCE - The inductive result is the change in the peak amplitudes of the three inductance values up or down, depending on which phase is closest to the rotor at a given degree rotation.

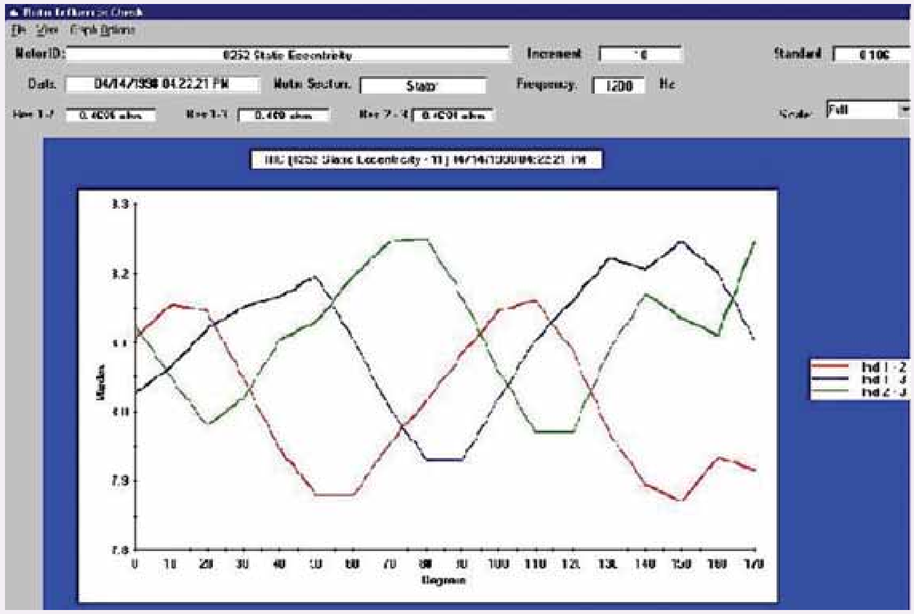
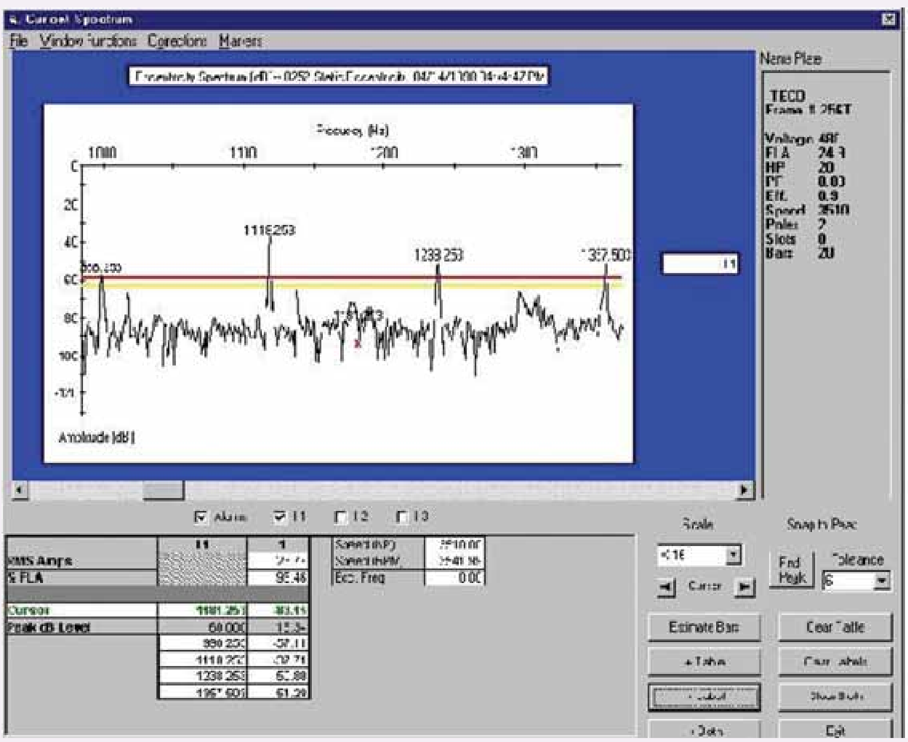


Figure 6 (below)
Emax - 1st and 3rd line frequency harmonics sidebands around eccentricity frequency of 1180 Hz is an indication of static eccentricity. The amplitude of these sidebands is used to determine the severity.



level to detect a faulty rotor condition increases dramatically. When the motor should be removed for repair is up to the technician.

The engineers at Advanced Energy separated 3 bars from the endring to create a broken rotor bar condition. Figures 3 and 4 clearly illustrate how the broken rotor bars are detected by the MCE and Emax technologies. Broken rotor bars, if left undetected, will result in further damage to adjacent bars, and possible insulation or rubbing damage of the stator.

STATIC & DYNAMIC ECCENTRICITY

The MCE identifies eccentricity through the performance of the same RIC discussed during rotor bar analysis. As mentioned earlier, a RIC test performed on AC motors illustrates the magnetic coupling between the rotor and stator. This relationship indicates the consistency of the air gap within the motor, as seen in Figure 5.

The Emax identifies an eccentric air gap by capturing three phases of current simultaneously. This signal is evaluated as a high frequency spectrum for non-synchronous peaks 120hz apart as seen in figure 6. These peaks appear as sidebands around the eccentricity frequency. Eccentricity frequency is calculated by multiplying the speed (in Hz) of the motor by the number of rotor bars. If the air gap is not consistent throughout the 360 degrees of the motor, uneven magnetic fields are produced.

These magnetic imbalances can cause movement of the stator windings, electrically induced vibration and eventually winding failure.

CONCLUSION

As the industry continues to develop more advanced ways to detect the faults that plague electric motors, facilities will have fewer unplanned failures and increased production. The excitement surrounding the correlation of technologies is growing.

The MCEmax combines the capabilities of the static MCE and the dynamic Emax testers to increase the confidence of the technician and to greatly improve the accuracy of the detection. This can only result in more educated maintenance groups and fewer mistakes in fault diagnosis.