MOTOR CURRENT SIGNATURE ANALYSIS AND INTERPRETATION

An ALL-TEST Pro White Paper By

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Introduction

Motor Current Signature Analysis (MCSA) involves the analysis of current and voltage supplied to an electric motor or from a generator. The analysis of collected data can be very straight-forward by following specific patterns and rules. The purpose of this paper is to provide the user with enough information to quickly review collected data.

This paper is based upon data collected using a combination of ALL-TEST Pro MCSA and Motor Circuit Analysis (MCA) equipment.

The ALL-TEST PRO™ OL MCSA Instrument

The ALL-TEST PRO OL (ATPOL) instrument is a hand-held instrument designed to collect voltage and current data for MCSA as well as being a fully functional power quality analysis tool. The instrument can be used stand-alone with the ability to store data directly into memory for later upload, or can be remote-operated from a laptop or PC for unlimited data collection.

Data is collected using a few simple keystrokes with at least nameplate horsepower, RPM, voltage and current rating being recommended. Bearing information and rotor bar and stator slot numbers can be used for even more accurate analysis. The software performs automated analysis of the incoming power and the electrical and mechanical condition of the motor. In most cases, analysis involves only collecting data and printing an automated report.

However, using the ALL-TEST PRO MD system, the user can view the complete motor system from incoming power to driven load for troubleshooting and analysis. Details on some of the calculations can be found in other ALL-TEST Pro papers, and so will not be covered here. However, we shall cover a simple method to quickly review data and, at a glance, make an accurate analysis.

The ALL-TEST PRO OL unit provides demodulated voltage and current, giving the user additional information for quick analysis.

Basic Steps for Analysis

There are a number of simples steps that can be used for analysis using MCSA. The steps are as follow:

1. Map out an overview of the system being analyzed.
2. Determine the complaints related to the system in question. For instance, is the reason for analysis due to improper operation of the equipment, etc. and is there other data that can be used in an analysis.
3. Take data.
4. Review data and analyze:
   - 4.1. Review the 10 second snapshot of current to view the operation over that time period.
   - 4.2. Review low frequency demodulated current to view the condition of the rotor and identify any load-related issues.
   - 4.3. Review high frequency demodulated current and voltage in order to determine other faults including electrical and mechanical health.

Most faults can be determined at a glance, with many rules being similar for both MCSA and vibration analysis. In addition, there are several rules that should be considered:

1. Pole pass frequency (ppf) sidebands around the line frequency indicate rotor bar faults. The higher the peaks, the greater the faults.
2. Harmonic pole pass frequencies often relate to casting voids or loose rotor bars.
3. Non-ppf sidebands that cause a 'raised noise floor' around the line frequency peak normally relate to driven load looseness or other driven problems.
4. 'Raised noise floor' signatures relate to such things as looseness or cavitation.
5. Peaks that show in current and voltage relate to electrical issues, such as incoming power. Peaks that show in current only relate to winding and mechanical faults.
6. Peak pairs that do not relate to running speed or line frequency are most often bearing related problems.

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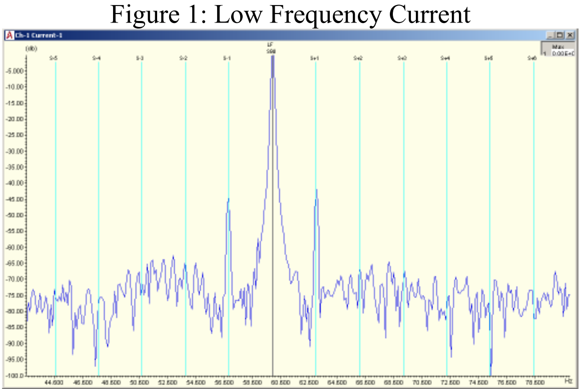
Knowing these rules, alone, will start us a long way towards being able to perform an analysis. Throughout the remainder of this white paper, we shall cover examples of this technique and these rules in use.

Rotor Bar Fault Example

Vibration analysis identified a potential rotor bar problem with a high-frequency running-speed related peak with ppf sidebands. Motor circuit analysis was performed. The unit was a 500 horsepower, 4160 Volt motor with current transformers (CT's) and potential transformers (PT's) available in a 120 Volt control cabinet. The system allowed for single phase voltage and current to be available.

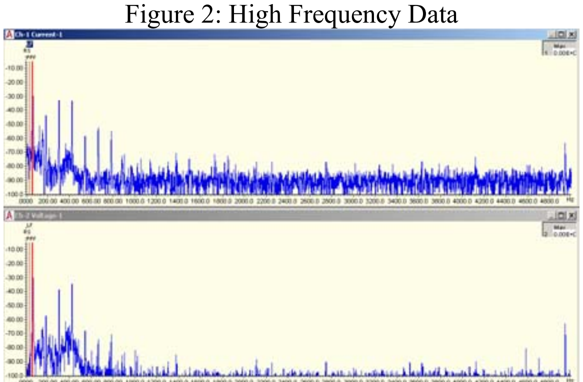
Figure 1: Low Frequency Current



The sidebands around the line frequency peak in Figure 1 identify a potential rotor problem. This case is obvious enough that the fault was identified without having to enter any nameplate information.

Higher frequency data, shown in Figure 2, does not provide information on any other serious potential faults in this compressor system.

Figure 2: High Frequency Data



Following the fault detection, the motor was removed and sent in for repair. The repair shop reported that the bearings needed replacement only. The following questions were asked of the repair shop:

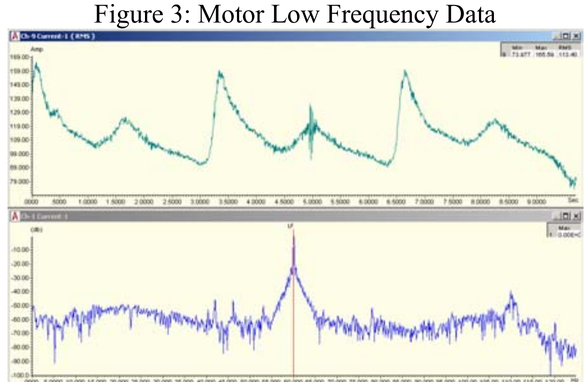
1. Was the rotor warmed up prior to performing a growler test. Sometimes a fracture will not show unless the rotor comes up to temperature.
2. Was the rotor tested using a single-phase method: 10% of the motor voltage applied to one phase then rotate the shaft using a clamp-on ampmeter.
3. Motor circuit analysis
4. Visual inspection

It was determined that no true rotor test was performed on the motor rotor and it was sent to a second motor repair shop. The second motor repair shop identified the rotor fault immediately using a growler test.

Punch Press Fault

An occassional noise eminated from an operating punch press for some time. The motor and eddy-current clutch are located at the top of the press with the motor connected to the clutch with a belt. The motor is 350 horsepower, 1690 RPM, 480 Vac and 420 Amps per the nameplate.

Figure 3: Motor Low Frequency Data

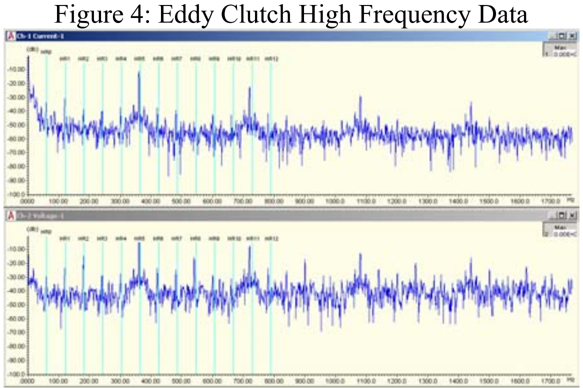


The low frequency data provides several key pieces of information. The upper graph shows the current across a 10 second period. The high peak currents are the lower part of the punch press stroke and the smaller peaks the top part of the stroke. With three occuring over 10 seconds, it was quickly determined that the punch press is operating at 18 strokes per minute. The middle top-stroke part of the current identifies that something is catching or rubbing at the top of the stroke. The second waveform shows a 'raised noise floor' around the line frequency peak. Both of these identify that the fault is most likely outside of the motor towards the load.

High frequency data identified some electrical supply related issues, that were also identified within the automated report as low power factor. Line sag was also identified as the motor progressed through its operation.

The eddy current clutch uses a full-wave rectifier. Data was collected to determine if the fault was located within the clutch.

Figure 4: Eddy Clutch High Frequency Data



When comparing the DC high frequency signature to the DC vibration troubleshooting chart, the multiple harmonics of 60 Hz (line frequency) and the multiple harmonics of 360 Hz (number of SCR's times line frequency) indicate a loose connection or bad SCR. In this case, it was a loose connection (for DC analysis, use DC vibration charts).

So far, we have been to determine that there are power quality issues, loose connections in the eddy current clutch, but nothing that would identify the particular noise that was the purpose of the investigation other than a load related rub. The direction of the investigation was now able to change to the driven equipment. It was concluded that the noise was coming from a loose counter-balance weight that would catch at the top of the punch press stroke.

Submersible Pump Problem

Rotor eccentricity was detected in a 7.5 horsepower, 1750 RPM submersible pump during a quality control analysis using MCA. The pump was tested at no load and compared to another submersible pump, also tested at no load. The MCSA analysis software allows for a quick comparison between signatures.

In this case, the comparison (Figure 5 and 6) identifies a problem with the rotor. The fault was determined to be both static and dynamic eccentricity with the rotor striking the stator core. The correction was to replace the rotor, which was found to be mounted off-center on the shaft.

Figure 5: Good Submersible Pump Signature

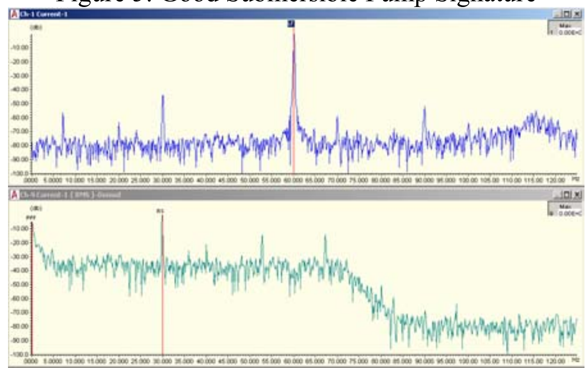
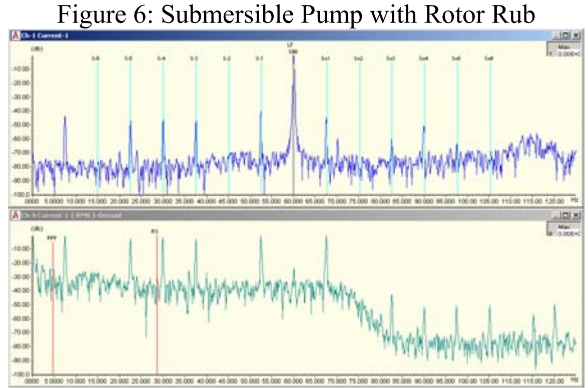


Figure 6: Submersible Pump with Rotor Rub



Condition and Energy Analysis

A 50 horsepower, 1775 RPM, 64.5 Amp, 440 Vac standard efficient motor driving a glycol pump was tested in operation. Automated analyisis indicated mechanical (bearing), winding and load faults.

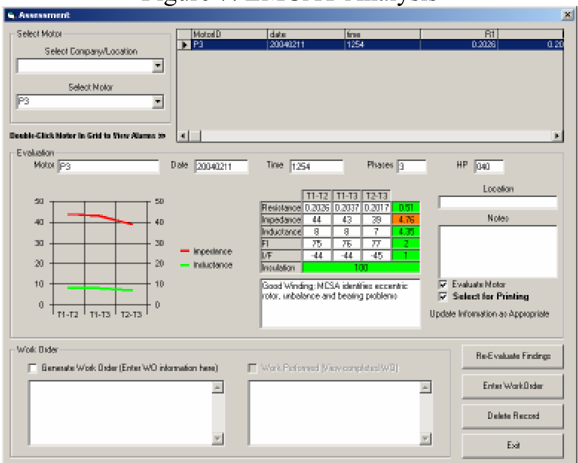
Using the collected voltage, current, software-determined RPM, power factor and kW demand, it was determined, using the US Department of Energy's MotorMaster Plus software, the motor was loaded 89.3% at 91.5% efficiency.

The motor was compared to a premium efficiency replacement using MotorMaster Plus, which determined that there would be a 0.9 year simple payback. This equates to a 366% after tax return on investment. In a few minutes, motor and load-related faults were determined and a repair versus replace decision made.

Multi-Technology Review

A 40 horsepower, 1760 RPM, 460 Vac, 46.5 Amp vertical pump motor was evaluated, due to noise, using motor circuit analysis. The MCA readings indicated that the motor windings were in good health (Figure 7).

Figure 7: EMCAT Analysis



MCSA data indicated poor bearing condition, static eccentricity and vibration (Figures 8 and 9).

Figure 8: Low Frequency Data

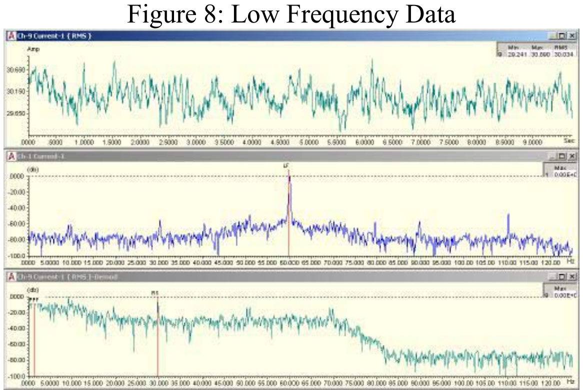
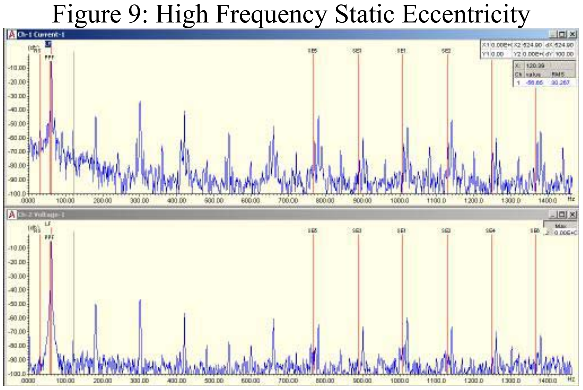


Figure 9: High Frequency Static Eccentricity



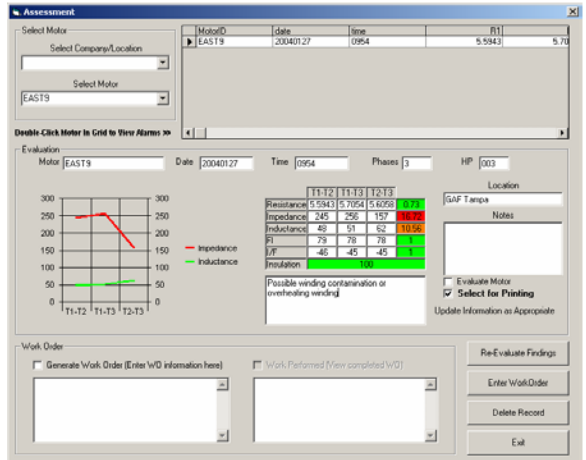
Winding and mechanical-related sidebands with slightly-raised noise floors exist in current data around the supply power frequencies.

Due to minor mechanical repairs and the type of motor, this motor was repaired versus replaced.

Motor and Fan Review

A small 4-blade fan driven by a 3 horsepower, 1765 RPM, 460 Vac, 9.3 Amp electric motor was reviewed in a high humidity environment mounted on the wall of a steel building. Motor circuit analysis identified winding contamination (Figure 10).

Figure 10: EMCAT Analysis of Winding Contamination



MCSA identified a series of motor-related problems including static and dynamic eccentricity and mechanical problems (Figures 11-14).

Figure 11: Low Frequency Data

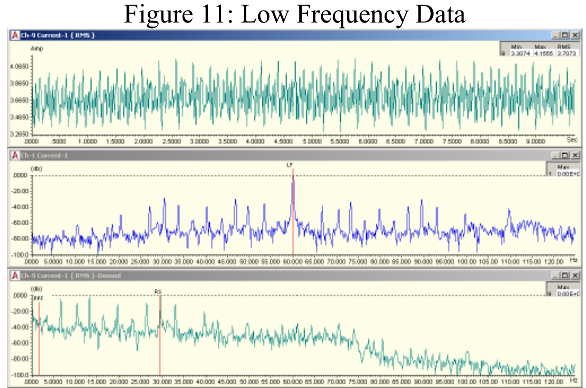


Figure 12: Static Eccentricity

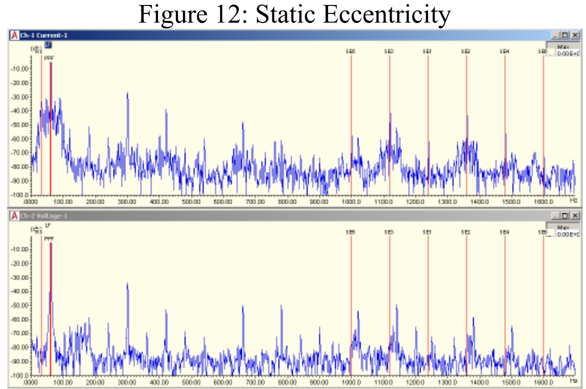


Figure 13: Dynamic Eccentricity

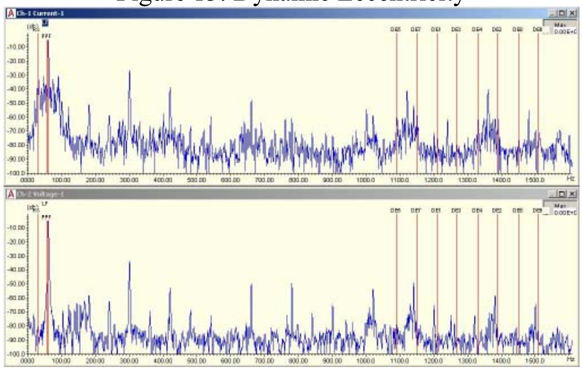
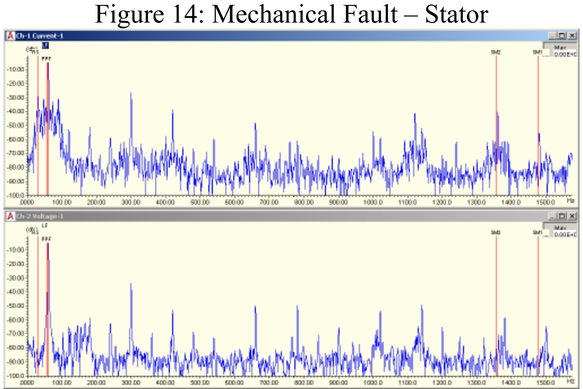


Figure 14: Mechanical Fault – Stator



Also noted were slight raised noise floors around critical frequencies. This indicates looseness.

MotorMaster Plus identified the motor as operating at 85% load and 82.8% efficiency. A replacement premium efficient motor was identified with an immediate payback with the replacement cost being less than the repair cost.

Conclusion

Most motor related faults are obvious when viewed with MCA and MCSA technologies. A simple method with simple rules can be viewed in order to determine system health.

Steps include collecting some basic operation and history information, viewing MCA data, when available, then viewing low frequency before high frequency data. The ALL-TEST PRO OL MCSA system can be used to perform automated analysis, with conclusions, as well as identifying specific frequencies automatically with limited information.

About the Author

Dr. Penrose joined ALL-TEST Pro in 1999 following fifteen years in the electrical equipment repair, field service and research and development fields. Starting as an electric motor repair journeyman in the US Navy, Dr. Penrose lead and developed motor system maintenance and management programs within industry for service companies, the US Department of Energy, utilities, states, and many others. Dr. Penrose taught engineering at the University of Illinois at Chicago as an Adjunct Professor of Electrical, Mechanical and Industrial Engineering as well as serving as a Senior Research Engineer at the UIC Energy Resources Center performing energy, reliability, waste stream and production industrial surveys. Dr Penrose has repaired, troubleshot, designed, installed or researched a great many technologies that have been, or will be, introduced into industry. He has coordinated US DOE and Utility projects including the industry-funded modifications to the US Department of Energy's MotorMaster Plus software in 2000 and the development of the Pacific Gas and Electric Motor System Performance Analysis Tool (PAT) project. Dr. Penrose is the Vice-Chair of the Connecticut Section IEEE (institute of electrical and electronics engineers), a past-Chair of the Chicago Section IEEE, Past Chair of the Chicago Section Chapters of the Dielectric and Electrical Insulation Society and Power Electronics Society of IEEE, is a member of the Vibration Institute, Electrical Manufacturing and Coil Winding Association, the International Maintenance Institute, NETA and MENSA. He has numerous articles, books and professional papers published in a number of industrial topics and is a US Department of Energy MotorMaster Certified Professional, as well as a trained vibration analyst, infrared analyst and motor circuit analyst.