

# Electric Signature Analysis

By Donald V. Ferree & Nissen Burstein  
Framatome ANP  
**UltraCheck**® Diagnostics

## Abstract

Electric Signature Analysis (ESA) is a diagnostic and analysis technique that is being used to analyze motors, generators, alternators, transformers, and other electric equipment. This new technology has the ability to test operating electrical equipment and identify a variety of mechanical and electrical problems. ESA traces can be used to analyze the driven load, the power supply, and perform inrush testing on motors. As a preventative maintenance tool, ESA can be used to perform a one-time test or periodic testing to track and trend equipment performance. ESA is remote, non-intrusive, and is invisible to the equipment being monitored!

## 1 Introduction

This lecture discusses the relatively new technology of Electric Signature Analysis and presents several case studies of real-world situations where a commercially available system was used to solve real problems.

ESA is used to evaluate rotors, stators, and rotor-stator air gap conditions in electric motors. This is one of its prime uses. In many cases, a one-time test can be used to determine if problems are present in the motor. More often, trending is required to determine severity and changes in conditions.

Current and voltage data are acquired directly from the Motor Control Center (MCC), while the equipment is in operation. The collected data is then used to determine phase imbalance, motor load, power factor, power harmonics, and the impact of the driven equipment on the motor. Rotor bar as well as stator health and rotor-stator eccentricity (air gap) characteristics are also assessed. In addition, degraded bearings can also be observed from the traces. ESA is particularly helpful in accessing mechanical conditions when it is not possible or convenient to make vibration measurements.

Figure 1 shows the three phase current sine waves for a 15 HP motor driving a pump. The unbalance in current is about 38%, much higher than acceptable to continue running this motor. When the motor was taken from service and opened up, a turn-to-turn short encompassing nearly half of one phase was observed.

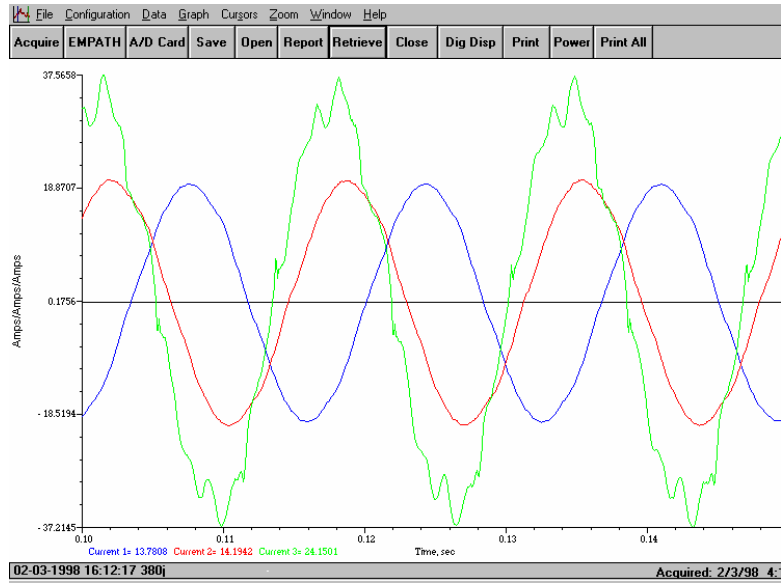


Figure 1. Three phase currents of 15 Hp motor with a severe turn-to-turn short.

Figure 2 shows the current spectrum of one phase of a motor driving a compressor. The rotor has broken rotor bars as evidenced by the amplitude of the pole passing sidebands around the line frequency peak at 59.97 Hz.

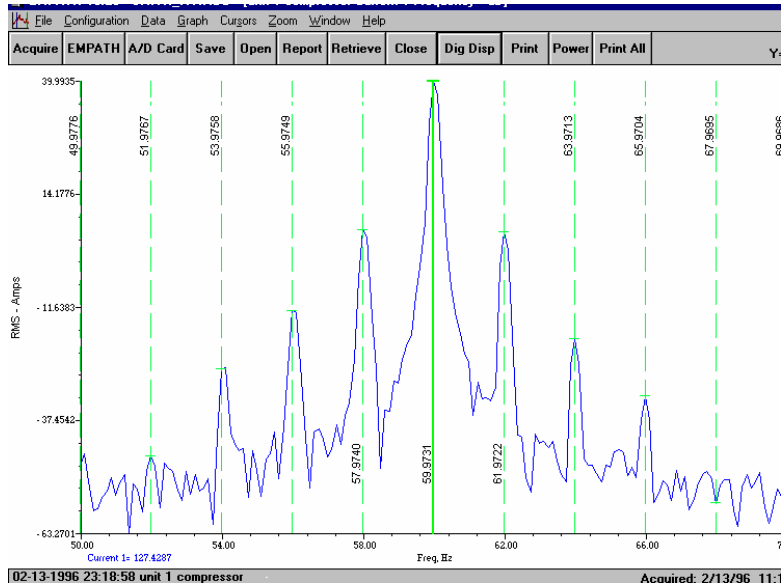


Figure 2. Current spectrum of 300 Hp motor showing pole passing sidebands to line frequency.

Figure 3 shows the peaks evident in the current spectrum of a motor that has a broken bearing. The peaks highlighted by colored cursors are a result of the modulation of the current draw of the motor by the broken bearing.

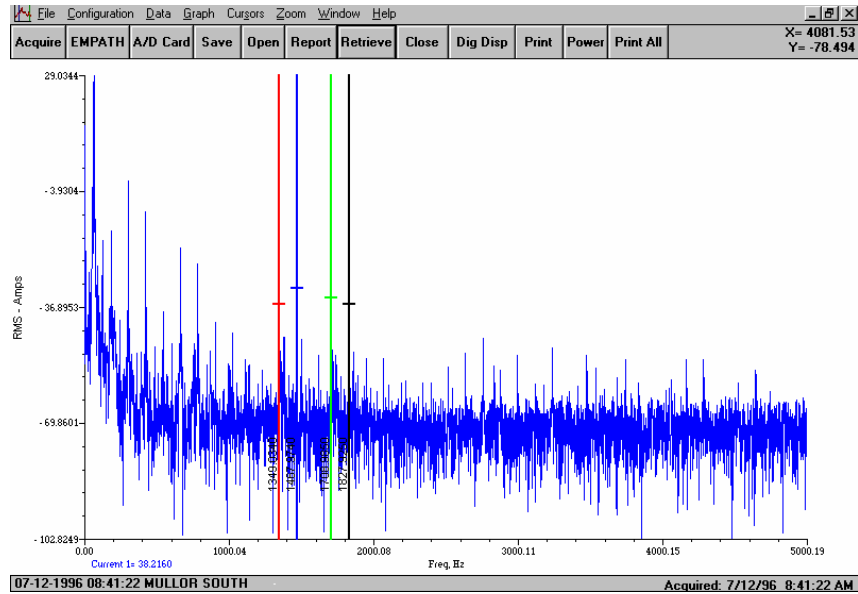


Figure 3. Current spectrum of a 200 Hp motor showing a bearing damage pattern.

For DC motors and motors with separate power supplies, such as variable frequency drives, ESA monitors the power supply and can point out problems in it.

Figure 4 shows the armature current spectrum for a DC motor. The large peak at 360 Hz indicates the DC drive is full-wave-rectified. The large peaks at 120 and 240 Hz indicate problems in the control circuitry of the DC drive.

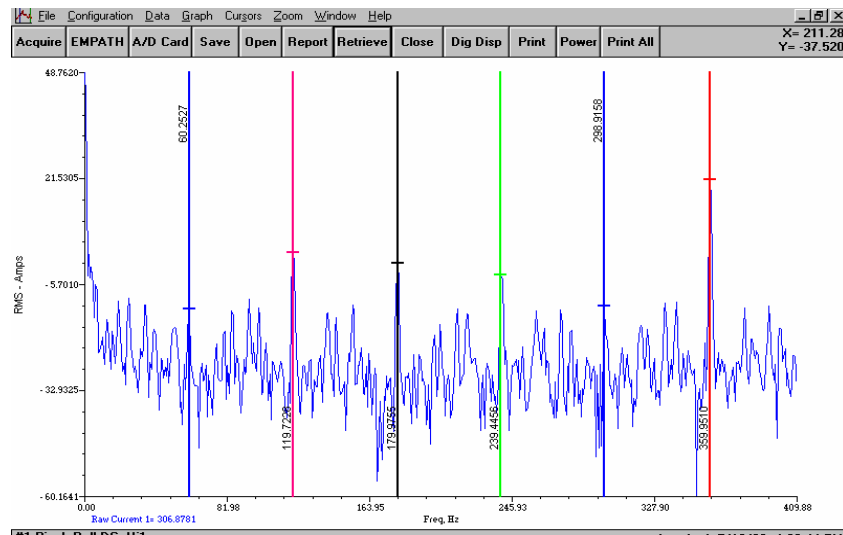


Figure 4. Current spectrum of DC motor showing drive characteristics.

## 2 Trending of Motor Data

ESA becomes even more useful, however, for trending motor indications; because, in some cases, a motor's base-line signature may not be known. The ideal information a predictive/preventive maintenance engineer needs to know is, "How long until I need to replace or repair this motor?"

Rarely can a one-time test provide this data. However, trending will give this input by providing an indication of how quickly a motor condition is changing. For example, if an indication of rotor degradation appears, it may not be clear from one test how rapidly the rotor circuit is degrading. Testing over several weeks or months will confirm if the rotor is stable and not changing. The number of starts and stops that a motor experiences is very important regarding rotor change. A motor with a high on-off duty cycle is much more likely to show rapidly increasing rotor degradation than a motor that runs constantly. These types of operating conditions can be factored into the trending data to provide a much clearer indication of motor health.

Figure 5 shows the current spectrum of a 1750 Hp motor that has "soft foot". The "soft foot" shows up as static eccentricity, or air gap variation. The peaks highlighted by the colored cursors are the rotor bar passing peaks indicative of static eccentricity. This condition can be determined with a single test. Degrading static eccentricity will be seen as the peaks grow in amplitude.

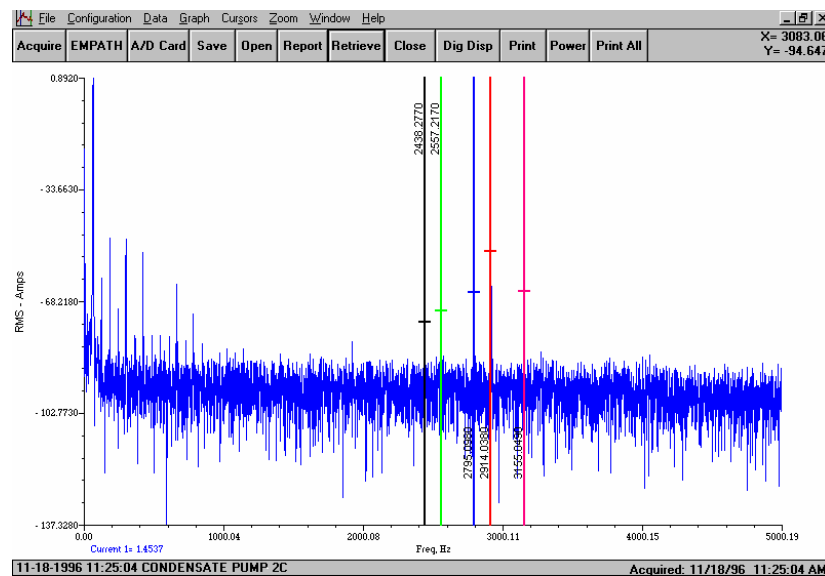


Figure 5. Current spectrum of 1750 Hp motor showing rotor bar passing pattern.

### 3 Monitoring the Driven Load

In some cases, it is the driven load that is more important to the Predictive/Preventative Maintenance professional than is the motor. In this case, ESA is used to differentiate between the motor and load characteristics. This has been successfully demonstrated on pulverizers at coal-fired power plants, on motor-operated valves, pump motors, and in other areas.

Figure 6 shows the demodulated current spectrum of a motor driven by a variable frequency drive. The motor drives a belt that drives a fan. The peaks in the spectrum are the belt passing peak at 5.64 Hz, the second harmonic of belt passing at 11.24 Hz, motor running speed at 22.05 Hz and fan blade passing at 41.44 Hz. The VFD was running at about 45 Hz and the motor has four poles.

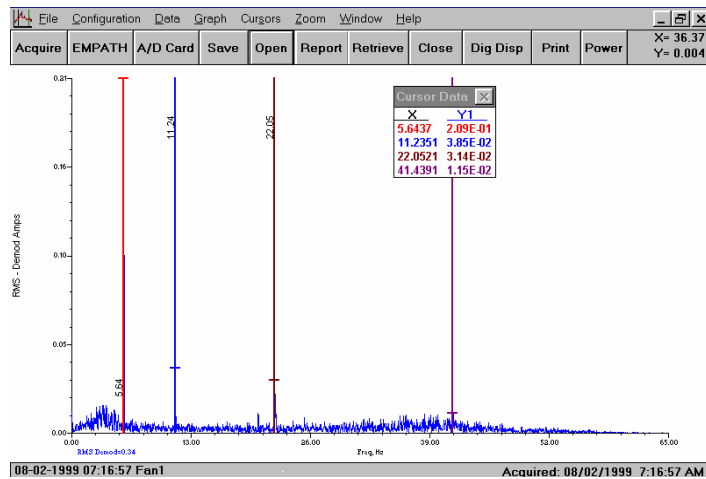


Figure 6. Demodulated current spectrum showing belt passing, motor running speed and blade passing.

Figure 7 shows the demodulated spectrum of a DC motor driving a gearbox. The peaks at 8.62 Hz and multiples are from one of the shafts in the gear box. Sidebands are evident around the peak at 8.62 Hz; these come from gear meshing modulation on the shaft. The numerous peaks at the lower end of the spectrum come from the gearbox shafts and from the hunting tooth frequencies in the gear meshing.

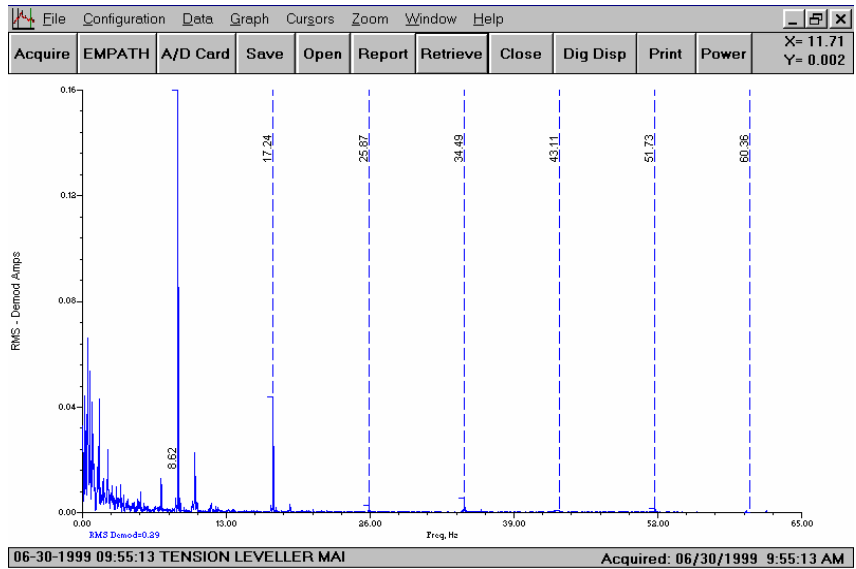


Figure 7. Demodulated current spectrum of DC motor showing gearbox features.

#### 4 Monitoring the Power Supply

The power supply, a variable frequency drive or the power coming in on the bus, are all-important components of the load-driving system. In some cases, the power supply contributes to the problems being experienced with the motor. ESA is used to diagnose problems in the power supply and can provide insight into the root cause of motor problems that can be obtained in no other way.

Figure 8 shows the voltage supplied by a VFD when the VFD is being overdriven by high voltage. Note first the peak at 52 Hz, the drive output line frequency. Then note the large number of peaks near 2975 Hz which arise from the chopping frequency of the VFD. In this case, the motor being powered by this VFD was being destroyed because of the high frequency ripple riding on the VFD line frequency.

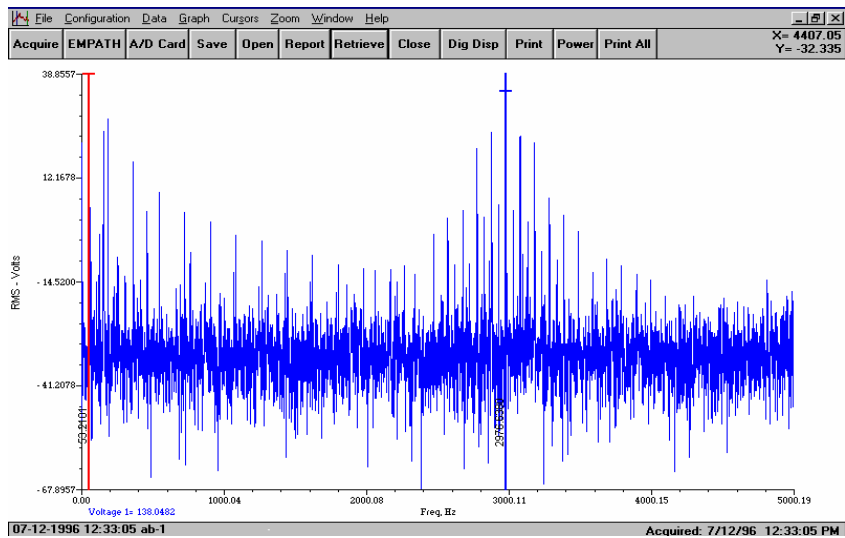


Figure 8. Current spectrum of VFD showing line frequency and chopping frequency peaks.

## 5 Inrush Testing

ESA is also useful for inrush testing. Inrush testing can provide data on the motor and the power circuit, including breakers. This information can be used to help diagnose motor or power supply problems that can be used to improve motor performance. In one case, breaker bounce was detected and enabled the plant maintenance engineer to understand why the plant struggled to bring the motor on line.

Figure 9 shows the inrush for a 9,000 Hp motor attached to a pump. Note that it takes over 11 seconds for this motor to come to its normal operating speed. Most motors achieve standard operating speed in a second or less, but this 9,000 Hp motor/pump represents a very large mass to bring up to speed.

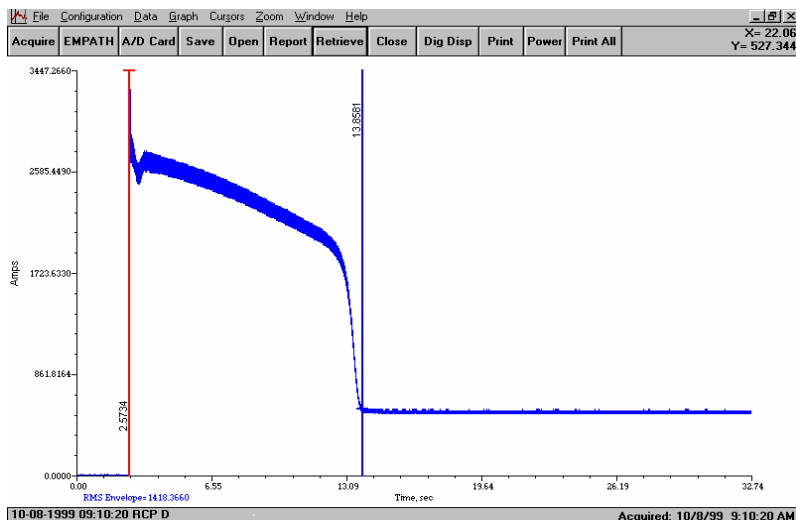


Figure 9. Inrush current of 9,000 Hp motor and pump requiring almost 11 seconds to start.

## 6 Conclusions

ESA is a useful tool to monitor and diagnose the power supply, the motor and the driven load. ESA can be used to perform a one-time test or periodic testing to track and trend equipment performance. ESA is remote, non-intrusive, and is invisible to the equipment being monitored. Data acquisition takes less than two minutes per motor. LAN-based, continuous monitoring of motors is readily accomplished.

## 7 References

- [1] Brown, E. David, "Current Signature Analysis at the Everett Plant of Boeing Commercial Airplane Group," *P/PM TECHNOLOGY*, August – 1998.
- [2] Lang, George Fox, "Of Cages, Induction, Deduction, Bars, Vars and Squirrels," *SOUND AND VIBRATION*, December - 1994.
- [3] Burstein, Nissen M. and Ferree, Donald V., "Monitoring Electric Motor Condition Using Current Signature Analysis: Case Histories and Success Stories," International Maintenance Technology and Information Symposium, November - 1996.
- [4] Lanier, Chris, "What to look for in inverter-duty motors", *PLANT ENGINEERING*, December - 1998.
- [5] Phipps, Clarence A., (1999) Variable Speed Drive Fundamentals, The Fairmont Press, Lilburn, GA.
- [6] Nailen, Richard L., (1996) Managing Motors, Second Edition, Barks Publications, Inc., Chicago, IL.
- [7] Patrick, Dale R. and Fardo, Stephen, W., (1996) Rotating Electrical Machines & Power Systems, The Fairmont Press, Lilburn, GA.
- [8] Berry, James E., (1992) "Comparison of Motor Current Analysis and Vibration Analysis in Detecting Rotor Bar and Air Gap Eccentricity Problems in Induction Motors," Technical Associates of Charlotte, Inc., Charlotte, NC.
- [9] Simoncic, David A. and Berry, James E., (1996) "DC Motor and Control Problem Identification Using Vibration Analysis," Technical Associates of Charlotte, Inc., Charlotte, NC.
- [10] Mazur, Glen A., (1999) Power Measurement and Trouble Shooting, American Technical Publishers, Inc., Homewood, IL.