

Abstract



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Electric Signature Analysis (ESA) is a diagnostic and analytic technique that is being used to analyse 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 analyse the driven load, the power supply, and perform inrush testing on motors. As a preventive maintenance tool, ESA can be used to perform a one-off test or periodic testing to track and trend equipment performance. ESA is remote, non-intrusive, and is invisible to the equipment being monitored

ELECTRIC SIGNATURE ANALYSIS

INTRODUCTION

As well as reviewing the relatively new technology of Electric Signature Analysis this paper will present several small examples of real-world situations where a commercially available system was used to solve real problems.

ESA is used to evaluate the state of rotors, stators, and rotor-stator air gap conditions in electric

motors. This is one of its prime uses. Although, in many cases, a one-off test can be used to determine whether problems are present in the motor, it is more often the case that trending is required to determine the severity of a problem and to detect changes in condition.

Current and voltage data are acquired directly from the Motor Control Centre (MCC, while the equipment

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

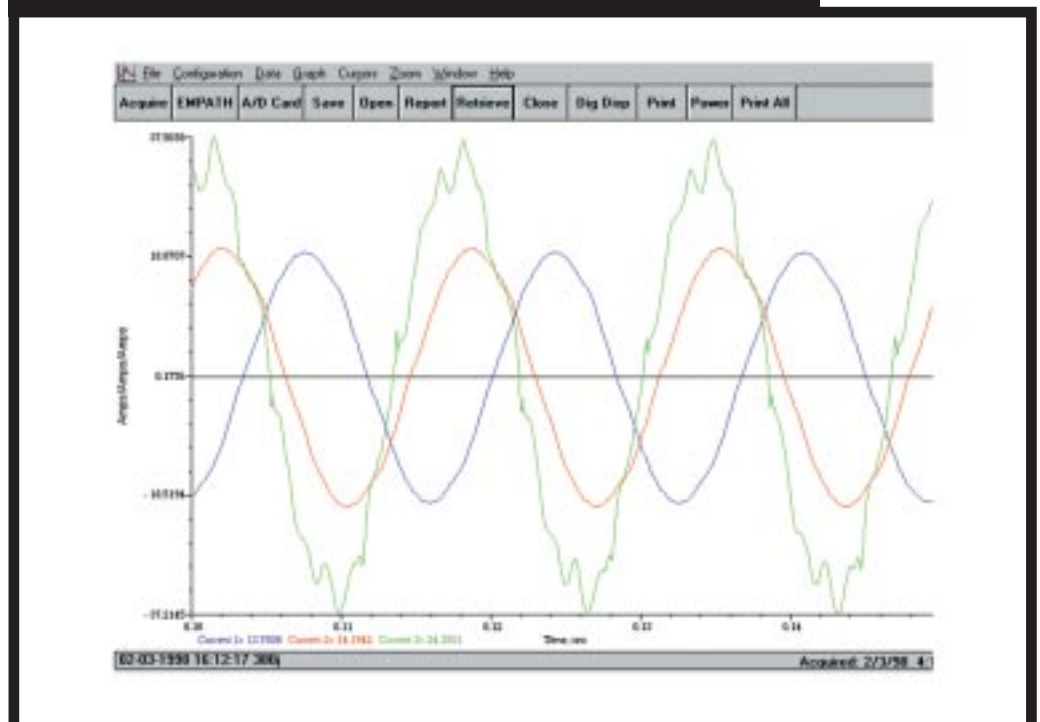


Figure 2
Current spectrum of 300 HP motor showing pole passing sidebands to line frequency.

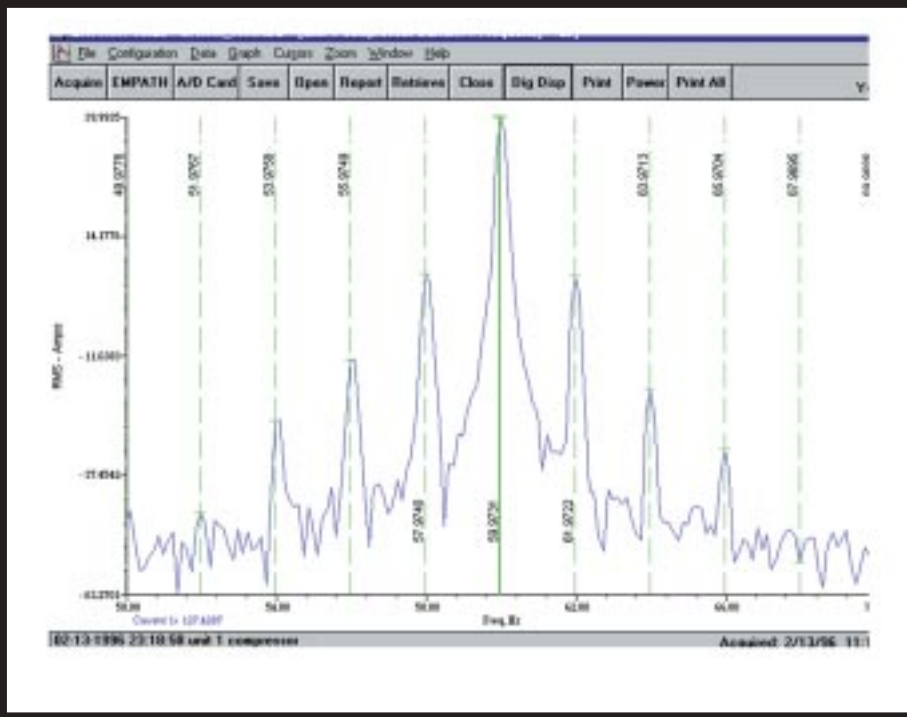
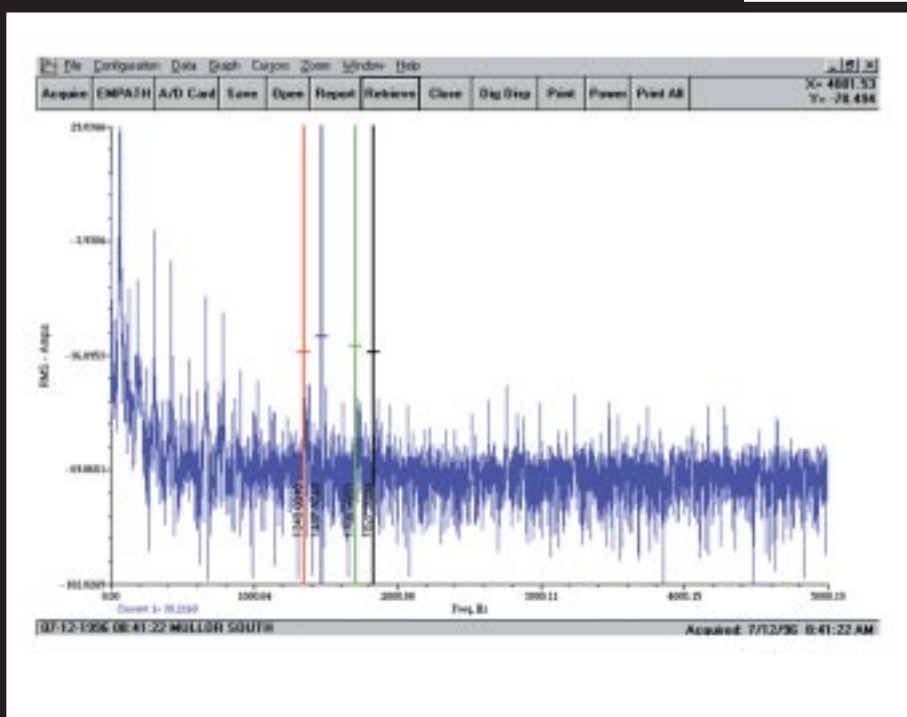


Figure 3
Current spectrum of a 200 HP motor showing a bearing damage pattern.



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 detected 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 for continued running of 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 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 at 59.97 Hz.

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

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 that 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

TRENDING OF MOTOR DATA

ESA becomes even more useful, however, for detecting trends in motor conditions when, as in some cases, a motor's base-line signature may not be known. The ideal information a predictive or preventive maintenance engineer needs to know is how long he has until he needs to replace or repair any particular motor. Rarely, however, can a one-

Figure 4
Current spectrum of DC motor showing drive characteristics.

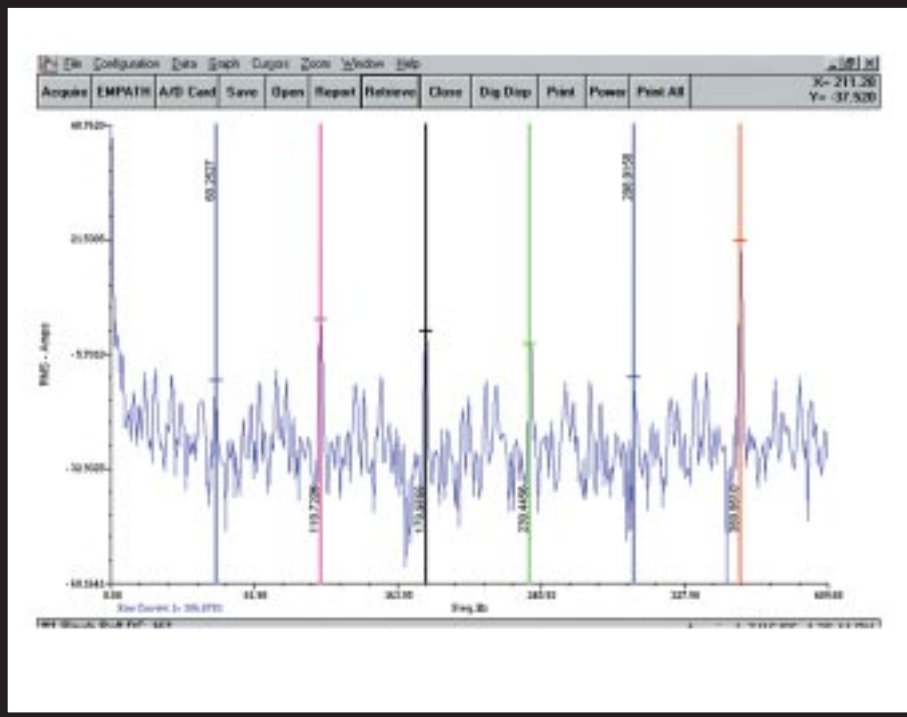
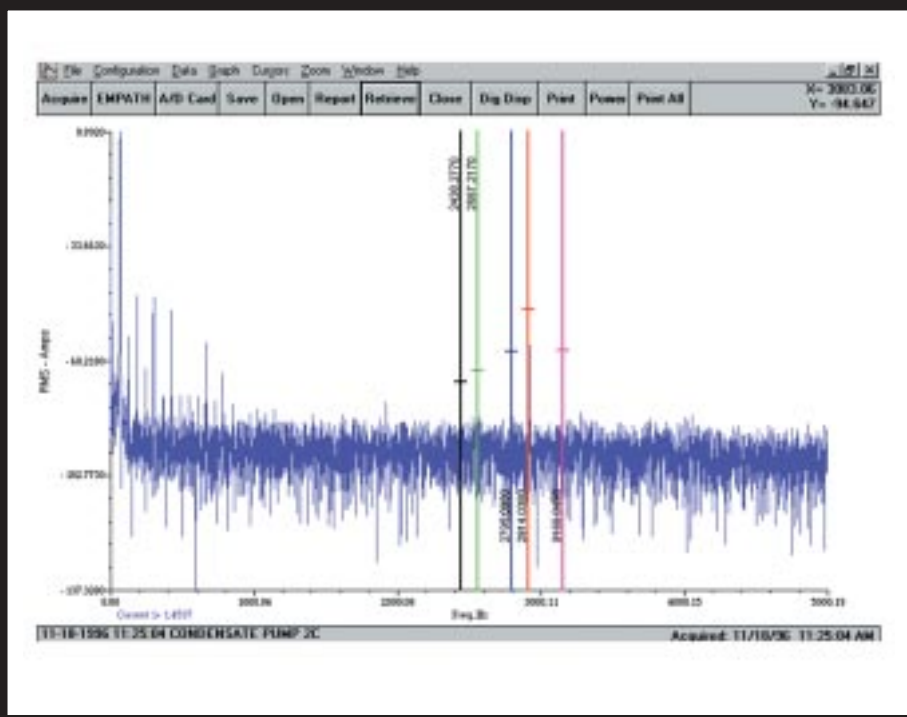


Figure 5
Current spectrum of 1750 HP motor showing rotor bar passing pattern



off test provide this information, but trending will do so 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 rapid such degradation is. 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'. This shows up as static eccentricity, or air gap variation. The peaks highlighted by the coloured 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

MONITORING THE DRIVEN LOAD

In some cases it is the driven load that is more important to the predictive or preventive 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 pulverisers at coal-fired power plants, on motor-operated valves, pump motors, and in other areas.

Figure 6 shows the de-modulated current spectrum of a motor driven by a variable frequency drive. The motor drove a belt that drove 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 had four poles

Figure 7 shows the de-modulated 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

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

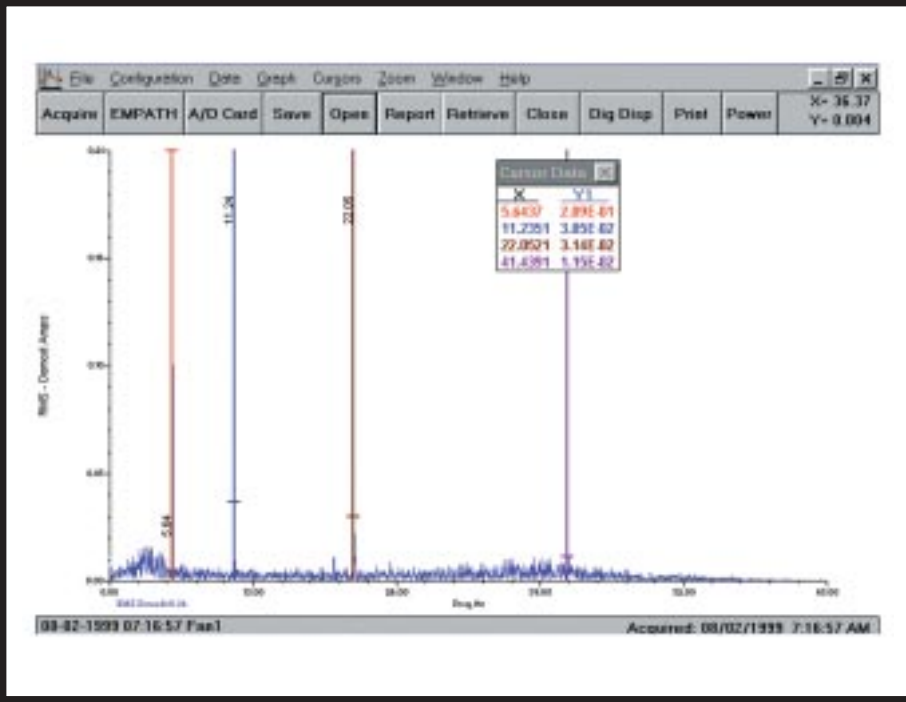
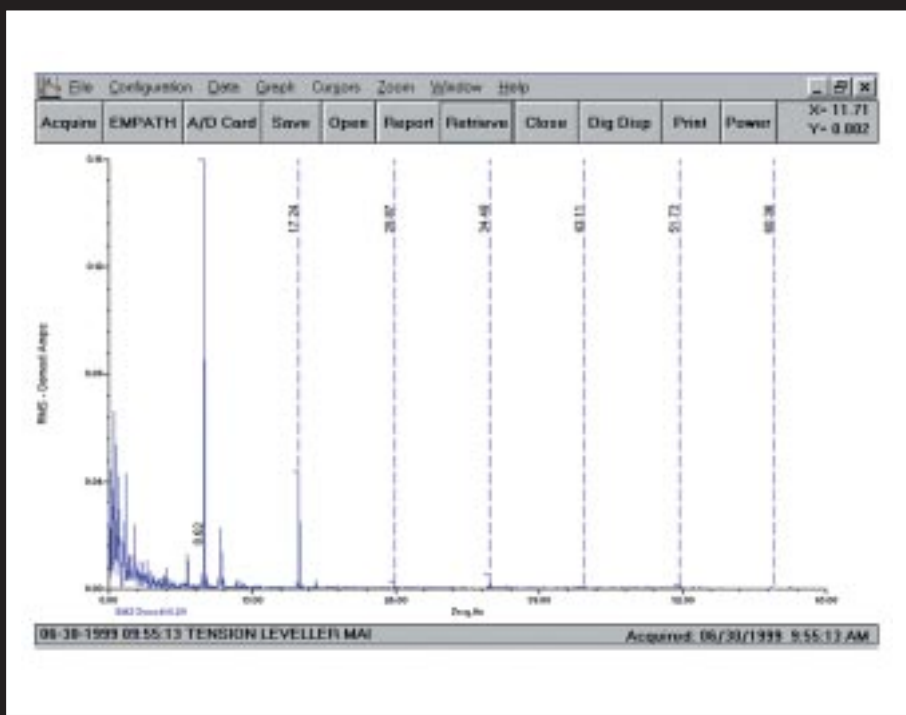


Figure 7
Demodulated current spectrum of DC motor showing gearbox features



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.

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.

INRUSH TESTING

ESA is also useful for inrush testing, which 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 eleven seconds for this motor to come to its normal operating speed. Most motors achieve standard operating speed in a second or less, but this motor and pump combination presents a very large mass to bring up to speed.

CONCLUSIONS

ESA is a useful tool for monitoring and diagnosing the power supply, the motor and the driven load. It can be used to perform a one-off test or as a periodic test to track and trend equipment performance. ESA is remote, non-intrusive, and is invisible to the

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

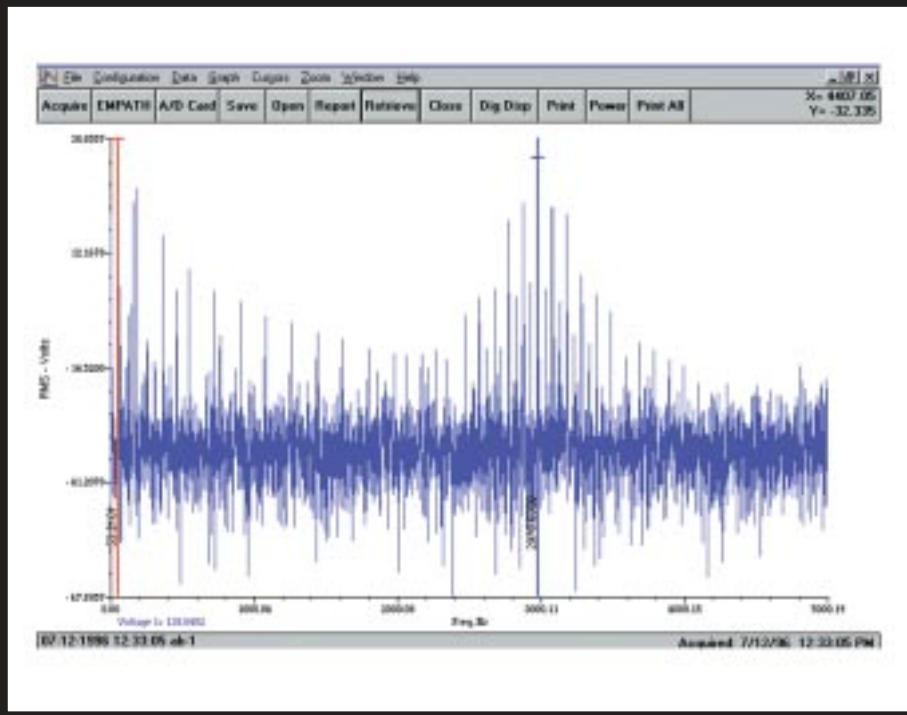
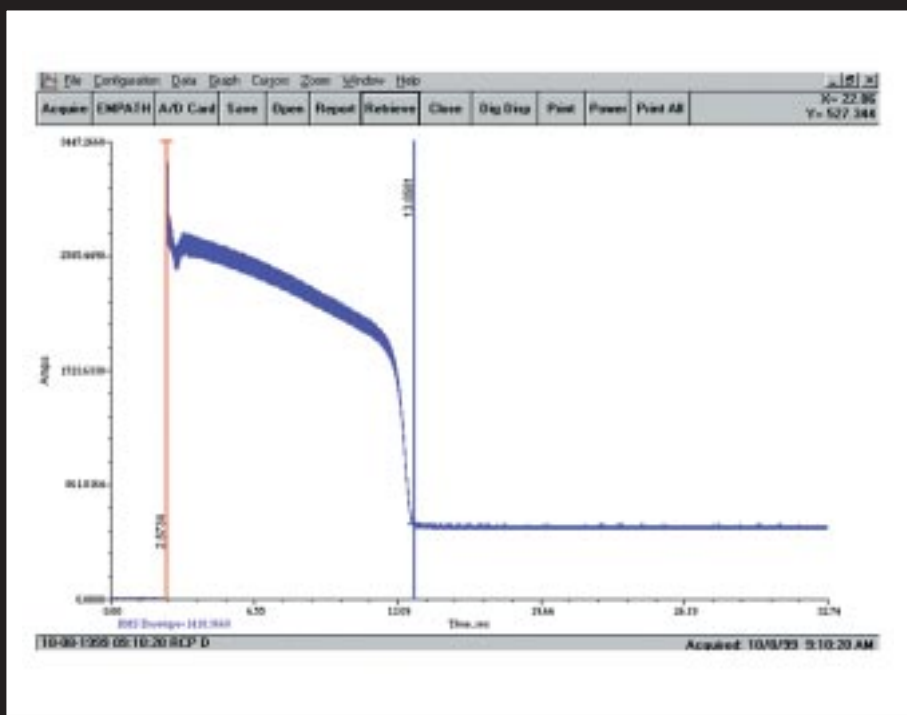


Figure 9
Inrush current of 9,000 HP motor and pump requiring almost eleven seconds to start.



equipment being monitored. Data acquisition takes less than two minutes per motor. LAN-based, continuous monitoring of motors is readily accomplished. ■

FURTHER READING

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