Eastman Chemical Company Motor Analysis…Stepping out of the Box

By: Tom Whittemore, Jr., P.E.; Paul Aesque; and Danny Hawkins, Eastman Chemical Company

Eastman Chemical Company started its Motor Analysis Program in late 1998 when we purchased an online power analyzer. After several months of testing, we found the analyzer to be limited for rotor/stator testing at our plant, due to the low-level loads on many of our motors. The power quality testing was also limited at our facility because we produce most of our own utilities and our power quality is very good.

Therefore, in 1999 we started pursuing other options for condition monitoring of motors. We set up three motors with controlled conditions: shorted wires in turn, offset rotor 0.01", shorted stator core steel and an open rotor bar. A vendor representative was brought in to test these motors offline. All conditions were correctly identified and a decision was made to purchase the vendor's analyzer. We have been using the analyzer for approximately two years now and are very pleased with the results. Although most of the analyzers are advertised as rotor bar analysis tools, this article discusses some of the areas into which we have expanded the use of this technology at our plant.

Rod Mill Clutch Engagement

Rod mills are used to crush the coal used in our gasification process. The pinion gear transmits motor torque through the gear reducer to the rod mill's gear reducer (Figure 1). The motor is connected to the gearbox through a clutch, which uses an inert gas to engage the clutch disk. The clutch in turn is coupled to the gearbox, which in turn is coupled to the rod mill. The pinion's design life is five years minimum. Between 1997 and 1998, five pinions failed (Figure 2) between the two rod mills in our gasification process.

Figure 1- Gasification process rod mill, 800 HP motor, clutch and gearbox.

Figure 2- Rod mill pinion shaft failure.

A Root Cause Failure Analysis Team was formed to determine the root cause(s) of the pinion shaft failures. Several problems were identified that could be attributed to shorter than design pinion life. Some of these were:

- Too high of a rod charge level.
- Improper pressure switches that allowed the mill to be started with inadequate oil pressure.
- An inadequate startup procedure. The original procedure called for the mill to come to a complete stop before restarting it. The revised procedure did not include this statement. Operators had been trained using the revised procedure.
- The inert gas pressure in the clutch was too high.
- Improper clutch engagement time. The clutch manufacturer said the clutch should smoke 5-7 seconds to fully engage. Faster times will overload the pinion shaft and motor. The clutch is designed to be the wear part of the system, not the pinion shaft.

During the root cause investigation, one of the verification steps was to determine the clutch engagement time. The Motor Analysis Team (MAT) proposed the idea of monitoring the current on the motor to attempt to determine the clutch engagement time. The MAT used the current analysis in-rush test function on the analyzer to capture the motor current data. From this data, we were able to calculate the engagement time for the clutch. The initial test indicated a very rapid clutch engagement time, approximately 2.25 seconds, similar to an across the line start for the motor and clutch (Figure 3).

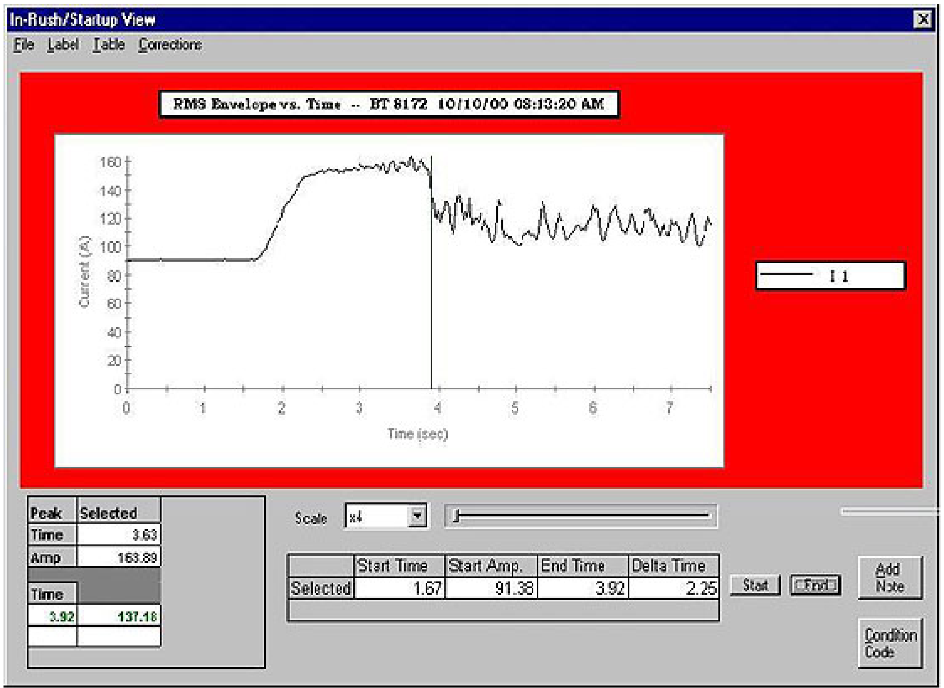


Figure 3- In-rush test results on initial clutch engagement test.

Using the analyzer to determine the clutch engagement time, while working with operations, maintenance and plant support engineering; the clutch engagement time was adjusted back to manufacturer's specification of between 5 to 7 seconds (Figure 4). The rod mills have not experienced a shaft breakage now for approximately 2½ years. The in-rush current test is now used as an annual proactive maintenance procedure to verify the clutch engagement time is within specification.

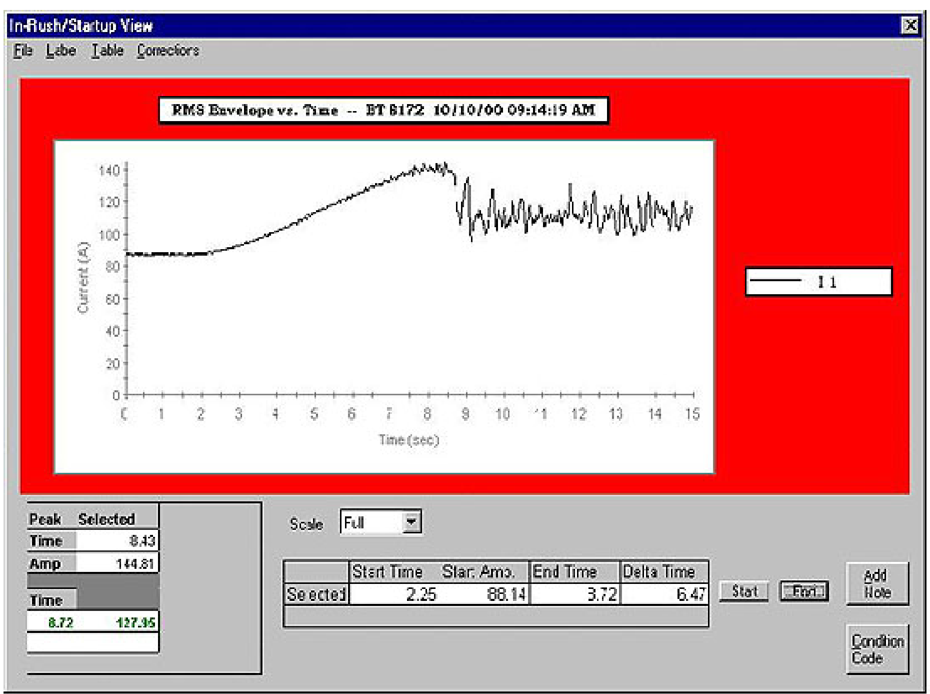


Figure 4- In-rush test results on final clutch engagement test.

Grinder Motor Failures

We currently have six grinders in our B-255 Polymer process plant being driven by 50 HP, 480 Volt, 1800-rpm motor. The MAT was requested to evaluate the subject motors because four of these motors were blowing 100 amp fuses at an excessive rate of approximately once per 12-hour shift (Figure 5). The CSM's were replacing all three 100 amp fuses at the motor starter when one would blow. This used more fuses, but resulted in fewer failures and less production losses.

Figure 5- Failed 100 amp fuse graveyard for grinder motors.

The MAT evaluated the six motors using the in-rush current analysis test. The results indicated that four of the motors had a very high startup acceleration rate compared to the other two motors. The instantaneous amps were 20% greater and the acceleration time was approximately 2.5 times longer on these four motors when compared to the other two motors (Figures 6 & 7). When comparing time versus current for these fuses, the MAT reps found that the motor was operating at or near the failure point of the fuse during startup. Upon closer investigation of the motors, it was determined that a NEMA A Design motor was being used in the four locations that were blowing fuses excessively. As a result, the MAT recommended replacing the NEMA A motors with a NEMA C Design motor. However, the motor was replaced with a TECO NEMA B Design, which has similar starting torque characteristics to a NEMA C Design motor. The replacement motor was checked on startup and no problems or concerns were noted.

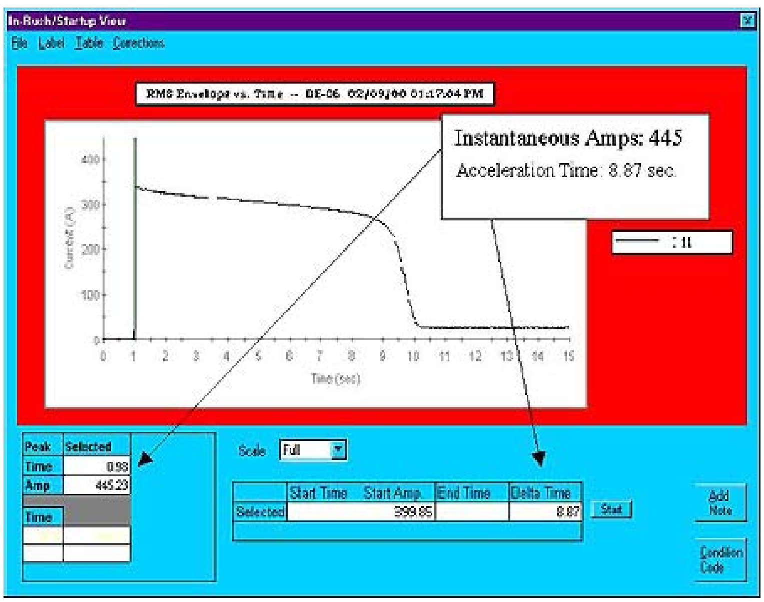


Figure 6- In-rust test results for NEMA A design motor.

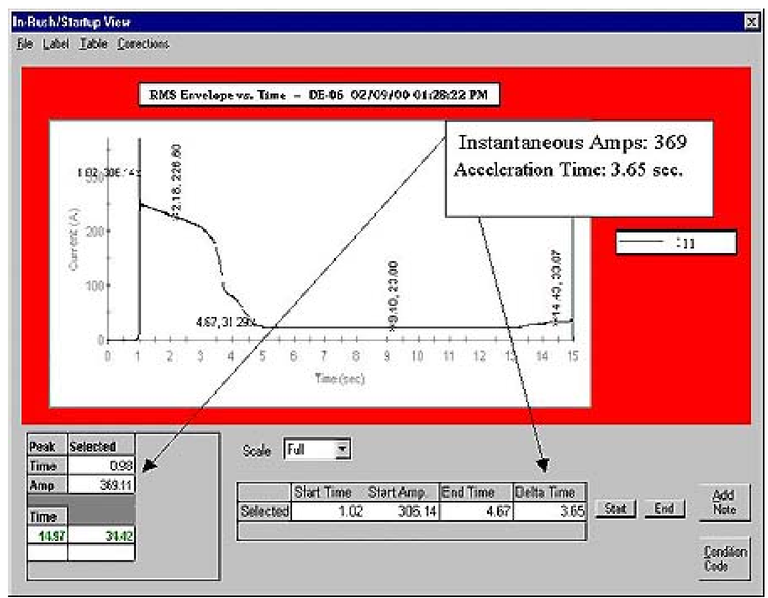


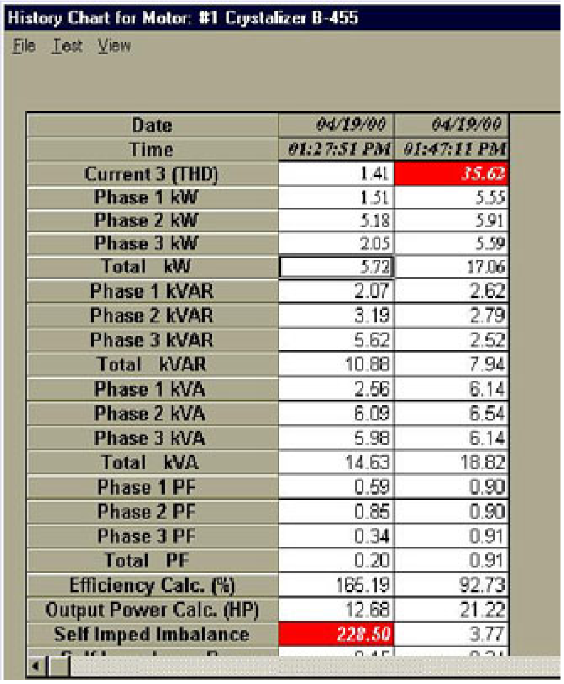
Figure 7- In-rush test results for NEMA C design motor.

VFD Driven Agitator Motor

The MAT was requested to check horsepower loading on three crystallizer agitator drive motors powered by Variable Frequency Drives (VFD) because operations had higher than manufacturer specified loading on the motors. Power Analysis Testing was performed on both the input and output of the inverter (Figure 8). The total KW on the input side corresponded with the KW displayed on the DCS in the control room. The total KW on the output side matched the manufacturer's estimate for horsepower load in this application.

During analysis of the test results, we determined that the instrumentation supplying the DCS was connected to the input side of the VFD creating higher than expected readings. This can be seen in Figure 9 where the input and output load readings are compared. When the voltage waveforms of the VFD output were analyzed, we also discovered one of the VFD output drivers had a distorted waveform (Figure

9). This was due to a failing output driver on one phase of the VFD. This distortion was not severe enough to trigger the self-diagnostics of the VFD.



Date	04/19/00	04/19/00
Time	01:27:51 PM	01:47:11 PM
Current 3 (THD)	1.41	35.62
Phase 1 kW	1.51	5.55
Phase 2 kW	5.18	5.91
Phase 3 kW	2.05	5.59
Total kW	5.72	17.06
Phase 1 kVAR	2.07	2.62
Phase 2 kVAR	3.19	2.79
Phase 3 kVAR	5.62	2.52
Total kVAR	10.88	7.94
Phase 1 kVA	2.56	6.14
Phase 2 kVA	6.09	6.54
Phase 3 kVA	5.98	6.14
Total kVA	14.63	18.82
Phase 1 PF	0.59	0.90
Phase 2 PF	0.85	0.90
Phase 3 PF	0.34	0.91
Total PF	0.20	0.91
Efficiency Calc. (%)	165.19	92.73
Output Power Calc. (HP)	12.68	21.22
Self Imped Imbalance	228.50	3.77

Figure 8- Test results on crystallizer motor, test 1-input side, test 2-output side.

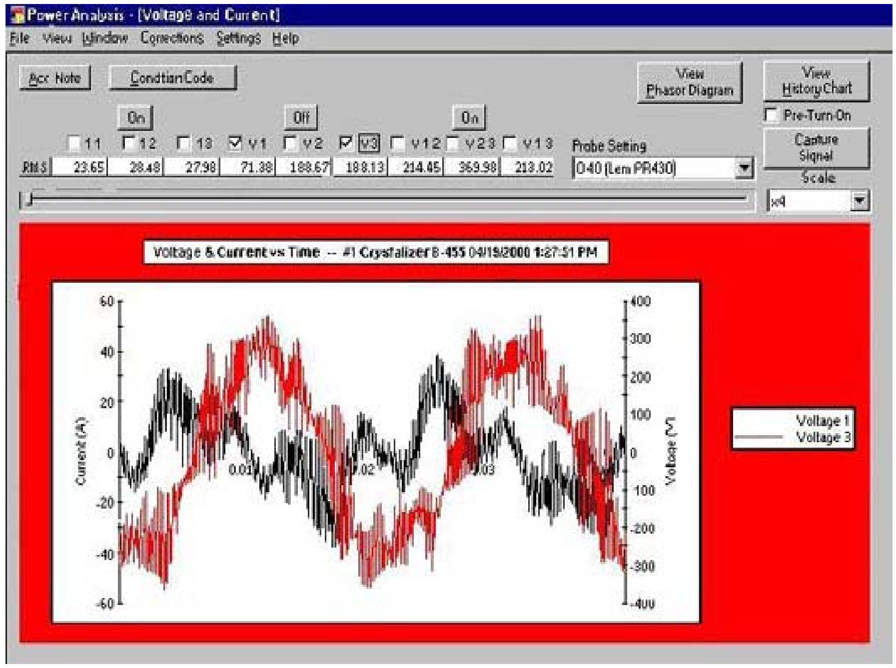


Figure 9- Voltage waveforms on output side of VFD feeding crystallizer motor.

Quality Assurance Testing

The MAT team has a quality assurance program in place for repaired motors. An off-line test is performed on all motors over 100 HP to verify the repairs and to establish a new base line. Quality Assurance testing was recently performed on a 125HP, 444T frame, 1800-rpm motor. During testing, a 5.1% resistive unbalance was noted. The motor was retested using a bridge type ohmmeter to confirm if errors were made during testing. The off-line results compared very favorably with the bridge results. The repair data sheet was reviewed and the motor shop had documented the 0% resistive imbalance. The resistance readings were identical across all phases.

It was also noted that the readings were off by a factor of 8 when compared to the readings we had made. The MAT requested that the motor repair shop personnel come to our facility to verify their resistance readings. Their measurements with their bridge ohmmeter found a 7% resistive imbalance.

The resistance imbalance results were discussed in a meeting with the repair shop, but they did not feel the imbalance was a problem because the motor had passed the surge comparison and load tests during the repair process. However, they agreed to perform additional testing for mutual learning. The motor was torn down and 25% of the nameplate voltage and full nameplate current were applied to the stator. An infrared image of the stator was taken after ten to fifteen minutes. As can be seen in Figure 10, two coils of the stator were approximately 25^{O} F hotter than the rest of the stator coils. Due to these findings, resistive imbalance limits have now been added to Eastman Chemical Company's Motor Repair Specification.

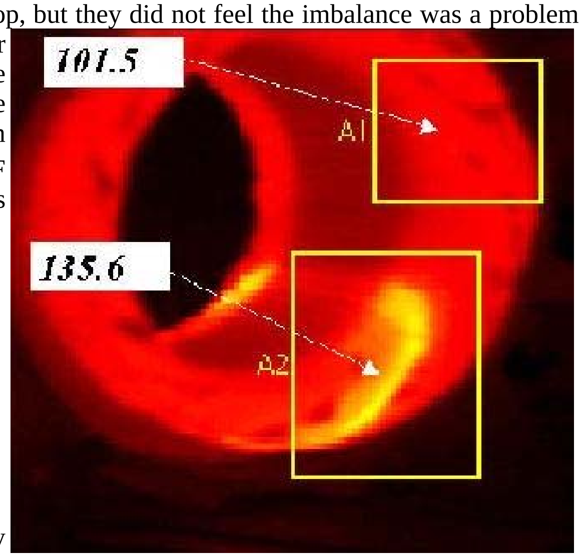


Figure 10-Infrared image of 125HP motor with 5.1% resistive imbalanc

Conclusion

Although we have found the advertised benefits of the motor analyzers to be very rewarding, we must be willing to step outside the box to find additional opportunities to reap the many benefits that can be realized.

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