Process Analysis – Your Path to System Knowledge

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How well do you know your system process? Could you identify the reason behind every precision variation in load of each of the motors throughout your system operations? If you answered Good to the first question but No to the second question then you are in the majority. The majority of maintenance professionals who are not taking advantage of the built in reliability sensors we call the electric motor.

Electrical to Mechanical to Electrical

The electric motor takes electrical energy and creates an invisible rotating magnetic field in the stator windings. This rotating magnetic field induces, or causes current and subsequent magnetic fields on the rotor. These two magnetic fields, like magnets over and under a table, will attract and repel to create torque that turns the shaft of the motor creating mechanical energy. This mechanical energy delivered to various processes throughout your system in turn provides feedback through the motor in the form of electrical energy. Variations in torque caused by load changes or mechanical faults will modulate or change the rotation of the rotor on which the induced magnetic field exists. This change in the rotating magnetic field will in turn modulate or change the invisible rotating magnetic field on the stator, thereby providing intelligence into the unseen inner workings of your system processes.

Quantitative Process Analysis

There are times where precision analysis of current values taken from a motor during a transient or process can identify a variety of issues. Starting a motor may be one of the most stressful transients that a motor experiences during normal operations. That being said it is common knowledge that performance and reliability may be best verified under a stressful condition. And, if a stressful condition is required (a motor can't work if it can't start) then what better opportunity to use that stressful condition to perform some assessment on the reliability of the motor.

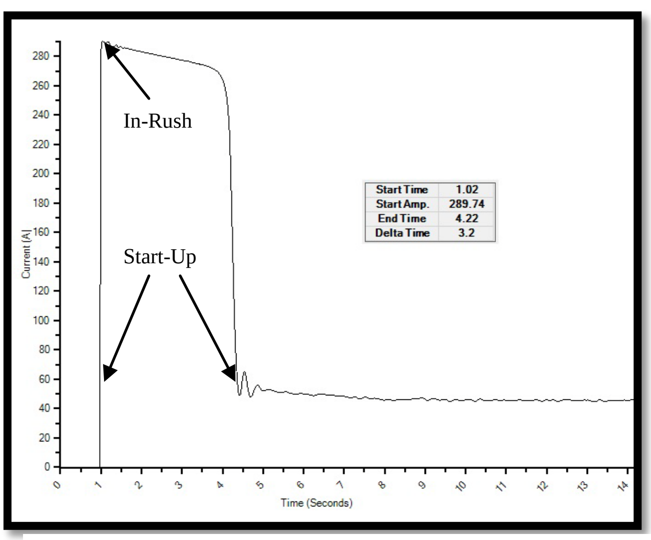

Figure 1. Normal In-Rush/Start-Up of a squirrel cage induction motor.

Figure 1 presents a fairly classic display of an across the line standard squirrel cage AC induction motor. Notice the rapid in-rush to 289 amps followed by a steady decrease in current through the beginning of the start-up and a quick drop to a steady state at the end of the start-up in approximately 3.2 seconds. These are quantitative values of current that can establish a healthy baseline and be used to compare to future values of acquired current for trending.

Qualitative Process Analysis

In addition to the quantitative side of data analysis there is the equally powerful but sometimes underrated qualitative analysis. Where quantitative analysis focuses on defined values to compare to a baseline or previous test, qualitative analysis uses more of a characteristic recognition or change as it applies to a process. Compared to Figure 1, notice the uncharacteristic start-up seen in Figure 2 for a motor used on a similar application. Ignoring the values, the initial magnetizing in-rush doesn't act so

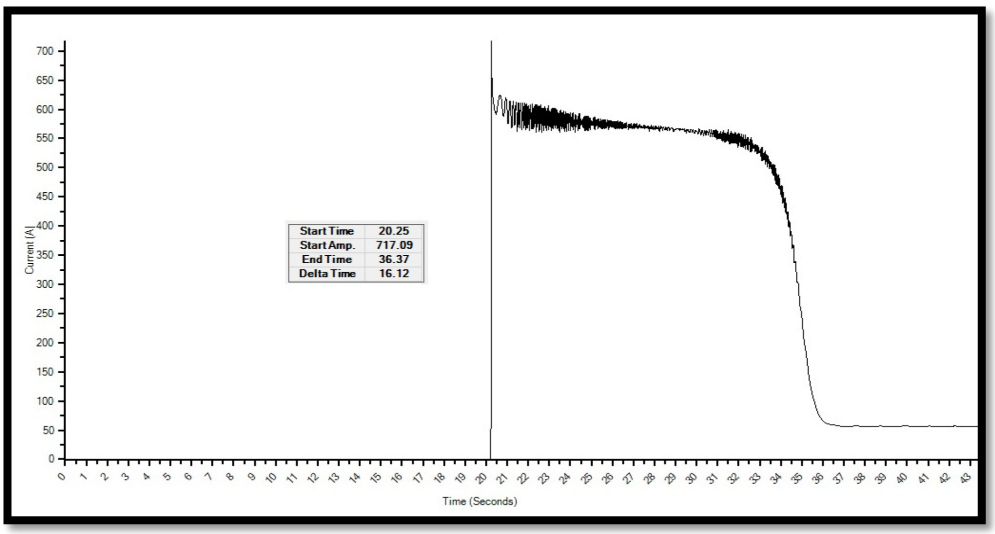

Figure 2. In-Rush/Start-Up of squirrel cage induction motor showing hunting throughout the start-up.

different but the start-up current is very different. Rather than a smooth gradual reduction of current through a three second start-up, a large amount of hunting or modulating is displayed over a 16 second start-up. Unlikely a product of the mechanical process, we must suspect that variations in rotating electrical impedance might be the source. And, where better to find varying rotating impedance than on the rotor cage?

There is an advantage beyond the use of current analysis towards the reliability assessment of the motor. As discussed in the paragraphs above, intelligence into the application (pump, compressor, etc.) and the process itself (boiler feed, condensation, lube oil, etc.) can be extracted from the current data taken on a motor.

Centrifugal Fan/pump frequencies are mechanically generated modulations of torque created each time a fan blade or pump vane passes the discharge piping. This modulation can be monitored using a demodulated current spectrum and focusing on the blade/vane pass frequency that is equal to the number of blades (or vanes) times the pole passing frequency (F_p). A simple calculation for F_p is the number of poles x slip. The number of poles can be calculated by taking the (line frequency x 120)/

synch speed, and slip is the differential frequency between the synchronous rotating magnetic field and the rotating rotor. A motor turning 1780 rpm has a synchronous rotating magnetic field of 1800 rpm or 30 Hz and has four poles calculated by (60 x 120)/1800. Therefore, it has a slip of 20 rpm or .33 Hz. Increasing amplitude at the blade pass frequency as well as a possible increase at the motor speed frequency peak is an indication of possible blade or pump vane damage. After initial installation or verification that the pump or fan is in satisfactory condition, identify the vane frequency and record the amplitude of the peak. Now with baseline amplitude for the equipment established, the demodulated current spectrum is used as a simple and efficient method to monitor for any deterioration in the equipment condition.

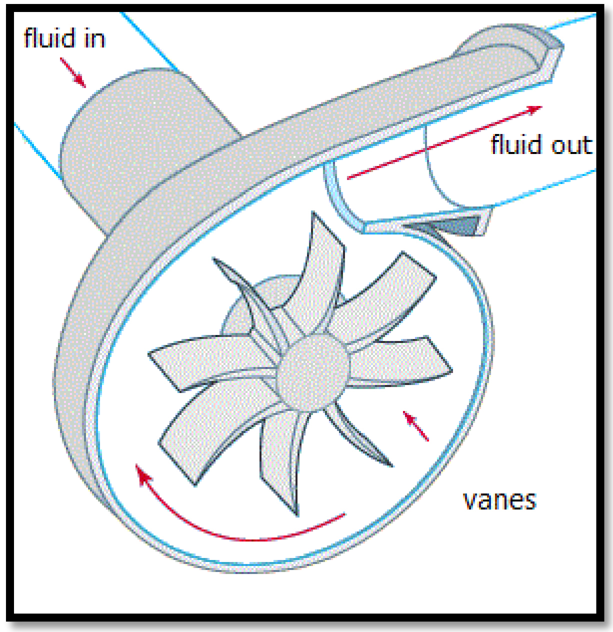

Figure 3. Centrifugal Pump

Figures 4 and 5 are a quantitative comparison between two identical horizontal pumps. Figure 4 is typical for this application with the pump vane frequency amplitude of 0.027 dB. In Figure 5, pump PF-8.6A pump vane frequency amplitude is 0.046 dB; nearly double that of all the other identical equipment platforms. Additional testing and a scheduled inspection of the impellor are recommended, given the substantial difference in these vane pass frequencies.

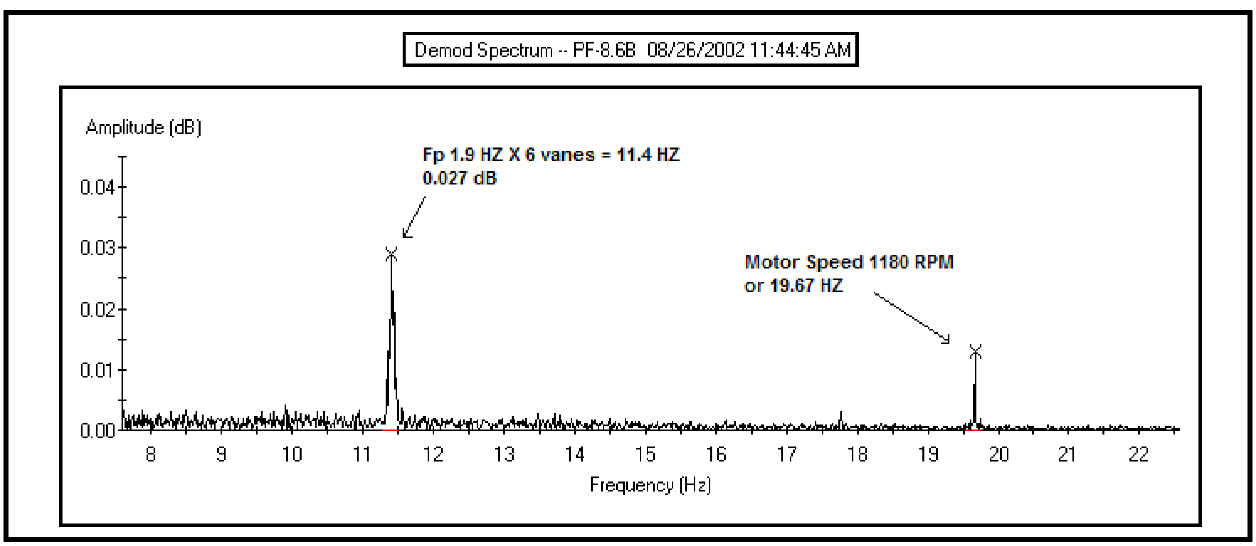

Figure 4. Current demodulation showing vane pass and speed frequencies for comparison to Figure 5.

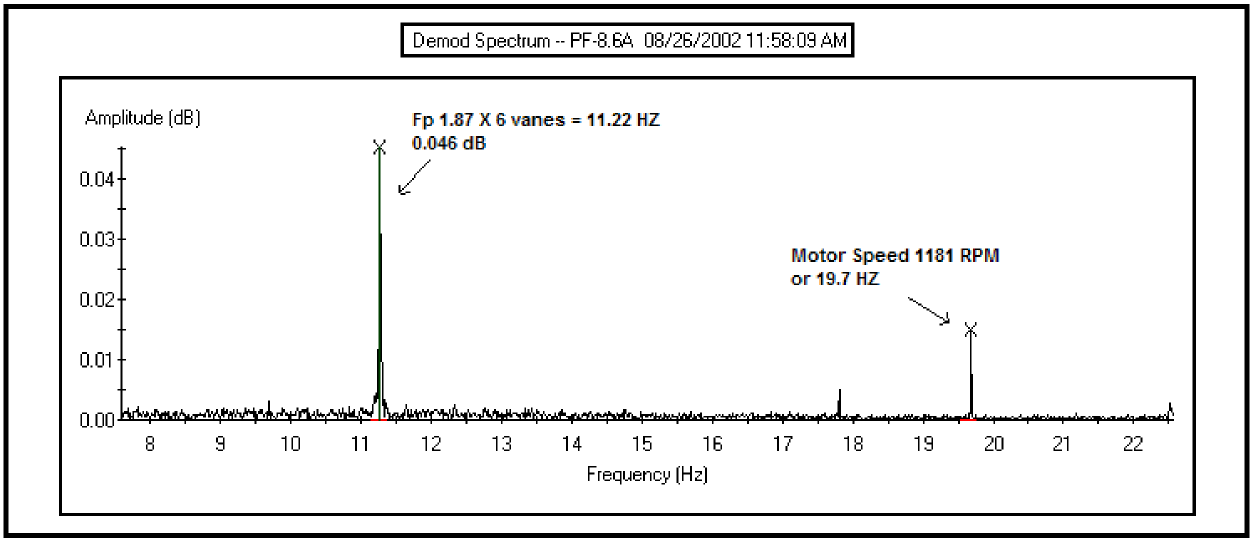

Figure 5. Current demodulation showing vane pass and speed frequencies for comparison to Figure 4.

Figures 6 and 7 are qualitative comparisons of data taken on the same circulating water pump at different times. This pump was being powered by a 4000v, 3000HP AC induction motor. So, not only is there interest in the very expensive motor, but additionally in the pump responsible for critical circulating water to the utility plant. The data in Figure 6 was taken in January, 2010, during a routine process analysis current test. Recognizing that the normal qualitative performance of a centrifugal pump under the proper head pressure and normal load would be a steady state demand the process capture in Figure 6 is very uncharacteristic.

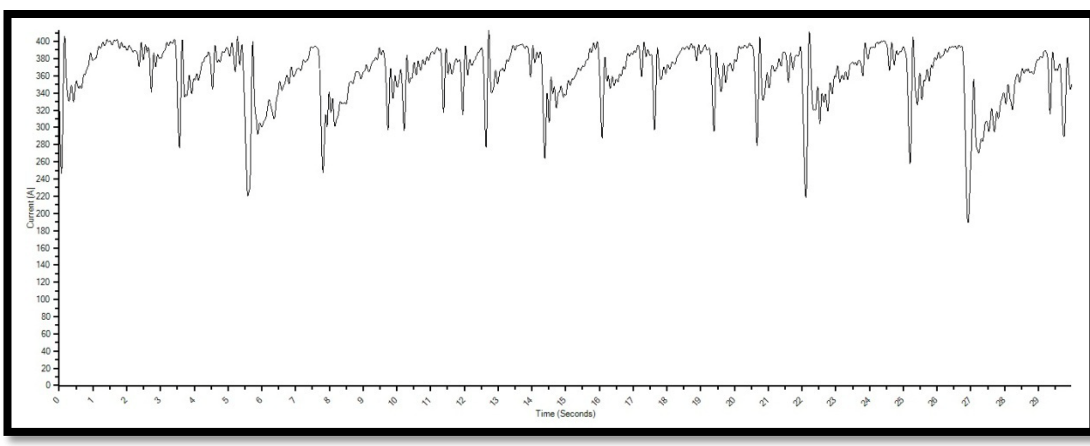

Figure 6. Qualitative current RMS envelope from a circulating water pump motor trended with Figure 7.

Taking the immediate steps to use this data in comparison to running characteristics of previous data from 18 months prior on the same pump you can see a dramatic difference in Figure 7.

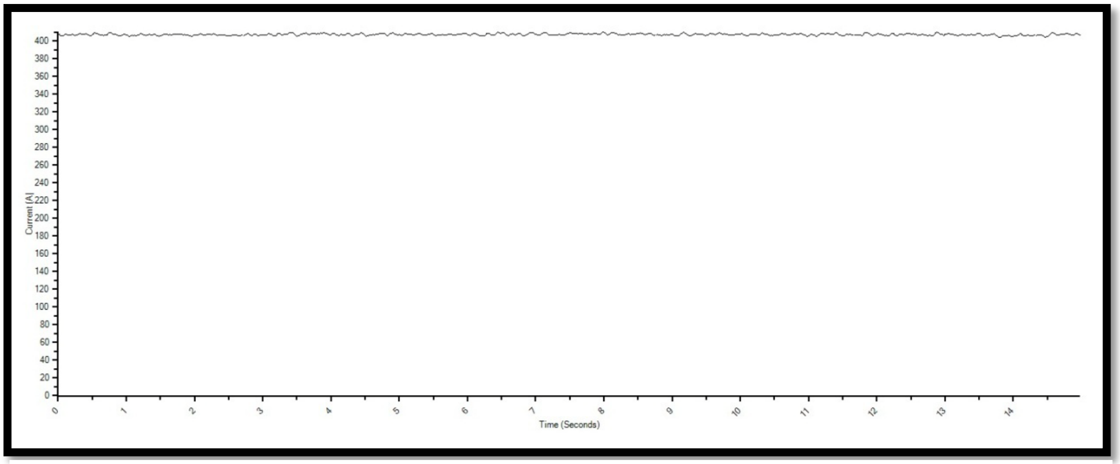

Figure 7. Qualitative current RMS envelope from a circulating water pump motor trended with Figure 6.

With no complaints from operations on the circ-water pump performance, no further investigation would have been made. However, given the simple qualitative analysis on the process current test and the fact that utility requirements were not at peak demand, a visual inspection was authorized. As can be seen in Figure 8 this pump could have experienced a potentially catastrophic failure that would have resulted in a reduction in the unit capacity. Had a catastrophic failure occurred in the middle of the summer when utility demand is high, well… "It's all about the MegaWatts" as we have heard from our utility customers. Figure 8 shows that the inlet bell has been broken. This could create the possibility of turbulent flow, which could cause cavitation in the pump and intermittent load variations as seen in Figure 6. Additional concern would be toward the possibility of the broken pieces of the inlet bell entering the pump cavity and causing impellar damage.

Figure 8. Damaged inlet bell on circ water pump.

The same qualitative and quantitative approach described by this pump case study can be applied to belts, fans, compressors, etc. Keep in mind the approach to using electric power as a sensor to identify mechanical anomalies is correlative. We are not expecting current signature to take a lead role in mechanical analysis as that position should always be dominated by the vibration analysis industry. However, the power to correlate and provide another means of identifying mechanical anomalies is unquestionable.

Process Analysis

We have discussed the application of current analysis towards the identification of mechanical anomalies. Building on the electrical to mechanical to electrical transition discussed in paragraph two, we can use the current trace seen in the RMS enveloped In-Rush/Start-Up test to provide time and amplitude sensitive information toward the process being driven by the motor. Take the example of a servo driven robotics application in the automotive industry seen in figure 9. Every transient can be linked to an event, a transfer, a move of an object between one place to another. There are six main events throughout the operation of this process that can be easily identified with some basic visual feedback and knowledge of the process. In Figure 9 the first event starts with a 36 amp signal that lasts for 1.5 seconds followed by a rapid 45 amp second event. After the six events the whole process starts over every 30 seconds. Once a baseline has been acquired with the expected amplitudes and times associated with each event it can be easily compared to follow-up tests. Overlaying two process analysis tests will easily identify which event is seeing a change.

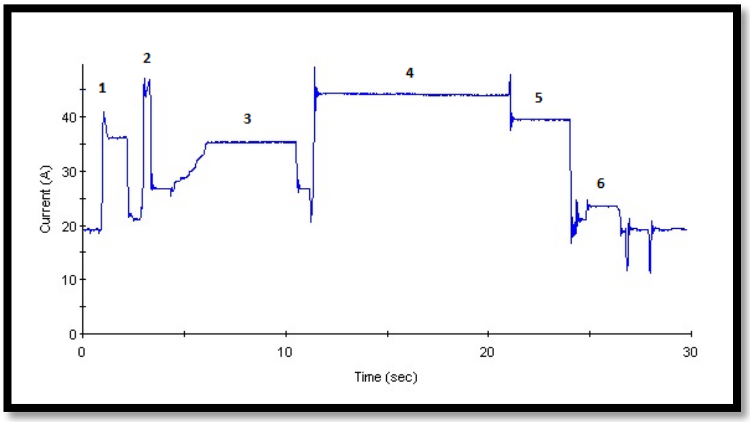

Figure 9. Process analysis of servo motor application.

Imagine how much easier it would be to isolate the fault if you had trendable process analysis timelines to show you the way. Its kind of like having a built in sensor for every application. Process Analysis as a baseline recording from each motor involved in our system processes provides the eyes and ears necessary to easily see the onset of reduced reliability.