Quad Plus ***Clean Power Drive***

Flicker Mitigation at European Metal Recycling: Birmingham, England

Synopsis

The European Metal Recycling (EMR) shredding facility in Birmingham, England had been struggling for years with an excessive flicker problem. They had explored many options but none could provide a satisfactory solution.

Today the facility is operating more effectively and efficiently than ever. Flicker is no longer a game-changing issue. Productivity is up and the company is saving money every month on its power bill.

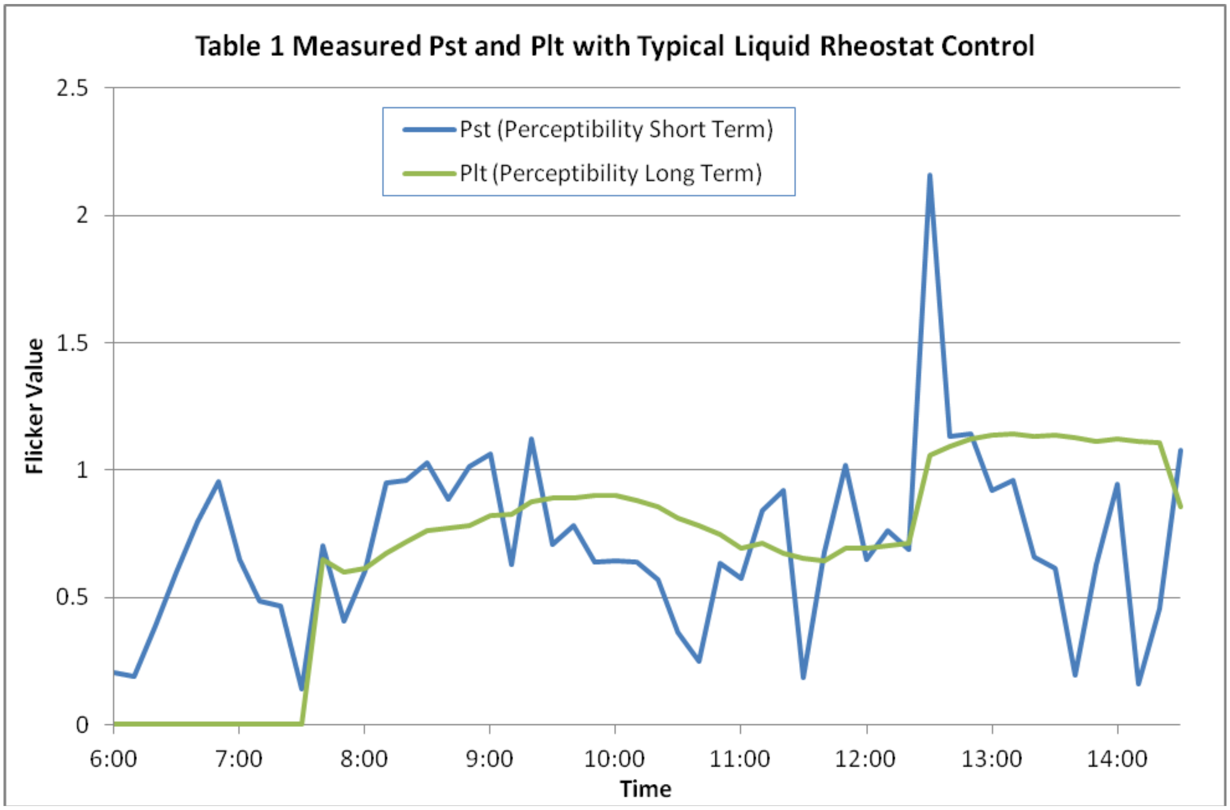
The key to EMR's dramatic turnaround: the Clean Power Drive.

Introduction

The EMR facility's 6000 HP wound rotor motor with an 11,000 volt primary used the industry standard electro-mechanical liquid rheostat control. The local power utility was adamant that EMR lower their flicker levels. EMR needed to identify and implement a new strategy and system.

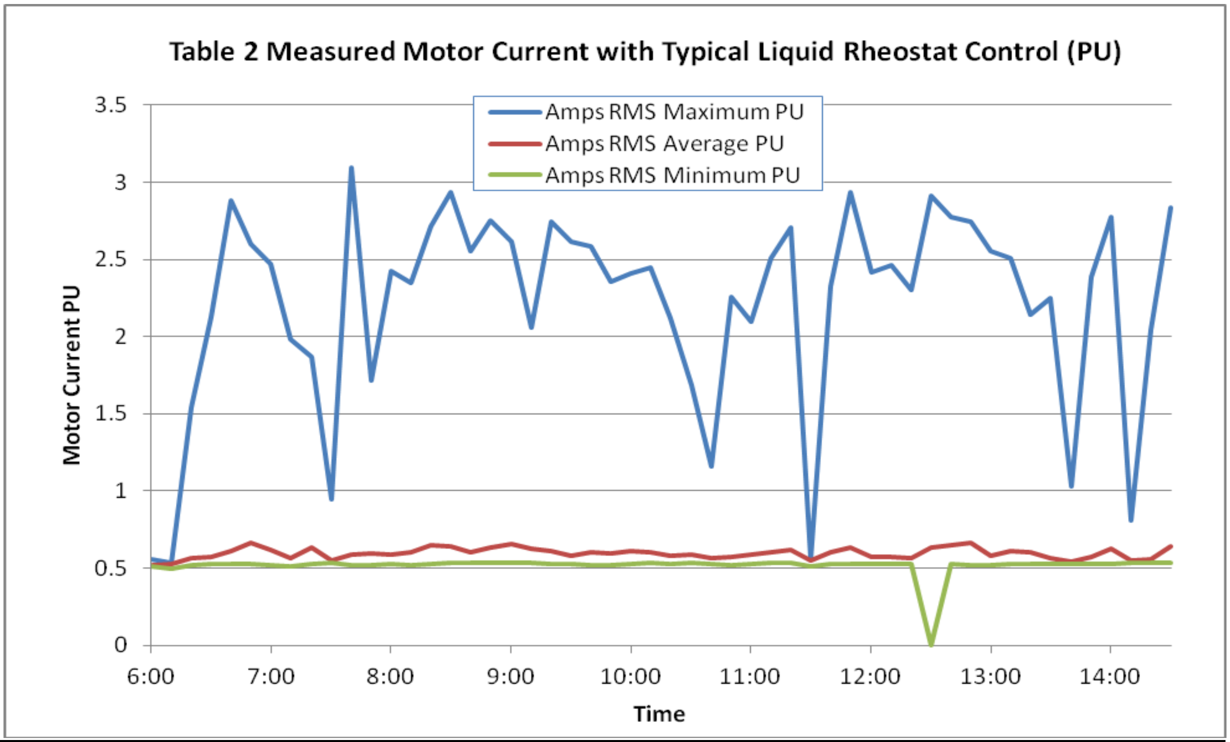
Preliminary Analysis and Engineering

Flicker data was recorded at EMR on April 6, 2011, running the facility's typical production using the liquid rheostat control. The data clearly documented the problem. For compatibility levels in low voltage and medium voltage systems, AS NZS 61000.3.7-2001 dictates short-term perceptibility (Pst) should be less than 1.0% and long-term perceptibility (Plt) should be less than 0.8%. But, EMRs numbers far exceeded those limits. Short-term perceptibility was measured at 2.106% with a 10-minute capture and long-term perceptibility was measured at 1.579% with a 2-hour capture (See Table 1).



The degree of flicker was a product of frequent load fluctuations (with the associated drop in power factor), electrode reaction delays inherent in industry typical electro-mechanical liquid rheostat control, and lack of an effective current limit on the motor.

During typical production, the motor stator current frequently exceeded 300% (See Table 2). In these short-duration (generally less than 1 second), high-current events, Volt-Ampere Reactive (VAR) consumption varied greatly as the liquid rheostat attempted to limit stator current by varying resistance in the rotor circuit. A static VAR compensator could have been used to mitigate the VAR consumption in peak periods, but it would not have addressed the other two critical aspects of the problem: an imprecise speed control and lack of an effective current limit on the stator.



To begin exploring plausible "what ifs", Quad Plus created a mathematical model using the data provided by EMR. During a "worst case" scenario, the model predicted that using the Clean Power Drive would reduce the Pst to 0.817, without the addition of the 2.5 MVAR capacitor bank the customer is currently using. This reduction in Pst would be realized because the Clean Power Drive can limit stator current, export VARs to maintain power factor, and run closed loop speed control algorithms.

The model did not take into account the tangential benefit of productivity gained by running the motor super-synchronous (above synchronous speed) with added horsepower and kinetic energy in the rotor.

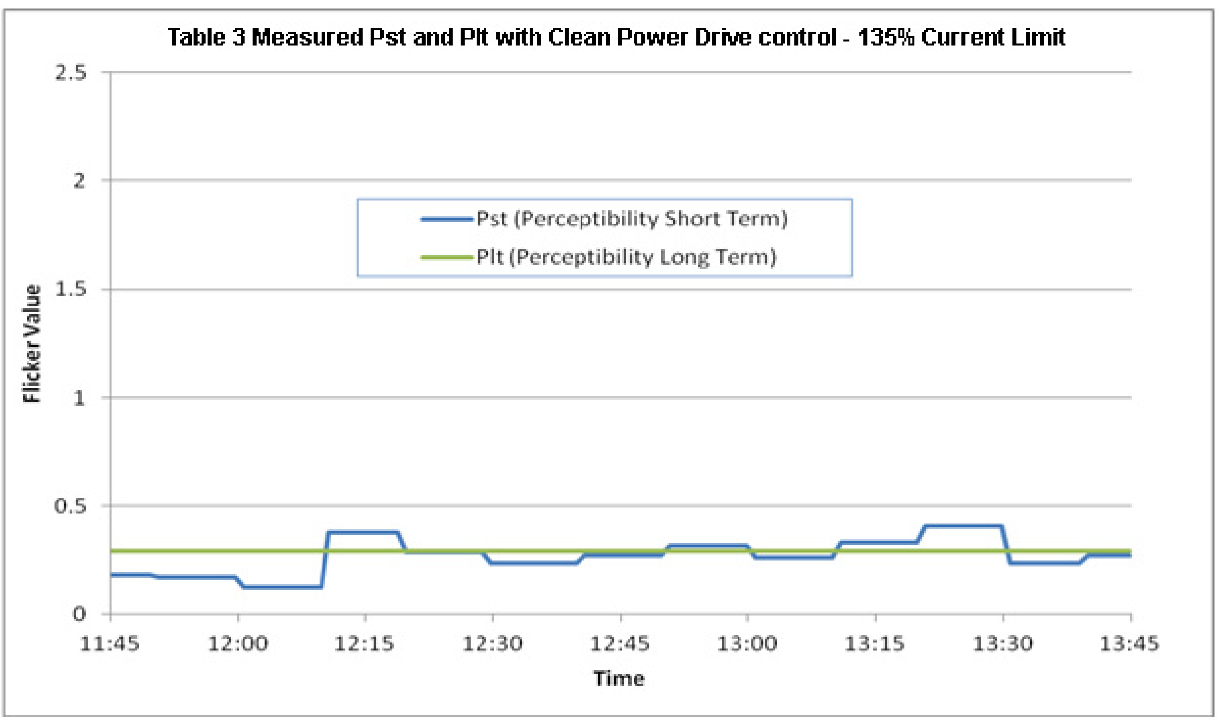
Because horsepower is a product of RPM and torque, increasing the RPM for the same torque (stator current) results in higher horsepower. When a wound rotor motor is run above synchronous speed (super-synchronous), the torque becomes constant and the horsepower increases. When it operated at 495 RPM, the EMR motor produced 6000 HP and 63,660 lbs/ft of torque. Running super-synchronous at 525 RPM, horsepower would increase to 6359 HP, as the following formulas illustrate:

- HP = (Torque x Speed) / 5252
- 6000 HP = (63,660 x 495) / 5252
- 6359 HP = (63,660 x 525) / 5252

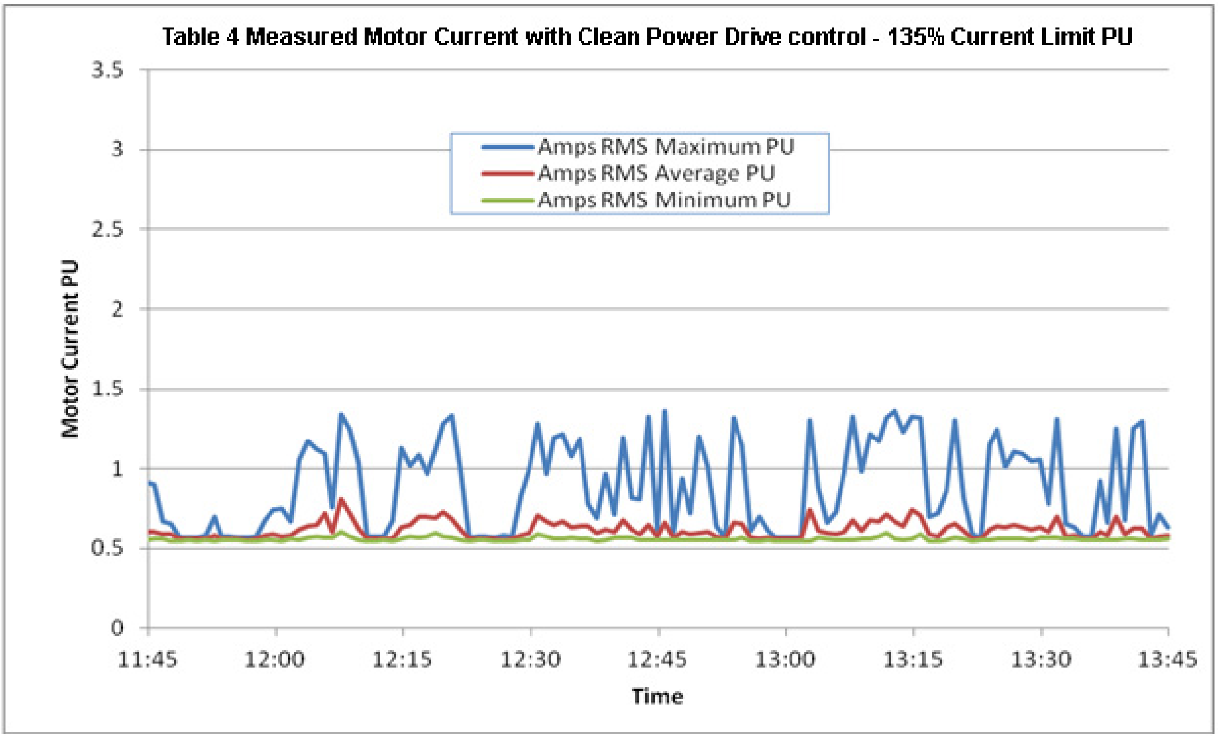
The process of shredding is about the conservation of energy. The more energy the rotor carries, the more work (tons per hour) it can accomplish. Increasing rotor speed to 525 RPM increased the kinetic energy by approximately 12.6%. That increase will have a noticeable effect on productivity, resulting in more tons per hour.

<u>Implementing the Clean Power Drive</u>

During the week of November 13, 2011, Quad Plus commissioned the Clean Power Drive at EMR. During production runs similar to those in the initial data collection process, the highest measured Pst value during a 10-minute capture was 0.4464 (See Table 3), a significant reduction from the 2.106 Pst reading taken during the initial data gathering in April.



The EMR operations staff immediately noticed an increase in perceived power. Product that normally would have tripped the main stator circuit breaker now ran through the shredder without exceeding 135% stator current (Table 4). Productivity was significantly increased because they were spending less time waiting for the rotor to recover speed. In addition, the motor was more effective at producing useful torque – not wasted heat.



<u>The Technology of Clean Power Drive</u>

The Quad Plus designed Clean Power Drive is a fully integrated electrical control specifically designed for Auto Shredder application. The Clean Power Drive consists of:

- input AC line reactor
- fully regenerative source converter
- inverter drive utilizing Pulse Width Modulation (PWM)
- inverter output dv/dt (delta voltage / delta time) filter
- crowbar circuit for overvoltage protection
- combining reactor
- contactor for switching from a starting circuit to Clean Power Drive control
- starting circuit
- feedback transformer
- Wonderware operator station
- plc

The inverter and converter incorporate the latest Isolated Gate Bi-polar Transistors (IGBT) and heat pipe cooling technology. Specialized firmware is used to control wound rotor motors. The speed regulator has an accuracy of +/- 0.01%. The fully regenerative source converter facilitates exporting VARs back onto the distribution system to regulate power factor on a real-time, dynamic basis. The motor doesn't need to be running to allow the converter to regulate power factor. Because the source converter can maintain near unity power factor (based on sizing of the equipment that is tailored to a site-by-site basis), it will have very low harmonic utility interface. The inverter uses Pulse Width Modulation (PWM) to produce a sinusoidal current for the rotor.

The benefit of this sinusoidal current is negligible rotor heating and torque pulsations. The inverter dv/dt filter controls the dv/dt in the rotor to less than 750V/µS, making the drive system safe to operate on most medium voltage wound rotor motors, without the need for special motor windings. This safety margin is due to the typical insulation system design of a medium voltage motor and the low voltages (<750 Volts) the Clean Power Drive uses to control the rotor.

The Clean Power Drive allows users to enter in a desired RPM for the rotor. This RPM can be sub-synchronous (motor speed below synchronous speed) or super-synchronous (motor speed above synchronous speed), as needed. This is important because some shredding applications can be optimized using a different RPM than what is normally available based on the number of poles in the motor.

With proper component selection, the EMR Clean Power Drive was designed for a +/- 17% speed range. With a 495 RPM base speed, the drive system could control the motor from 411 RPM to 579 RPM. EMR determined that 525 RPM would be the optimum operating speed for their shredding application, and the desired operating RPM was entered on the Wonderware operator station provided by Quad Plus.

Again, it was verified that the facility was processing more tons per hour due to the higher RPM, increased kinetic energy (12.6%), and the rise in horsepower to 6359 HP (from 6000 HP). Depending on the secondary voltage of the wound rotor motor and Clean Power Drive ampacity, a speed range of up to +/- 30% can be provided for a specific application.

Solution Integration

The Clean Power Drive can easily be retrofitted into existing applications or designed specifically for a new installation. At the EMR site, it was decided that the existing motor start/stop circuit would remain nearly untouched. This enables the operations staff to begin using the system with minimal training.

The main motor is started the same way it was started prior to the Clean Power Drive installation – with a start button on the operator's chair. As the motor reaches synchronous speed, a status light on the Wonderware operator station indicates the Clean Power Drive is ready to start. Once the Clean Power Drive Start button is pressed, the sequence is fully automatic. The addition of a contactor panel allows the rotor circuit to be controlled from the liquid rheostat or the Clean Power Drive. The contactor sequences between the liquid rheostat and the Clean Power Drive. Once the Clean Power Drive contactor is closed, and the liquid rheostat contactor is opened, the Clean Power Drive takes over, accelerating or decelerating the rotor to the desired speed set point.

Modern feed roll control algorithms currently used by most of the major original equipment manufacturers can take advantage of the lower thermal capacity and closed loop speed controller provided by Clean Power Drive. These factors allow the feed rolls to be set more aggressively to maintain the commonly used "full box" shredding technique. Using a properly tuned speed controller, the feed roll automation system will not have to wait as long for the rotor to recover speed after a load hit.

A properly tuned speed controller allows the feed rolls to begin processing material at a significantly faster rate than when the motor is run on the liquid rheostat. Lower thermal capacity is a result of the motor spending less time “under the curve” or constantly trying to recover speed due to a lack of an effective speed control. In addition, the true current limit in the Clean Power Drive eliminates the highly inefficient 200% to 300% spikes which are frequent with electro-mechanical liquid rheostat control.

The bottom line is a system that becomes more efficient at producing scrap, resulting in a lower cost per ton ratio. For most large mills, this savings can be significant.

Summary

Flicker is often the main concern for utilities when it comes to installing a large wound rotor motor on their distribution system. This may influence the utility to insist on the installation of a dedicated substation installed at the customer’s expense. The use of the Clean Power Drive can limit flicker and greatly reduce the probability of additional expenditure for utility upgrades.

For EMR, the use of the Clean Power Drive allows for real-time VAR compensation, closed loop speed control, and effective current limit in the stator circuit. That combination reduces flicker to manageable levels and increases the overall efficiency of the system.

In addition to production gains realized through better speed control and increased RPM when needed, the Clean Power Drive can provide EMR owners and staff with a power management tool to limit demand charges, similar to the technology used in Quad Plus’ DC drive systems. The use of Kilo-Watt Demand Limiting Technology will enable more accurate forecasting of monthly expenses, yielding significant savings on utility bills over the course of a year.