Precious metal heating control beyond energy efficiency

The focus on achieving better energy efficiency in glass manufacturing has led to the development of a ground breaking collaboration project between RoMan Manufacturing and Eurotherm. Here, the partnership visually demonstrates the benefits of their enhanced methodology, which not only proves energy savings but also indicates further gains in terms of increased production and better quality end product. Stanley F Rutkowski III and René Meuleman report.

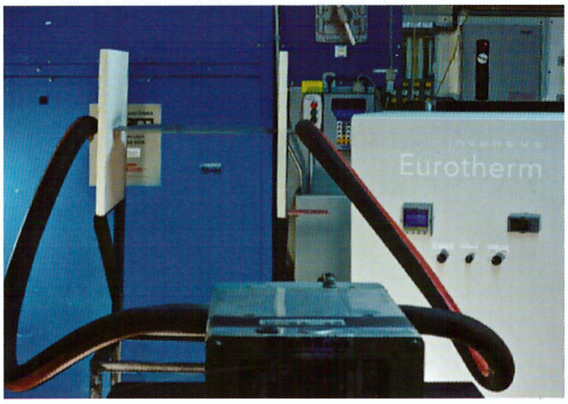
The idea first came from the challenge to provide the most electrically efficient system for precious metal heating applications, so a collaboration project was established between the two companies, combining Eurotherm control strategy with load tap changing and low inductance equipment supplied by RoMan. The innovative solution was trialed in several glass manufacturing plants where customers could not only see the difference in energy consumption but over time, were also reporting more uniform product quality. In order to prove what was going on, the partnership decided to run some tests to visually demonstrate the negative effects of inductance and an augmented wave form on the heat pattern and mechanical vibrations in the load during a continuous application.

Before taking a look at the results, it is necessary to define some of the technical terms and show the benefit of using the LTC (load tap changer) method over phase angle firing to control the incoming voltage to the transformer.

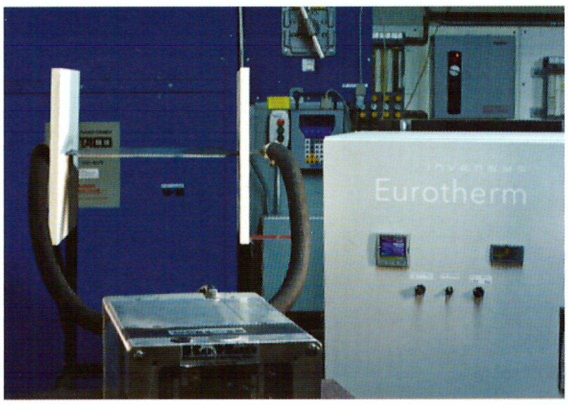
Phase angle firing: With a single SCR on the primary or secondary of the transformer, it is possible to control when the voltage to the system is turned on but not when it turns off (off is determined by the wave form crossing through the zero point). Chopping the waveform in this way generates harmonics, which lower the power factor.

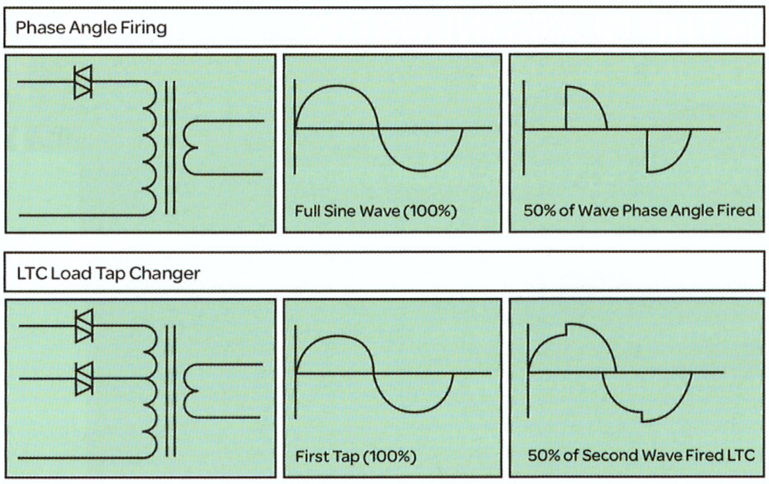
Load tap changing: LTC is a method to control the incoming voltage to a transformer that allows for a full voltage wave form to be applied from the lower voltage tap (highest number of turns on the primary) and then applies a percentage of the higher voltage waveform to reduce the amount of 'chopped' waveform that is applied to the transformer. In theory, the harmonics in the waveform are reduced, increasing the power factor.

Cost of power: The following five quantities need to be taken into consideration when calculating the cost of power used in an application. Total power (kVA); reactive power (kVar); real power (kW); power factor (cos (Φ)); and peak demand. The relationship between these is shown in the triangle diagrams, where total

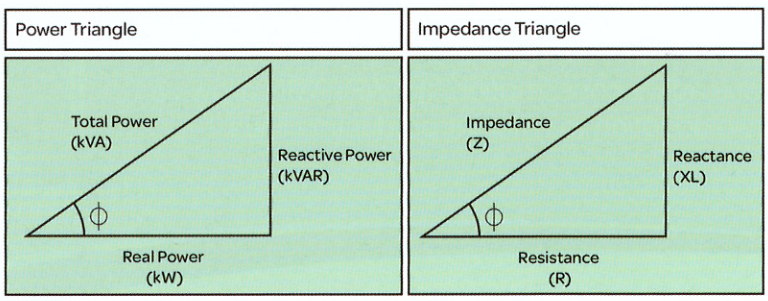


Large loop setup (above) and small loop setup (below).

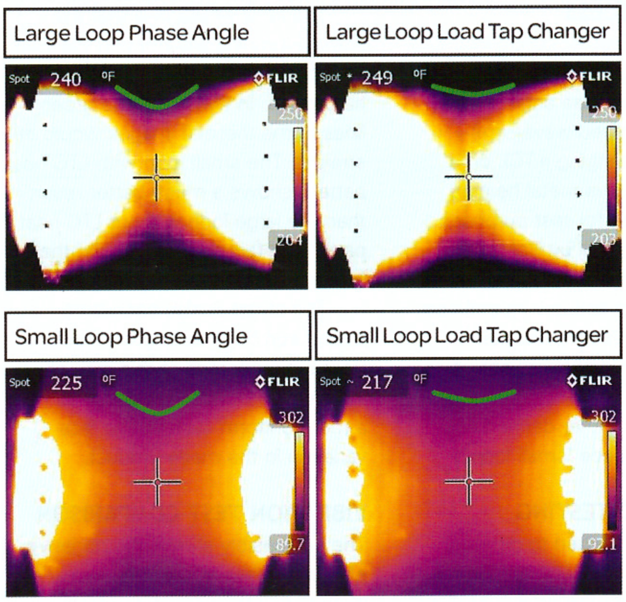




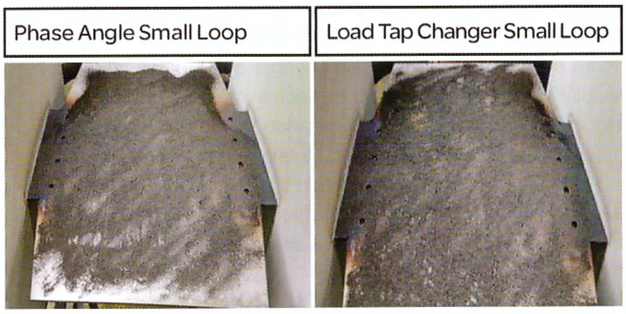
Comparison of connections and wave forms between phase angle and load tap changer.



Power and impedance relationship triangles.

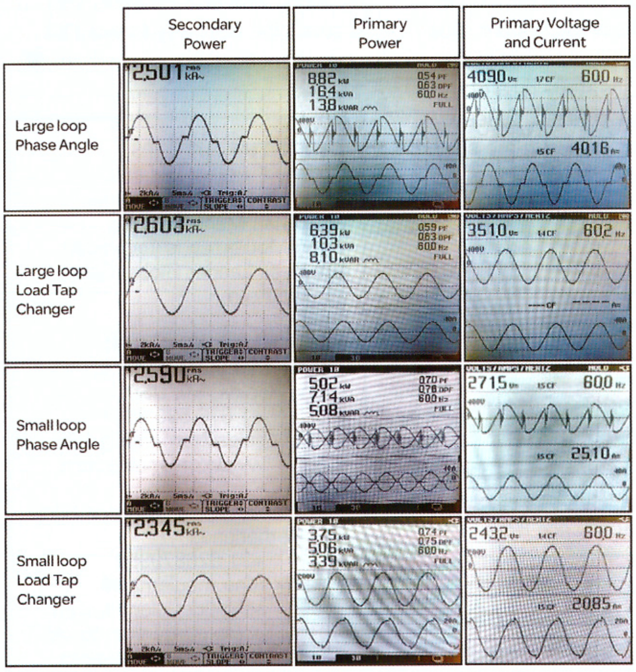


Heat pattern comparisons.

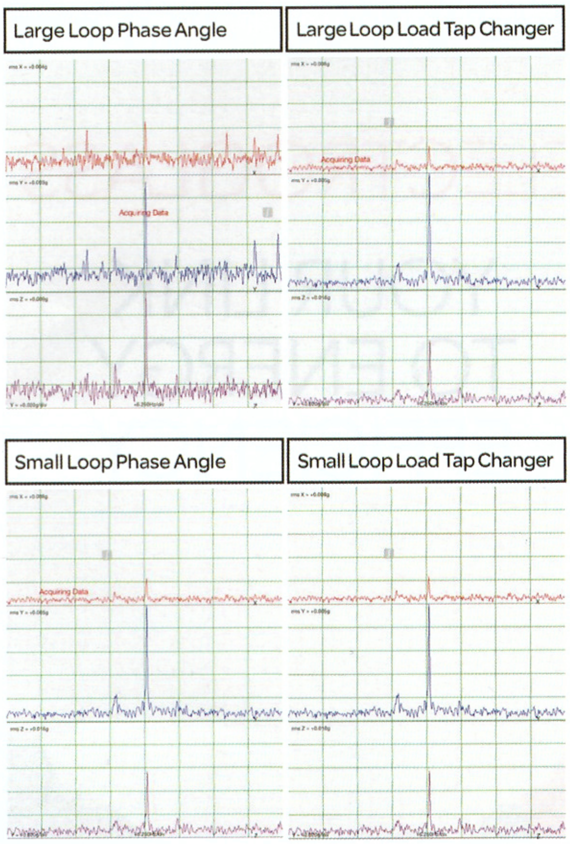


Iron flake test comparisons.

power is a function of impedance (Z) of the system, reactive power is a function of the reactance (XL) of the system, real power is a function of the resistance (R) of the system and power factor is a function of the angle created in the impedance triangle. The additional current associated with reactive power heats the wiring and transformer, therefore wasting energy. >



Power, voltage and current results.



Vibration test comparisons.

Reducing it increases the power factor, leading to reduced total power and lower energy costs.

Reactance: The reactance of the system includes the losses in the transformer and the cables in the system. Reactance has a direct impact on the power factor of the system, as does the applied wave form because inductance is calculated by 2 x π x frequency x reactance. When a wave form is chopped, harmonics are introduced into the system and these harmonics are at higher frequencies than the base waveform. This results in more losses, with greater harmonic content and possible mechanical vibrations in the system. So, to maintain a good power factor, the reactance needs to be as low as possible, which in turn reduces damage from mechanical vibration.

Skin effect: In an electrical conductor, the usable cross-section is determined by the frequency of the signal being passed through the conductor. Skin effect reduces the amount of current that passes through the centre of the conductor and concentrates it to the outside (or skin) of the conductor. This phenomenon is a function of the frequency of the signal. In resistance heating applications using phase angle control, the frequency of the signal can be increased, causing harmonics to be created at the switching point. This is another good reason to use the LTC method instead.

Smile/frown effect: The premise of this article is to show how high inductance in the secondary circuit restricts the current path in the load, causing uneven heating and wear to components in the system, thus also demonstrating how the path of the waveform in the load increases with the reduction of inductance in the system. The resulting thermal images of the heating effect in the load show a curve that has been named the 'smile/frown effect'.

TESTING PROCESS

A Eurotherm EPower controller was used to demonstrate the effects of both phase angle firing (traditional chopped waveform) and load tap changing (LTC), on a simulated precious metal heating element created for test purposes from stainless steel by RoMan. To show the difference between a high inductance and low inductance circuit, two secondary circuits (transformer to load) were set up, one defined as highly inductive 'large loop', the other defined as reduced inductance 'small loop'.

CONTROLLED TESTING

Meters were attached to different points across the heater load in order to measure the power, current, voltage and waveforms and an FLIR thermal imaging camera was used to record the heat patterns.

Iron flakes were applied on top of the load to visually identify the magnetic patterns created during each test.

POWER, VOLTAGE AND CURRENT RESULTS

The power, voltage and current measurements and waveforms confirmed that less energy was consumed with the use of the small loop and load tap changing system because the power factor was increased. This allowed for less inductive power (kVAR) to be used in the system and less total power (kVA).

The increase in power factor could also allow for the removal of capacitor banks in the system. Due to lower voltage requirements on the load side, the turns ratio of the transformer is increased, so less primary current is used in the system for the same production rate.

Additional benefits include less peak demand on the power system and the possibility of lowering the ratings of upstream devices such as SCR size, breaker size and primary wire feeds.

HEAT PATTERN AND IRON FLAKE TEST COMPARISONS

The heat pattern clearly demonstrates the additional heating in the load in the higher inductance large loop system in comparison to the more balanced combination of small loop and load tap changing, which allows for a more uniform heating of the precious metal.

The ideal situation is that the current runs equally through the load, not affected by any inductance or harmonics. In that case, the green lines in the thermal images would be straight. The small loop with LTC heat pattern shows a much better result than the large loop without LTC heat pattern, in fact the less 'smile' the better the system performs.

The effect is also confirmed by the iron flake testing method. Possible outcomes of this include increased production rate due to a more uniform system and less variation in the made product.

VIBRATION TEST COMPARISON

The data visibly shows the negative effect of phase angle firing in a higher inductance circuit, which causes the most damaging mechanical vibration in the load. The advantages of utilising the load tap changer system, which reduces the mechanical vibration, include less variation in the made product due to reduced mechanical stress applied to the material during manufacturing and increased life of the precious metal load.

CONCLUSION

The clever strategies within the Eurotherm EPower controller combined with expertly designed power transformer equipment from RoMan, are proven to make savings not just in energy but also by extending the life of equipment and enabling glass manufacturers to make stronger, better quality products, with less variation. This is surely the best way forward for glass manufacturers everywhere. ■

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