

The benefits of two-leg versus three-leg power control, in three phase heating applications

Power knowledge white paper

by René Meuleman

Eurotherm[®]

Executive Summary

Traditionally, three-leg power control is used in three phase heating applications. However, in some cases three-leg control is not a necessity and two-leg control can be a better option. Technological developments in SCR (silicon controlled rectifier) power controllers have resulted in new products and methods that can reduce both CAPEX and OPEX in these situations.

This paper discusses the benefits of utilizing two-leg power control in the EPower advanced SCR power controller, compared with traditional three-leg control.

Introduction

Traditional three-leg power control is needed for three phase applications running in grounded star configuration, or where SCR's are situated in a delta configuration. However, not all applications have these requirements, for example, the control of SiC (silicon carbide) element based tin bath roof heating, in the glass industry.

In these situations, more suitable control methods can be utilized to greatly improve the energy efficiency, overall load management and robustness of these systems, while remaining economically competitive.

Eurotherm by Schneider Electric have over 50 years' experience in the design and manufacture of power control products, systems and services. Carefully considered design and advancements in technology have led to the EPower SCR controller series which is specifically designed to provide efficient power control for high energy industrial heating applications, such as glass manufacturing and heat treatment of metals.

Through the development of EPower, Eurotherm provides a high end, robust product line that meets the growing efficiency, reliability and economic viability requirements of customers running high quality, high throughput industrial heating processes.

Improved energy efficiency

Traditional three phase SCR power systems have an SCR in each leg. Having an SCR in all three legs is a requirement in applications running in grounded star configuration, as in Figure 1, or where the SCR's are situated in delta configuration as in Figure 2.

Figure 1
Grounded star three phase power supply, using three-leg control

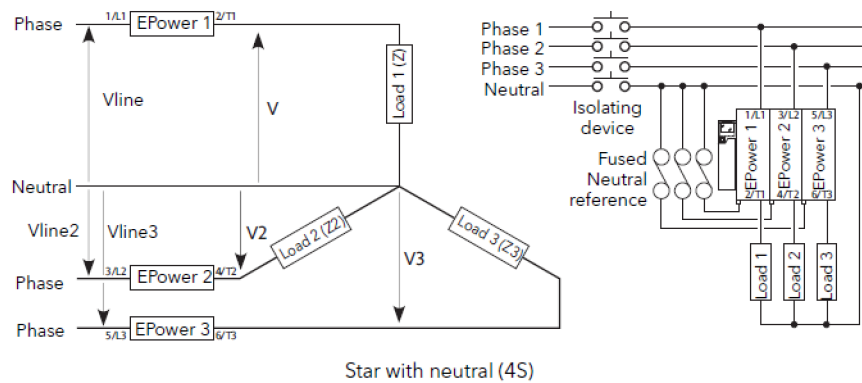
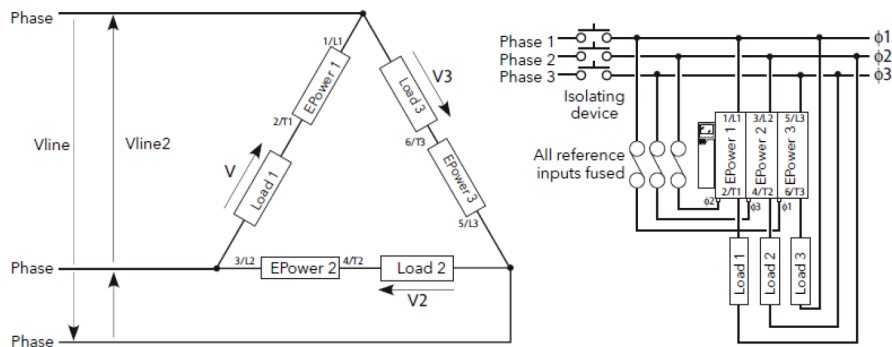


Figure 2
Delta configuration three phase power supply, using three-leg control



However, the above requirements are not needed to control certain types of applications, such as SiC element-based tin bath roof heating systems in the glass industry. This was one of the most important types of application considered by Eurotherm during the design of the EPower range in terms of possible efficiency improvements, and it resulted in the recommendation of using two leg burst firing control either in star or delta configuration, as in Figure 3 and Figure 4.

Figure 3

Star three phase control using two-leg EPower control

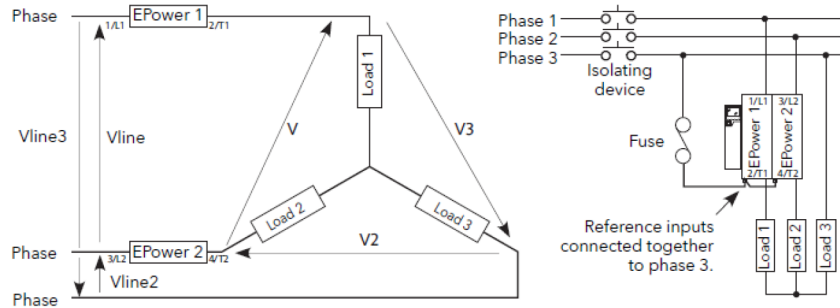
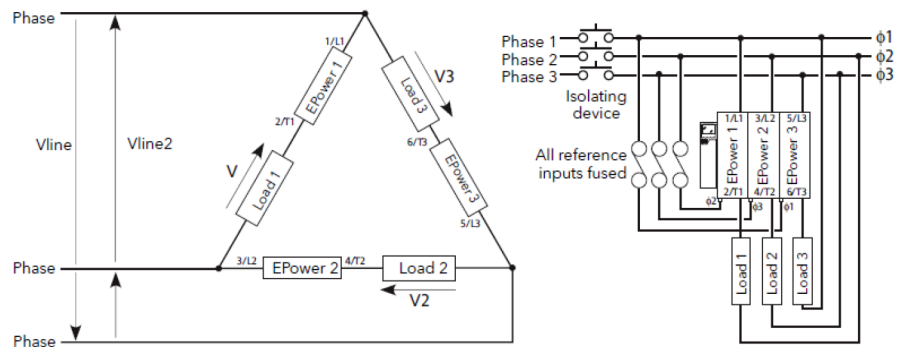


Figure 4

Delta three phase control using two-leg EPower control



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Power efficiency considerations

Each SCR dissipates approximately 1.3 watts per amp through the SCR. Using two SCR's instead of three to control the power applied to the roof zone, means the power losses in the SCR controller are reduced by 33%. Since these systems are most often installed in air-conditioned environments these energy savings will also have a beneficial effect on the energy consumption of the cooling systems and robustness of the overall power control system. EPower controller was designed to run at 690Vac, which reduces the overall current in the system, dissipates less power and reduces operating costs. It is also capable of controlling two zones in one four power stack device (in two times two-leg control), which reduces the overall system power requirement.

Reducing THD

In order to run these systems at the highest possible power factor and lowest THD (total harmonic distortion), and to make two leg control possible, these systems are run in burst (zero crossing) mode. With three-leg control, although the load is turned on at the zero crossing, it is never possible to switch on all three phases at the zero crossing at the same time. In other words, it is physically impossible to avoid return paths, which results in 'clipping'. It is therefore better to run the system in two-leg control instead of three-leg, as two leg control produces less harmonics.

Deal with peak power demand

To prevent multiple burst fire zones from causing excessive peak power demands, EPower provides a sophisticated predictive and self-tuning power management strategy called Predictive Load Management (PLM). More information on this subject can be found in our White Paper www.eurotherm.co/using-predictive-strategies-for-better-performance

CAPEX and OPEX considerations

With the capability to run four SCR power control modules, EPower can accommodate two-zone-control in one device, which reduces the cost of equipment. At the system design stage it is wise to consider this useful feature to reduce cost, by combining important zones in frequent use, with unimportant normally unused zones. If properly designed such a configuration will operate as and when required, reducing operating expenditure.

The importance of transformer design and control

Care needs to be taken when connecting the supply to the transformer to prevent the inrush current from exceeding the SCR's maximum current rating, and subsequently blowing the semiconductor fuse. The inrush current can be around 20 times the normal running current, depending on the flux density of the transformer. In the example of tin bath roof heating applications, transformers with a low, <1.25 flux density rating should be used, however EPower allows higher, up to 1.35 tesla.

Considering the B-H (magnetic flux density -magnetic field strength) curve, it is a matter of chance, where on the curve the equipment is left on disconnection. The residual magnetism in the transformer core is therefore not known at re-start, so to prevent inrush current, a phase angle ramp is applied. This technique is referred to as 'soft start', and is also applied when current limiting is required at start-up of the load.

Switching the thyristors at zero crossing on the primary of the transformer can lead to an over current approximately twice the nominal current. To avoid this inrush, which is due to magnetic flux in the transformer, the first firing of each phase must be delayed until the voltage on load corresponds with the minimum current through the load. To cope with this, Eurotherm developed a technique of burst firing with delayed first cycle firing. The optimum delay angle can be adjusted to minimize transient over-current, dependent on the transformer, load and Q factors, typically around 60°. Thus inrush currents can be minimized whilst the benefits of burst firing control are realized.

Conclusion

Eurotherm's EPower product line is specifically designed to improve the efficiency of industrial heating applications such as tin bath roof heating in the glass industry. To run these types of system at optimum energy efficiency, highest power factor, lowest THD and with minimized CAPEX and OPEX, Eurotherm recommends the use of EPower to control two zones in one device, using two-leg burst firing control method with predictive load management (up to 64 zones). If single zone integrity is desired, each zone can have a separate EPower with two power modules. However, the two by two-leg EPower control system has been found to be a reliable, cost effective and energy efficient solution on many roof heating and similar heat treatment furnace applications.

About the author

René Meuleman has over 30 years' experience working as an engineer within the glass industry involved in the design and development of container glass quality electronic equipment, implementation of the first generation Programmable Logic Controller (PLC) and Distributed Control Systems (DCS) and electronic timing systems for IS-machines, model based predictive control projects and object oriented engineering method developments. He became responsible for process control inside the BSN group and later was responsible for the European plant process control and forming electronics inside the Owens-Illinois group. At Eurotherm, René took the role of Process and Power Control Solutions, Energy Management and Model Predictive Control (MPC) for end-users, OEMs and solution providers. His motto is: "If you wait, all that happens is that you get older".

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