white paper
Glass Industry

How can Predictive Strategies contribute to improved Power Management and decreased Energy Consumption?

In co-operation with leading glass manufacturers Eurotherm have developed their next generation intelligent electrical Power Management Control System, EPower™. The EPower Power Management System is based on a Control (CPU) module which is capable of controlling up to 4 thyristor power stacks in a "PLC-like" design layout. Up to 63 of these Power Management Control Modules can be integrated together via a fast network (CAN-bus) to become a large scale intelligent power control system. This large scale Intelligent Power Control system further enhanced by Eurotherms' patented "Predictive Load Management" functionality (PLM©). Such a system is able to manage effectively the varied requirements of both small and large scale heating installations from glass bending lines, tempering furnaces and autoclaves to complete Float Glass Bath and Annealing Lehr installations. Managing these power demands to maintain an almost constant power demand and preventing load peaks and spikes.

In applications where manufactures have to control multiple loads the load management features of EPower will give these users a better control over their peak power demands. In many countries the monthly peak power demand is a critical factor in the cost that the end users have to pay for electrical energy. Our lecture will explain in detail how PLM (Predictive Load Management) works, its capabilities and the projected cost savings which can be enjoyed in large scale electrical heating system installations typified by those in the glass industry.

Objectives

In multiple full cycle firing[1] load applications, like the operation of several bending or laminating furnaces and annealing lehrs, peak power demands are likely to occur if no special measures are taken. In multiple load situations where phase angle firing is used the whole facility may suffer from a poor power factor (cos φ). Both, high peak power demands as well as poor power factor will lead to higher energy costs and increased CO_2 emissions.

Most utility companies apply a surcharge when the power factor goes below 0.9 (or 90%) or if agreed maximum power demands are exceeded. By the end of the year this can translate into thousands or even tens of thousands of dollars, depending on the size of the installation.

The "demand charge" represents the cost per kW multiplied by the greatest 15-minute demand reached in kW during the month for which the bill is rendered; however the demand is subject to power factor adjustments. Electric power suppliers reserve the right to measure such power factors at any time. Should measurements indicate that the average power factor is less than 90%; the adjusted demand will be the demand as recorded by the demand meter multiplied by 90% and divided by the percent power factor.

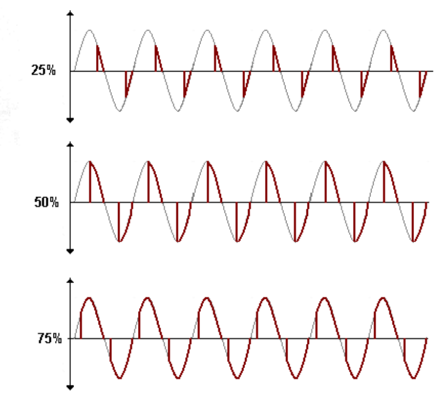
In addition to this energy cost penalty, these possible peak power demands result in investment in unnecessarily large (oversized) power distribution systems.

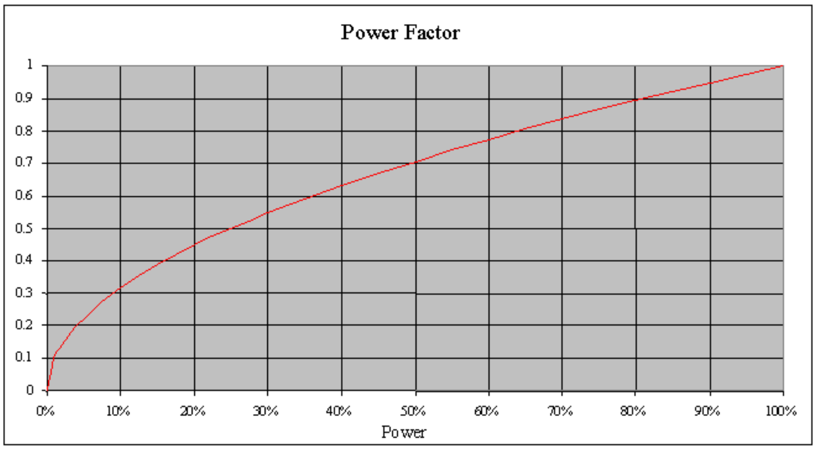
Predictive Load Management (PLM) is able to eliminate those full cycle firing drawbacks resulting in more effective performance not just through simple synchronised firing or 'Load Optimisation', but through advanced load balancing and load shedding strategies provided as standard features of each Eurotherm EPower.

In most applications EPower makes it possible to switch from phase angle firing into full cycle firing mode. If phase angle firing is still necessary, then LTC (**L**oad **T**ap **C**hanging) strategies are able to potentially increase the power factor and help to minimise any energy cost penalties.

Fundamentals
Electrical heating systems such as glass furnace boosting, fibreglass insulation and reinforcement bushings, tin bath and annealing lehr heating systems normally use SCR[2] (semi conducting rectifier) controllers, firing in phase angle mode.

Rene M – Brief overview of the Benefits and drawbacks of Phase Angle firing Phase angle firing typically degrades the power factor while increasing harmonics and electrical noise.





With phase angle firing, the power factor decreases rapidly with output power. At 50% power, the power factor is only 0.7. At 25% power, the same power factor decreases even more to 0.5. Moreover, phase angle firing creates all sorts of disturbances on the grid, such as harmonics, RFI, line losses, wasted energy (kVAr) and transformer overheating. The manufacturer will eventually be forced to increase the capacity of their equipment to compensate for these disturbances, for example by installing active or passive systems such as costly capacitors.

Conclusion :
While Phase angle firing is a simple and smooth way to control power demands with SCR's. It has two major disadvantages; poor power factor and lots of harmonics.

Power factor improvements
There are two effective methods to improve power factor in SCR driven power control systems.

- Load tap changing
- Full cycle or Burst firing

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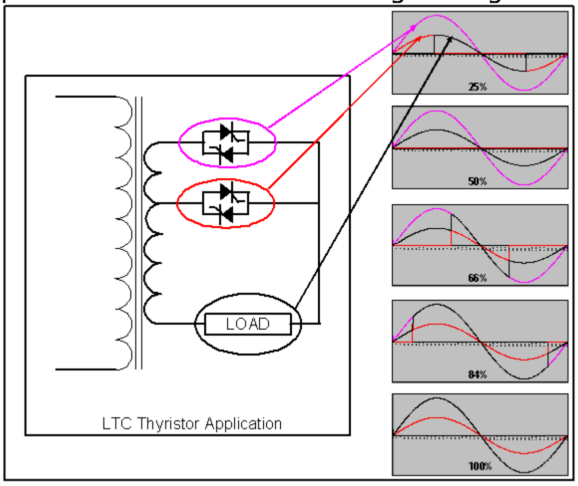
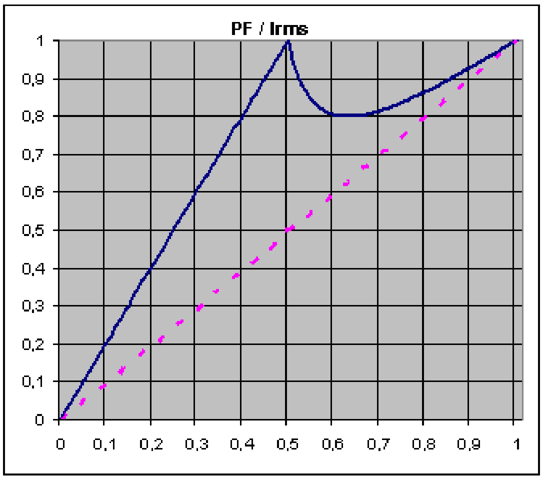
Load tap changing

Although it is outside the scope of this abstract we need to spend some time understanding how 'On Load' tap changing provides an effective way of increasing power factor of an SCR driven power system. An automatic LTC system can be used in either Phase Angle or Burst Firing modes of operation. By adding several taps to the transformer with a dedicated SCR for each tap, together with overlapping firing orders, such a system is capable of running at an increased power factor over a much larger range when using phase angle firing.

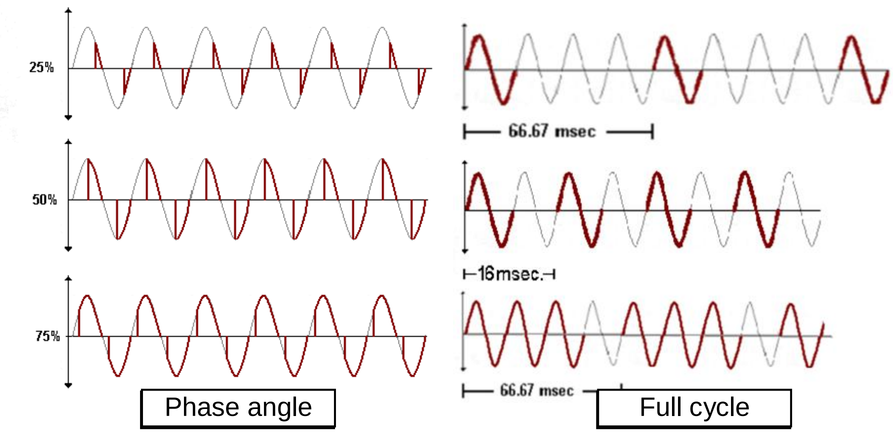




The example above shows a two tap LTC configuration running in phase angle mode and the corresponding improved power factor of such a system. By adding more taps the power factor performance increases. At the design stage it is of course necessary to have a clear understanding of the overall voltage range and the daily voltage operation range, as the best power factor can only be achieved by carefully calculating the tap-voltages. For more information on LTC please review Eurotherms' LTC white paper.

Full cycle firing

The easiest way to increase the power factor is to switch from phase angle to Full Cycle firing, also called Zero Cross or Burst firing. In this firing mode a modulation period is defined and inside such a modulation period the SCR is modulated with single or multiple full cycles according to the power demand.



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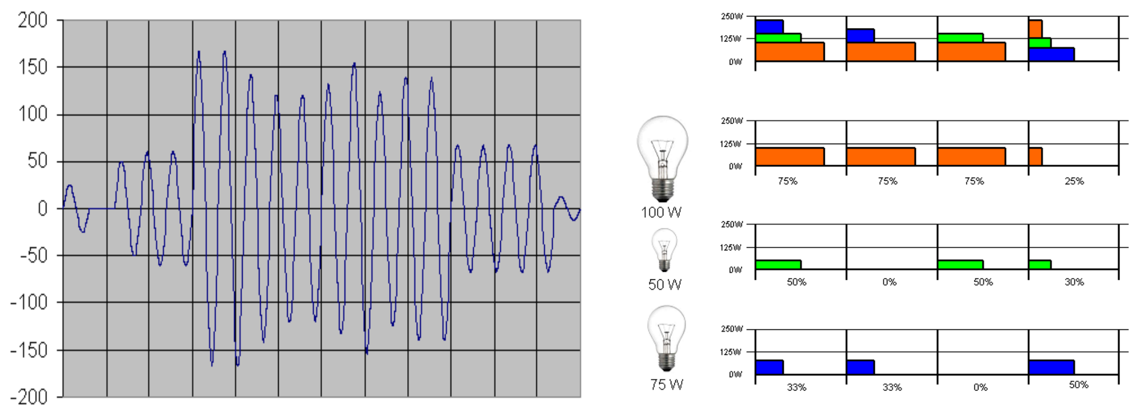
The figure shows a comparison between a single SCR power system running in phase angle mode and full cycle firing mode at respectively 25%, 50% and 75% of the maximum power. Theoretically full cycle firing will result in a power factor of 1 but due to unavoidable inductive loads like transformers, wiring etc, such a system will have an overall power factor >0.9. In fact these systems will run at the highest achievable power factor whilst avoiding the phase angle influences on the overall power factor.

Unfortunately, full cycle firing can introduce a flicker effect (main voltage variation) which in turn can affect motors and create a visual disturbance (light flicker, similar to fluorescent lighting). This effect can become more severe in multiple SCR controlled applications such as tin bath heating, annealing lehr and bushing controls when running large numbers of zones. These systems can easily contain more than 40 zones running at different power levels and variable set points. If not properly monitored, this may lead to large uncontrolled peaks of power.



Thus, many zones randomly fired in time will increase the random peak power consumption. With two possible scenarios :

1. On new installations we therefore design in this overhead based on the maximum possible peak values, and accept the consequential additional cost of this exercise.

2. On existing installations where we may be making process improvements, changing products or increasing production capacity. This additional load may exceed the designed total power capacity of the installation resulting in possible overloads even possible black-outs.

It is however possible to address both of these scenarios firstly by ensuring that peaks of power are reduced by balancing or sharing automatically the demand across many loads to 'smooth' the average power demand on the distribution, whilst importantly still maintaining the desired power to each of these zones. Secondly by optimising and limiting the maximum allowable peak power demand of a system.

Conclusion: the power factor benefit of the full cycle firing mode provides such a big advantage that methods need to be developed to overcome the peak power related problems. One of the most sophisticated methods is Eurotherms' "**P**redictive **L**oad **M**anagement".

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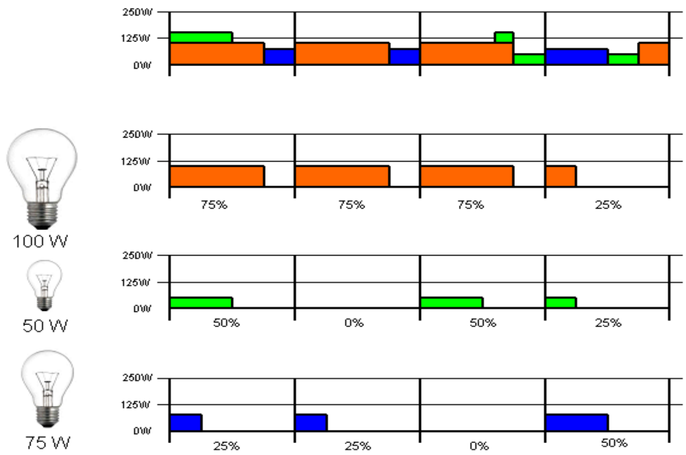
Predictive Load Management
There are two key features of PLM which help us to address the above effectively, these are Load Balancing (or Load Sharing) and Load Shedding and are described briefly below:

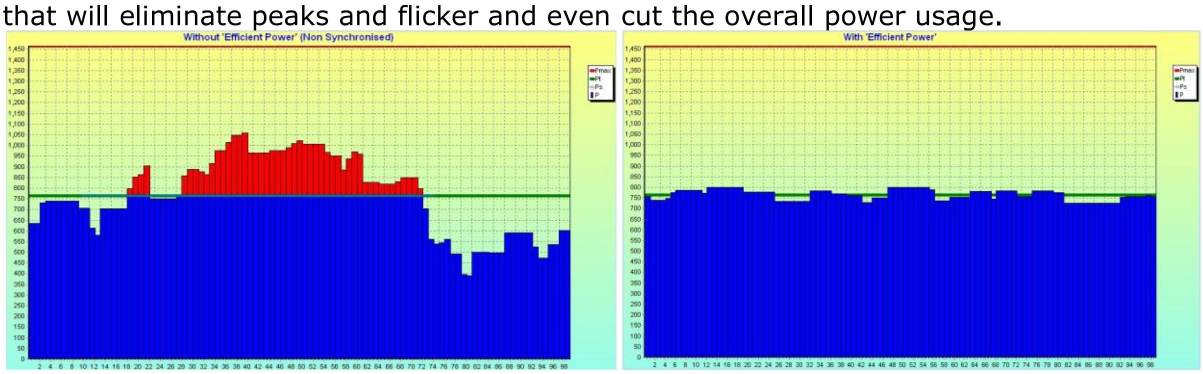
Load Balancing
Overall the Load Balancing strategy is the most important part of PLM functionality, allowing us to combine multiple Burst Firing SCR's whilst maintaining a stable overall power demand.

Load Balancing is a strategy of equally distributing power of different loads to obtain an overall power consumption as stable and balanced as possible thus eliminating peaks of power. Combining multiple SCRs which are burst firing into different loads at different rates necessitates a number of sophisticated algorithms.

Each heating zone controlled by an SCR controller, is defined by an output power, cycle time and a maximum power (max capacity), which can be pictured as a rectangle. Rather than letting these rectangles pile up randomly, the PLM equipped controller uniformly distributes them thereby ensuring that at any given moment the overall power is as stable and balanced as possible. It is important to understand that the PLM function does not change the output power but rather balances and shifts the power evenly thereby eliminating any disturbance. The result is optimum load management through intelligent load balancing and load sharing, a strategy



that will eliminate peaks and flicker and even cut the overall power usage.



By using the PLM function, manufacturers are now able to use zero cross firing for their system without any drawbacks. Eliminating Phase Angle firing significantly improves the power factor which in turn results in substantial savings.

Additionally, using energy more efficiently (i.e. substantially decreasing the reactive power (KVAR)) results in less power generated by the utility company. In fact, we should consider that consuming reactive power is in the end simply a waste of energy. While a bad power factor forces the utility company to generate this extra reactive power, it will be of absolutely no use to the end user. Besides saving costs, implementing a best practice of efficient energy consumption also results in considerably less CO_2 emissions released to the atmosphere.

Load Shedding: Demand reduction and Load Control strategy
The shedding function allows limiting and shifting the overall energy consumption all together or with fully adjustable user-defined priorities. Adjustments can be made through fieldbus communication (Profibus, DeviceNet and Ethernet) enabling dynamic adjustments in view of current PeakTime period surcharges.

Increased Quality of Main Power Supply
While an efficient load strategy can result in substantial savings and an improved environment, using synchronized SCR's will drastically increase the quality of the main supply. As described above, eliminating phase angle will remove harmful harmonics and RFI[3] generation, which for example could disturb the IT infrastructure or overheat transformers.

For customers already using full cycle firing, the PLM function can help achieve constant power balance without the flicker effect. Moreover, PLM can be of critical importance in installations where the overall installed power of the heating elements exceeds the capacity of the main transformer. In such cases non-synchronized firing may result in a total black out caused by tripped overloaded main circuit breakers. The PLM function will avoid heavy peaks of power that could overload the system by constantly monitoring and balancing the firing.

Examples

Furnace 500KW	Phase Angle		Zero Cross with EPOWER Load Balancing	
Basic Facilities Charge		$332.50		$332.50
Demand in KW	500KW		500KW	
Power Factor	**0.7**		**>0.9**	
Demand Correction KW	**643KW**		**500KW**	
Demand Charge: $9.72 per KW		$6,249.96		$4,860.00
Hour of operation	720		720	
Consumption per month (avg 50%)	180.000KWh		180.000KWh	
Energy Charge:				
First 100 kWh per Kw	$.0529/KWh	$5,290.00	$.0529/KWh	$5,290.00
Next 200 kWh per kW	$.0495/KWh	$3,960.00	$.0495/KWh	$3,960.00
Monthly Energy Cost		$15,832.46		$14,442.50
Annual Energy Cost		$189,989.52		$173,310.00
Annual Savings				**$16,679.52**
				-9%

Energy Costs
Load sharing, based on predictive strategies, will bring us substantial cost savings. However, proper calculation of the savings can only be made when details of the rates and conditions of the supply chain are fully known.

In addition, the possible savings in the price for the connection to the grid can be significant. Therefore Eurotherm can work with our customers at the early design stages to help them realise the full benefits prior to installing new infrastructure and negotiating energy contracts.

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Many companies will have an energy manager or a specialized purchaser that knows the complexity of its company energy usage and associated costs. Both technical and purchasing personnel need to work together to find a valid technical solution to reduce energy consumption and CO_2 emissions without impact on production yield or quality.

Conclusion

Improving the power factor, controlling the demand charge and reducing peak consumption during ON peak times can result in substantial savings. In addition the PLM function helps to improve the quality of the main power supply and also ultimately reduce CO_2 emissions.

[1] Full cycle firing is also called burst firing mode
[2] Semi conductive rectifier
[3] Radio Frequency Interference

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