invensys
Operations Management

white paper

Automatic Load Tap Changer for Industrial Loads

Using Phase Angle - the Solution for Cleaner Supply and Cost Savings

Problem:

- Traditional power controllers in phase angle firing mode generate harmonics. Harmonic distortion is a form of electrical pollution that can overheat cables and motors connected to the same power supply and accelerate ageing of equipment. Harmonic distortion can trip relays, circuit breakers and can interfere with communication and other equipment such as computers.

- Harmonic distortion increases losses as it wastes energy (reactive power), impacts the demand charge by reducing the power factor and reduces the capacity of the supply.

- A low power factor circuit consumes more current than a high power factor circuit with the same amount of power transferred to the load. The higher currents increase the energy lost in the distribution system and require larger cables. The wasted energy generated can result in penalties applied to industrials with a power factor lower than 0.9 or 0.85 by the utility company.

- As a result harmonic distortion increases electric bills as well as capital expenses due to the oversized installation needed.

Solution:

- The use of a load tap changer power controller on tap transformers to provide total control over the full range, while drastically reducing the harmonic generation or even eliminating it in some cases.

- Multiple configurations are available from two taps to four taps, either on the primary or secondary of the transformer, achieving all application requirements.

- No more mechanical moving parts and plant personnel intervention to change the taps.

- Eliminate most of the power quality problems listed above.

Benefits:

- Reduce the energy bill if penalties are applied.
- Save energy through reduction of the losses.
- Optimize the size of transformers, cables and switchgears.
- Green: less energy produced at the source results in reduced CO2 emissions.
- Reduce ageing of equipment.
- Reduced disturbances on surrounding electronic equipment.
- Improved compliance with international EMC standards.
- No manual operation or moving mechanical parts.

EPower™ Load Tap Changer:

Eurotherm introduces an innovative function to maximize the power factor when phase angle is the only alternative due to the nature of the load for example.

Not only can this solution improve the power factor, it reduces the harmonic generation, Total Harmonic Distortion (THD) and can lead to substantial energy cost savings.

Rather than compensating for harmonics with filters or banks of capacitors, the idea is to drastically reduce the harmonic generation or even eliminate it in some cases, as well as increase the Power factor.

The Load Tap Changer is an arrangement of several channels of the EPower unit that control a transformer with several taps.

The EPower load tap changer will automatically switch from one tap to the next based on its unique input signal and internal feedback control in order to match the load voltage as close as possible to a sinus waveform.

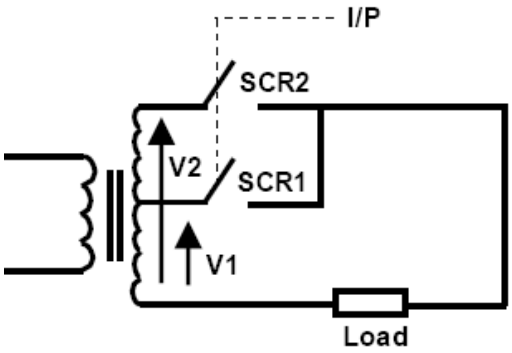
Important: Taps can be either on the primary or on the secondary side of the transformer.

The LTC proposes two types of control: Primary or Secondary of the transformer will be used depending on the application and condition, such as medium or high voltage on the primary, low voltage (<100V) on the secondary and/or current on either side of the transformer.

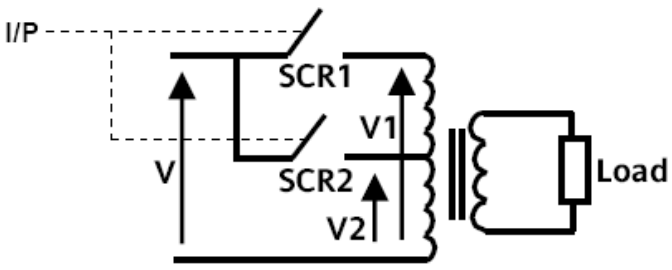
Eurotherm offers solutions from 1Amp to 4000Amps. For more information consult Eurotherm.

In both cases, each tap is controlled by one leg of the EPower SCR power controller. The selection of the used tap is automatic and self adjusting.

Example 1 (fig.1)



Example 2 (fig.2)

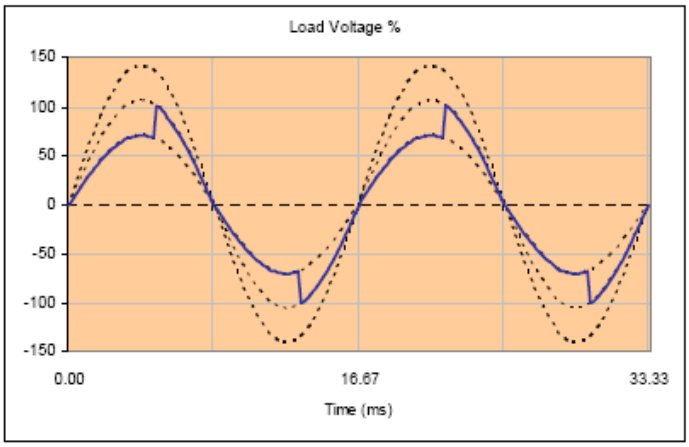


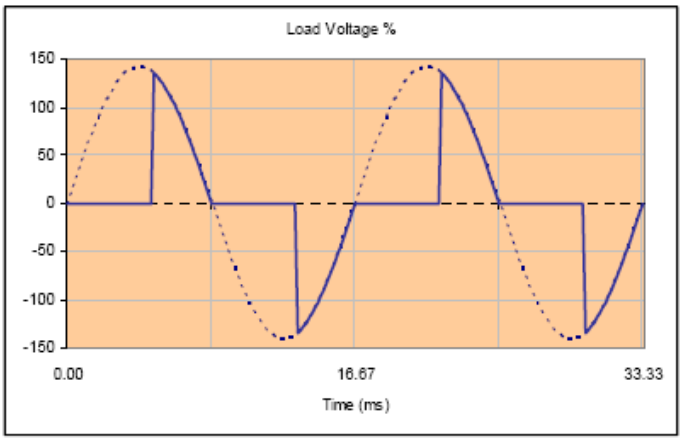
Example 1 shows two taps on the secondary side of the transformer. EPower can actually have up to four single phase legs on the same unit.

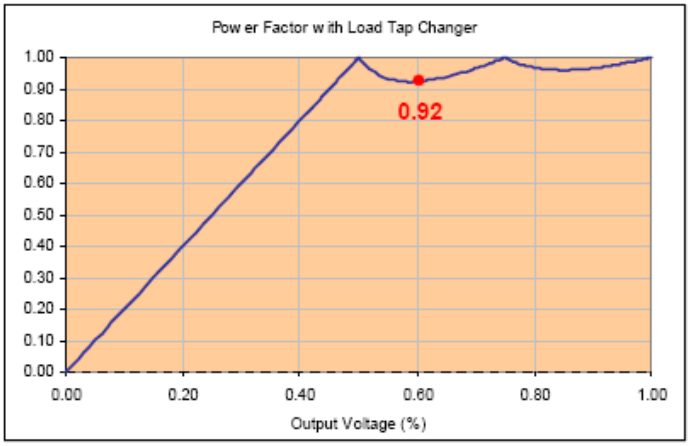
In Example 2, instead of one traditional SCR with one leg, we have one EPower unit with two legs each controlling one tap on the primary side of the transformer from one single input signal.

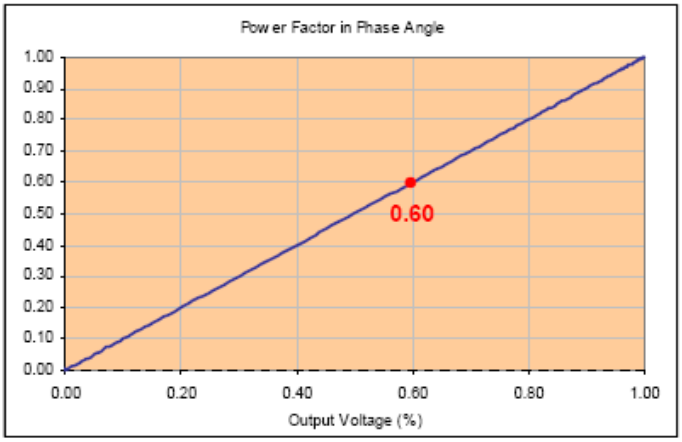
Eurotherm Limited, Faraday Close, Durrington, Worthing, West Sussex B N13 3PL UK
T. +44 (0)1903 268500 F. +44 (0)1903 265982 **www.eurotherm.com**
Reg Office 3rd Floor, Grosvenor Place, London, SW1X 7AW United Kingdom Reg in England No. 853008

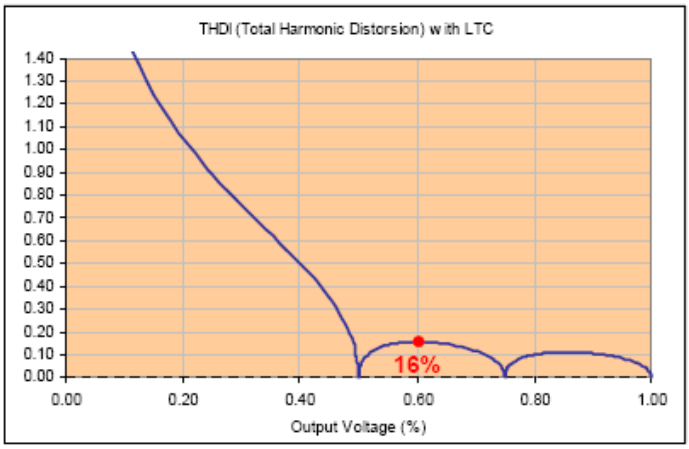
Below are the results of the Load Tap Changer effect on the Power Factor and Total Harmonic Distortion using an example with three taps (240Vac, 360V and 480Vac) versus a traditional solution in phase angle, without LTC, at 480Vac.

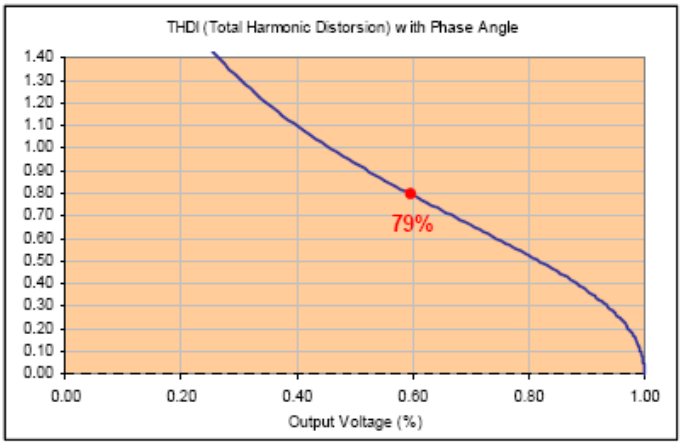












With LTC – 60% Output Voltage

Without LTC – 60% Output Voltage

(fig. 3)

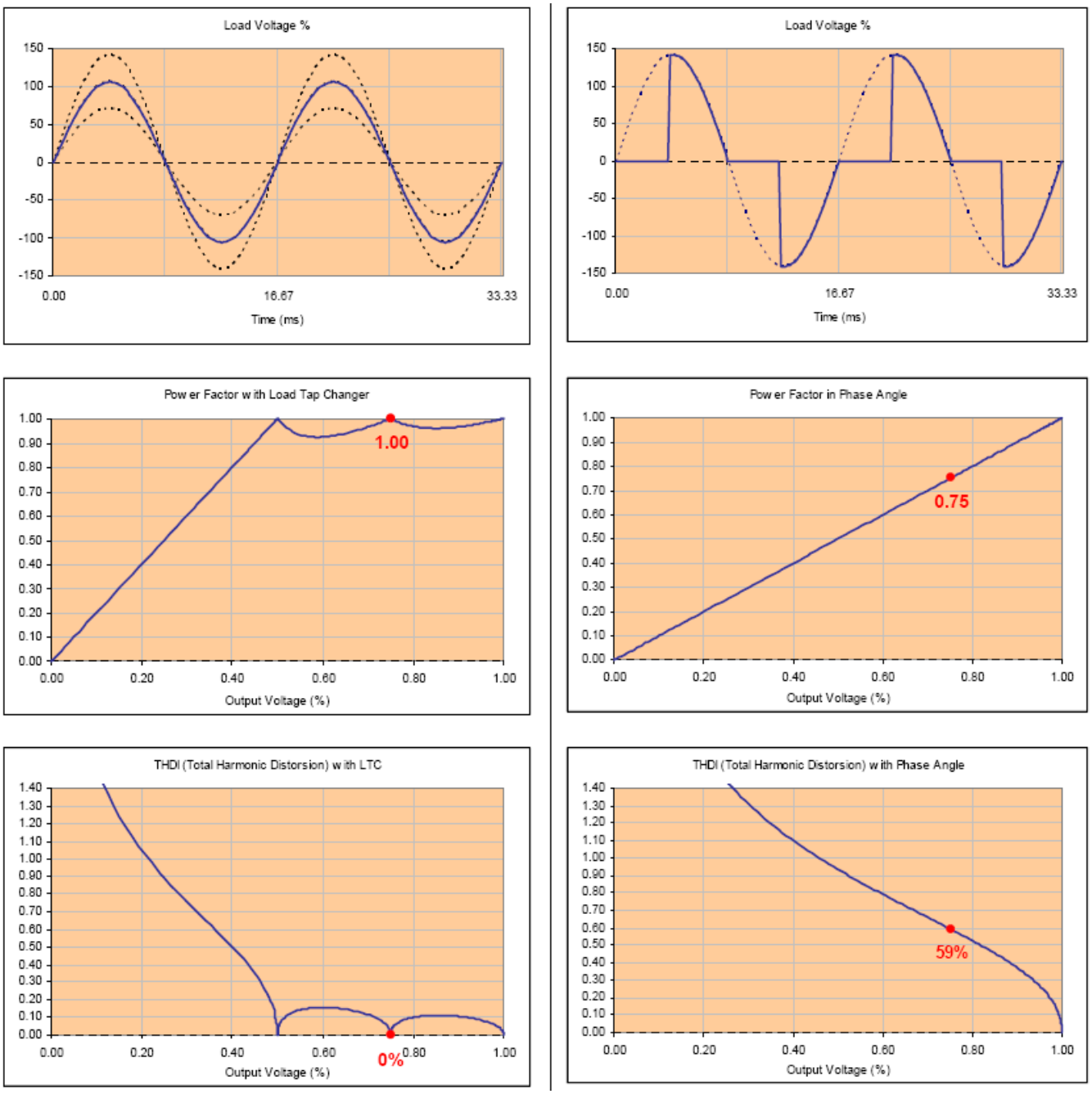
Eurotherm Limited, Faraday Close, Durrington, Worthing, West Sussex B N13 3PL UK
T. +44 (0)1903 268500 F. +44 (0)1903 265982 **www.eurotherm.com**

Reg Office 3rd Floor, Grosvenor Place, London, SW1X 7AW United Kingdom Reg in England No. 853008

For both we have the following:

- Vrms Load = 288V
- Equivalent to 35% of maximum nominal power on a linear load to up to 60% power if, due to the nature of the load, the current is maintained at 100% nominal.

It shows a drastic amelioration of the power factor which rises from a poor 60% to an excellent 92%.
The result of the THD is even more impressive with a THD at 16% versus 79% with traditional Phase angle.



With LTC – 75% Output Voltage

Without LTC – 75% Output Voltage

(fig. 4)

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At 75% voltage (Vrms load = 360Vac), while the power factor = 1 with the LTC, the traditional solution still displays a poor value at 0.75 leading to energy penalties.

As for the THD, because the output voltage is perfectly sinus, there is no distortion whatsoever meaning absolutely no disturbance. In the opposite, with regular phase angle, the THD is still very high at 59% resulting in all sort of problems listed at the beginning.

Remark: To get the best result it is important to wisely choose the value of the first tap.

On most furnaces the power demand will fall to around 20% to 50% when the furnace is at temperature. The idea is to match this value with the maximum output voltage (or Power) when at full conduction on the first (or second) tap. If calculated accordingly, the power factor will eventually be equal or close to 1 for the furnace during most of the process.

Obviously, this will result in serious savings on the cost of energy.

The following simulation represents a 600KW furnace made of 6 equivalent single phase zones. The furnace runs at an average 50% power. For such a furnace, it will be suitable to have only two taps with the first at 320Vac, which at full conduction gives 44% power (linear load).

At 50% power, with a traditional Phase Angle solution, the average power factor is below par at 0.71.

Compared this to EPower with the Load Tap Changer, and the result is much better. (fig.5)

Furnace 600KW	Phase Angle		Phase Angle with Load Tap Changer	
Basic Facilities Charge		$332.50		$332.50
Demand in KW	600KW		600KW	
Power Factor	**0.71**		**>0.9**	
Demand Correction KW	**760KW**		**600KW**	
Demand Charge: $9.72 per KW		$7,387.20		$5,832.00
Hour of operation	720		720	
Consumption per month (avg 30%)	130.000KWh		130.000KWh	
Energy Charge:				
First 100 kWh per Kw	$.0529/KWh	$5,290.00	$.0529/KWh	$5,290.00
Next 200 kWh per kW	$.0495/KWh	$1,485.00	$.0495/KWh	$1,485.00
Monthly Energy Cost		$14,494.70		$12,939.50
Annual Energy Cost		$173,936.40		$155,274.00
Annual Savings				**$18,662.40**
				-11%

(fig.5)

This example shows a potential savings up to $18K+ on cost of energy using EPower with the LTC feature. The return on investment can be achieved in a matter of months.

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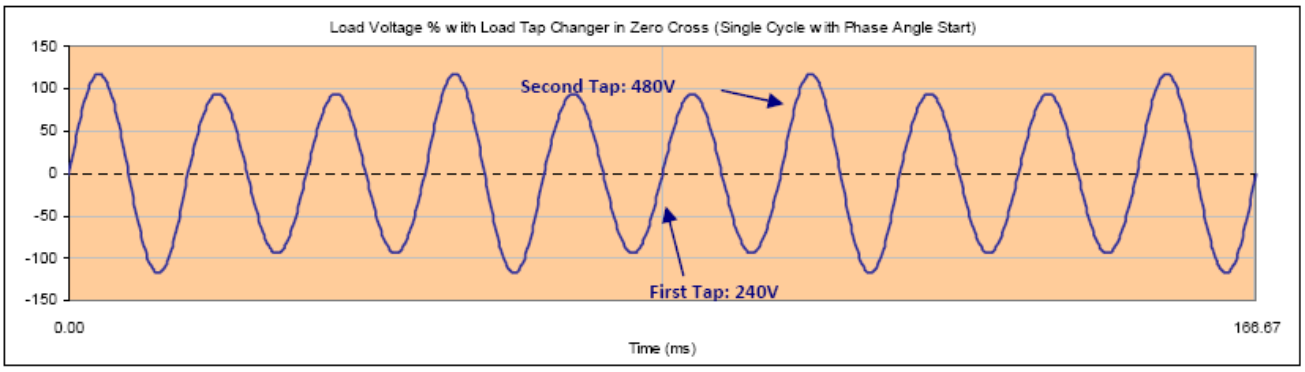
Combining Phase Angle and Zero Cross with Load Tap Changer:

To minimize the effect of phase angle or eliminate it altogether, we can combine both phase angle and zero cross firing with the Load tap changer functionality.

For loads with heavy inrush current requiring current limiting at start up, Phase angle can first be used on the first tap till it reaches full conduction. Next, instead of continuing in phase angle on the following tap(s), it is possible to switch to fast zero cross firing as shown in fig. 6 below.

This solution provides a power factor at unity (minus the inductive part of the load itself) on an even wider range.



50% Power with LTC in Zero cross (Single Cycle)
(fig.6)

Remark

Even without the LTC function, EPower offers easy settings in every configuration (single phase, two leg three phase and true three phase) to switch automatically or on demand from Phase angle to Zero cross to minimize the effect of phase angle and to maintain a power factor as high as possible.

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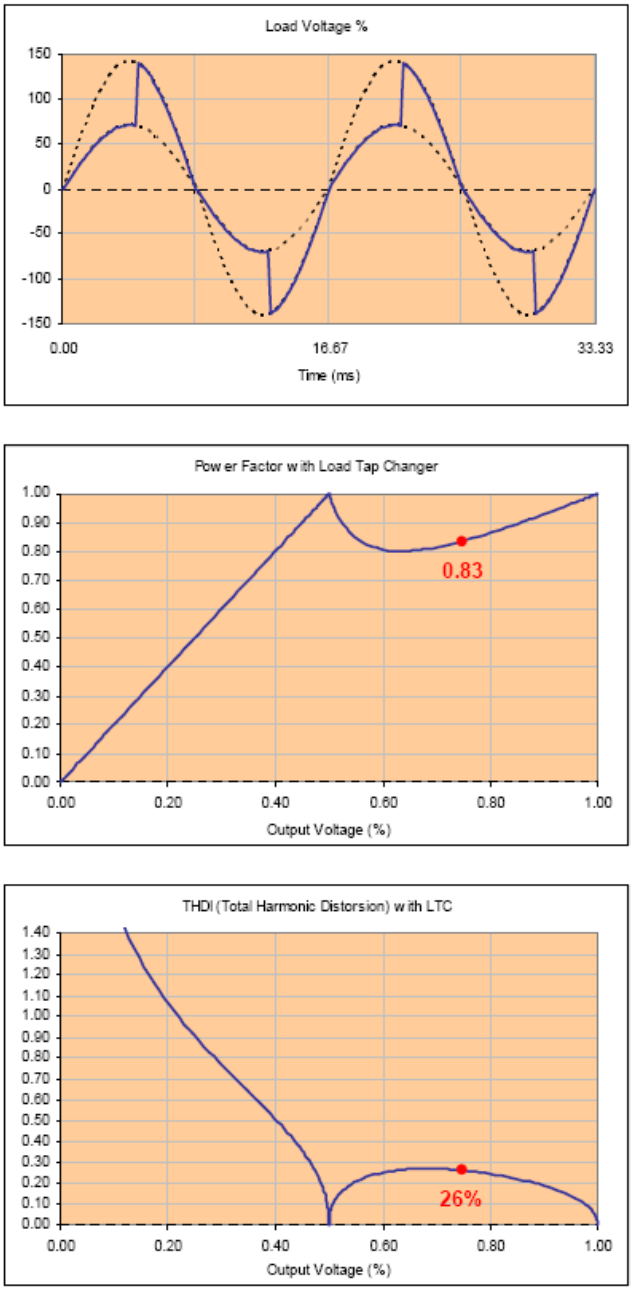
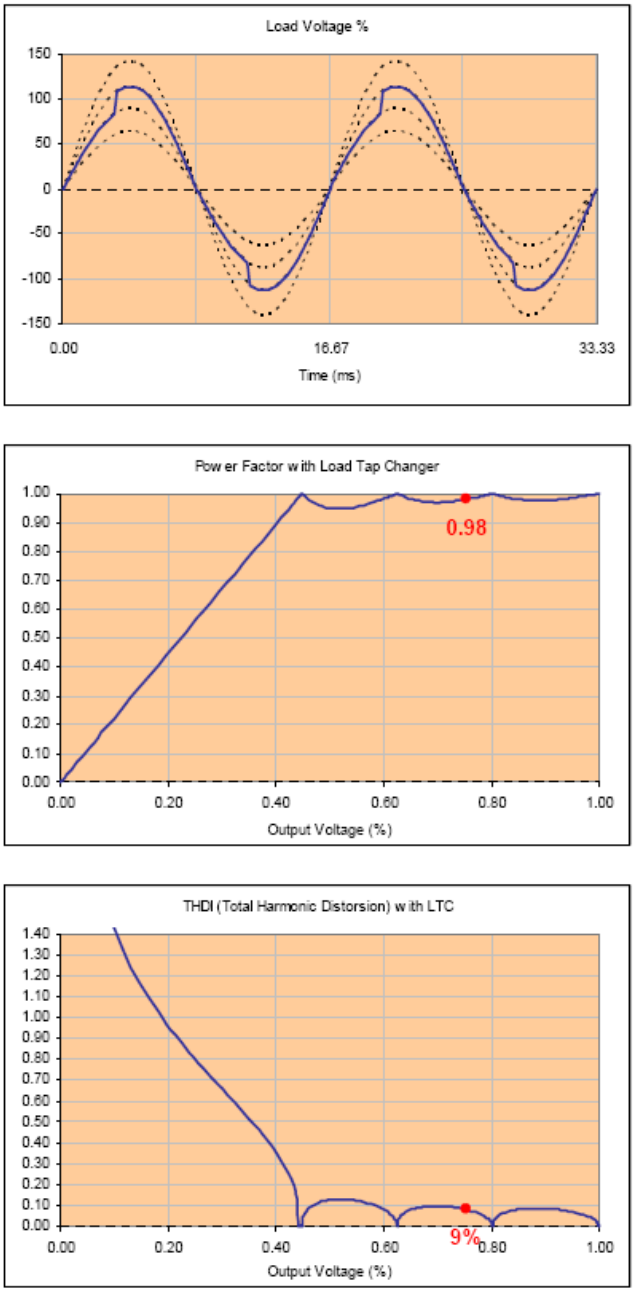
To get the optimum results on the power factor, harmonic generation and global current distortion harmonic content (THDI), the load tap changer can be used on solutions from two taps up to four taps.

As shown on the pictures below, if we reconsider the example shown in fig.4 at 75% output voltage, the power factor will be 0.83 with two taps and 0.98 with four taps, while it is 0.75 with the traditional solution.





EPOWER LTC with two taps (75% voltage)

EPOWER LTC with four taps (75% voltage)

(fig.7)

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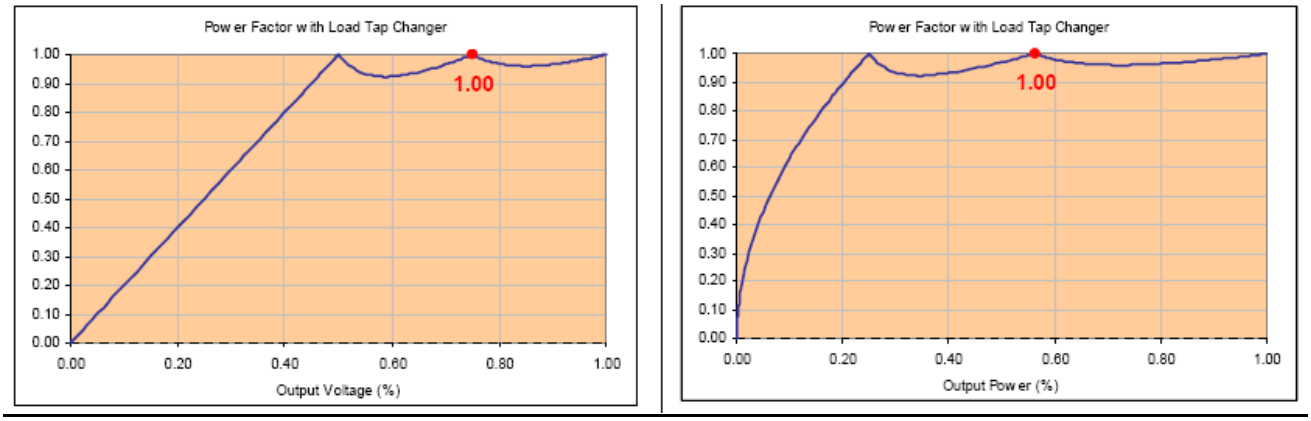
The power factor will always be above 0.9 from about 45% to 100% output voltage with an EPOWER LTC solution with 3 taps.

With the four tap example, the position of the taps have been modified to increase the range even more, as the power factor stays above 0.9 from 40% to 100% output voltage.

Remark:



(fig. 8)

It's important to understand the parallel between the power factor versus the output voltage and the same power factor versus the output power as shown with two graphs in fig.8. We can see that while, in this example with three taps the power factor is above 0.9 for 45% voltage and up, it actually translates to a power factor above 0.9 for 20% power up to 100%.

However, this is true only for linear loads for which resistance remains constant over time and temperature. For non-linear loads in a wide variety of glass and heat-treatment applications, we will use the graph on the left to design and select the appropriate taps for better results.

NOTE: For simulation purposes use the "EPower – Load Tap Changer" simulator tool.

Conclusion:

The load tap changer is a powerful solution for applications that require phase angle firing due to the nature of the load or for convenience. By dramatically improving the power factor compared to a traditional phase angle solution, it results in limiting the harmonic generation thus reducing any associated issues. Even more important, it reduces the Demand Charge of the utility company resulting in substantial savings.

As for the PLM function, the new LTC function helps to improve the quality of the main power supply and ultimately reduces CO2 emissions.

Eurotherm Limited, Faraday Close, Durrington, Worthing, West Sussex B N13 3PL UK
T. +44 (0)1903 268500 F. +44 (0)1903 265982 **www.eurotherm.com**

Written by:
Mikaël Le Guern
Product Marketing Manager – Power Products
mikael.leguern@eurotherm.com
EUROTHERM Inc.
U.S.A.

Written 2009

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