THE FAIRFORD SYSTEM OF ENERGY OPTIMISING FOR FIXED-SPEED INDUCTION MOTORS.

It is well known that an induction motor connected to the normal fixed-voltage supply network will experience a worsening power-factor and efficiency as the motor load reduces.

This effect is due to the rotor current vector shortening and swinging towards a more upright angle while the rotor speeds up and approaches synchronous speed under the influence of excess flux. Because the motor terminal voltage remains fixed to that of the power supply, the magnetising current remains constant and the resultant stator current vector shortens and falls back towards the magnetising current vector. As a consequence, the phase angle (φ) between the supply voltage and the stator current vectors increases, and the cosine of the phase angle (known as the power-factor) tends towards zero. In addition, because the mechanical and magnetising losses remain constant although the load (mechanical output) is falling, the motor efficiency also tends towards zero.

The energy optimising mode is the normal operating condition for a Fairford System soft starter once the motor has reached full speed and driving the load at the torque required by the application. The energy optimising process is continuous and remains in effect until the optimising is inhibited or a stop command given.

While accelerating the motor in the ramp-up phase, the system software also computes a reference value for the power-factor of the motor being controlled. During optimising this value is constantly compared with the running power-factor and from the comparison, the software continuously computes, adjusts and updates the firing points of the power thyristors so that the total energy delivered to the motor corresponds to that required by the load. By eliminating the waste of energy in over-fluxing the air gap the efficiency is improved and simultaneously, the power factor of the motor is maintained at the best value possible for all load conditions.

The management of power factor by the Fairford System of control does not detract in anyway from the capability of the motor to respond to a fluctuating load demand and the performance of the motor is unaffected in every respect.

The optimising feature is a purely electrical function which has the effect of ensuring that motor delivers the torque demanded at all times, but only drawing the precise amount of magnetising current necessary to support the motor output. Without this feature, the motor would draw a constant magnetising current based on the supply voltage regardless of load.

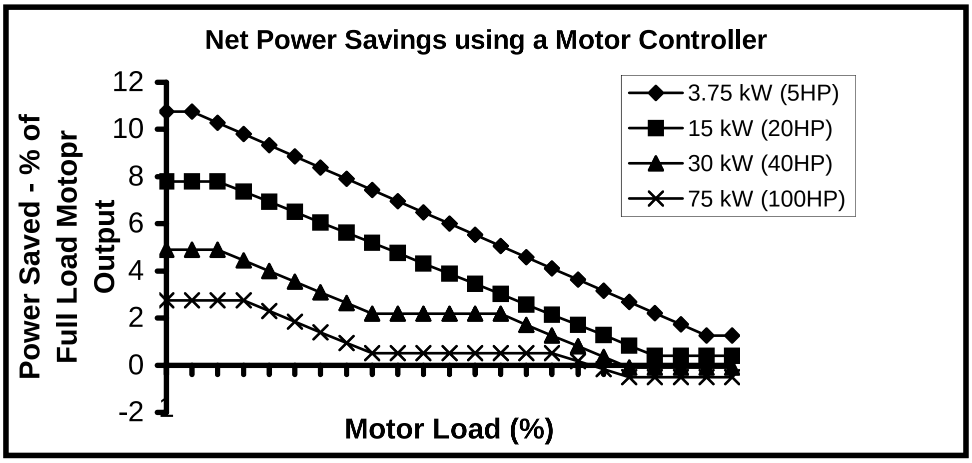
Reducing the current in proportion to the load results in a reduction in I^2R losses giving rise to an improvement in motor efficiency that is both continuous and cumulative.

Although the power factor of the motor is improved by the operation of the optimising function, it should noted that it cannot be improved beyond the nameplate value, and will not eliminate the need to fit power-factor correction capacitors if the power tariff warrants it.

What sort of improvements can be expected?

In many ways this is a similar question to how long is a piece of string since there are so many variables involved, ranging from the motor characteristics to the voltage of the supply network. As far as the power-factor is concerned, the lighter the load, the greater the improvement. For instance, a motor running at 10% of rated output would normally have a low power factor, perhaps in the region of 0.3. With the Fairford optimising active, this could rise to the region of 0.4 or so.

As far as the motor efficiency is concerned, the losses most affected by the optimising function are the excitation or "iron" losses, followed by the I^2R or "copper" losses. These elements are in turn, very dependent on the degree of saturation of the iron core of the stator, and thus on the supply voltage present at the motor terminals. With the trend for Power Supply agencies to increase their network voltage towards the higher levels allowed by the tolerances over nominal voltages, the opportunity for savings to be obtained from optimising improves. This effect can be seen in pronounced form in the USA where historically, motors are designed for 460 volt working, but connected to networks which are widely operated at 480 volts and higher. The following graph is taken from the UK Department of Energy Efficiency Office Good Practice Guide 2 shows the extent of the savings to be had from a variety of compressor motors operated at 483 volts, but designed for 460 volt nominal.



Much also depends on the efficiency of the motor being controlled. As a rule of thumb, larger motors tend to be better designed with more copper and iron, relatively smaller air-gaps etc., making for higher efficiency machines, whereas their mass-produced low kilowatt counterparts can exhibit quite low efficiencies. The following tables can be used to give an approximation of the potential savings to be had from motors connected to power supplies whose voltage is in the region of 5% above nominal for the motor design and whose average load is 30% or less than rated output.

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MOTOR SIZE		Estimated savings (% rated kW)
kW	HP	
Less than 5	Less than 7.5	10
5 - 22	30	6.5
22 - 55	75	3.5
55 - 110	150	2.5
More than 110	150	1.5

The estimated savings must be modified as follows:-

MOTOR POLES		PERCENT SLIP	
Number of Poles	Change to est. savings	% Slip	Change to est. savings
2	- 0.5 %	0.5	- 0.5 %
4	No change	2	No change
6	+ 0.5 %	3	+ 0.5 %
8	+ 1.0 %	5	+ 1.0 %

To estimate the potential annual cash value of the optimising function the following formula should be used :-

Savings (£) = (Unit cost of electricity/kWh) x (motor rated kW) x (hours run/year) x (% estimated savings for motor size ± motor poles modifier ± percent slip modifier)

For example, an injection-moulding machine, due to the cyclic nature of the load, typically runs with a load factor of 10% for 90% of the time. So, assuming it is fitted with a 20 HP (15kW) 1480 rpm motor and operated on a 7 days a week, 50 weeks/year, 3-shift working pattern at a unit cost of power of 5.0 pence/kWh, the estimated saving would be :-

(£0.05) x (15) x (50 x 7 x 24 x 0.9) hr. x (6.5 + 0 + 0)% = £368.55 per year.

Depending on the tariff applied, an additional amount in the region of £40 p.a. could arise from a reduction in maximum demand due to the optimising feature.

Even allowing for an error factor of 50% (e.g. motor efficiency is higher or load factor is greater), the savings would still represent an attractive rate of return on capital employed in most circumstances.

Although this paper points towards the benefits obtained by the consumer of energy, there are knock-on benefits to be obtained by the distributor of energy in that he is able to make more efficient use of the network, thereby obtaining a better return on capital employed.

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