Energy Savings in Retail Refrigeration Units

using *EnviroStart* Motor Energy Controllers

David Sands Supermarket - Kinross

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Optimal Energies

Contents

1 Background

David Sands are one of the region's leading high street convenience store retailers, with a well established presence in Fife and the surrounding districts. One of the company's strengths is its standing within the locale, involving an awareness and promotion of local issues. The company employs around 500, mainly retail staff.

Next to staffing, energy costs are one of the most significant overheads incurred by the business. While the business has a structured procurement system to ensure low energy rates, there is a recognised need to reduce consumption. Coupled with this, the company is keen to present a responsible environmental stance and recognises the beneficial impact of such an outlook with the buying public.

A large part of the energy load for David Sands comes from refrigeration, freezers and air-conditioning equipment; it is a fact that such equipment does not run under full load continuously and hence there is a potential to save energy through the introduction of intelligent motor control hardware such as the *Envirostart* Motor Energy Control (MEC) units manufactured by EMS (European) Ltd and distributed by Optimal Energies Ltd. As a result of an energy audit conducted on 27th November 2007 at the David Sands Kinross store, potential savings levels of between 8 ~ 25% had been predicted, depending on the application.

Following the issue of the energy audit results, a meeting was held at the David Sands company headquarters in Kinross on 14th January 2008, attended by representatives of Optimal Energies, EMS (European), R*DL* Associates and Vertex Scotland (responsible for the maintenance of the refrigeration and air-conditioning equipment on all David Sands sites). It was agreed that Optimal Energies would undertake a trial installation of both a single-phase and a three-phase unit in one of the group's supermarkets in order to obtain 'before vs. after' energy consumption data to demonstrate the effectiveness of the MEC units. A second object of the trials was to reassure Vertex Scotland that the installation of MECs would not be detrimental to the existing refrigeration plant. Assuming a satisfactory outcome of the trials, it was the intention of David Sands to roll-out complete pilot installations in a total of five stores in 2008 - Kinross, Kelty, Auchtermuchty, Bridge of Earn & Cardenden were suggested.

The following sections describe how the trial installations were carried out and includes survey measurements that demonstrate the effectiveness of both single-phase and three-phase MEC units in freezer applications.

2 How motor energy controls work

AC induction motors run at a fixed speed determined by the number of poles in the motor, and the frequency of the electricity supply. AC motors only run at maximum efficiency and effectiveness when they are running at the plated rating of the motor.

Once the motor starts to run below its maximum plated rating it starts to waste energy and the lower the load measured against plated rating the more inefficient and ineffective the motor becomes, this is usually displayed by the generation of heat and vibration within the motor.

The graph below shows current consumption of the motor with and without energy savings.

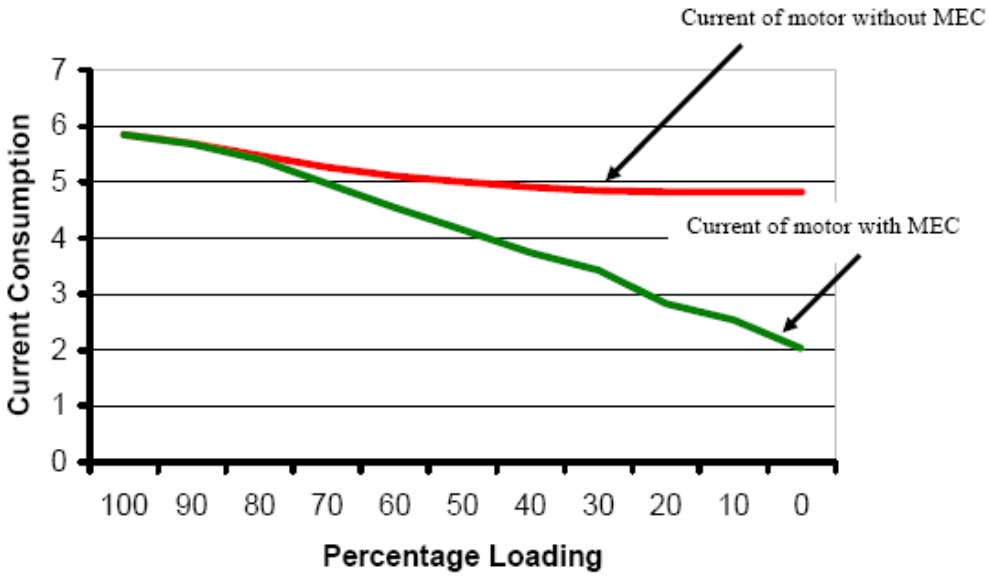

Figure 1: Measured consumption of 0.5 kW single-phase motor

EnviroStart saves energy by sensing when the motor is running off full load by looking at Pf, the phase angle between voltage and current.

The lower the load, the wider the phase angle between voltage and current. *EnviroStart* uses this "positioning" to constantly balance reduction in the supplied voltage to the motor to reduce current consumption thereby reducing the breadth of the phase angle and improving the Pf. This careful "dynamic" adjustment causes the power supplied to the motor to always be in balance with the torque demand of the motor load thereby creating real kW savings within the system without detriment to the motor or reducing the capability of the load itself.

The graphs below show the current and voltage waveforms both with and without energy savings.

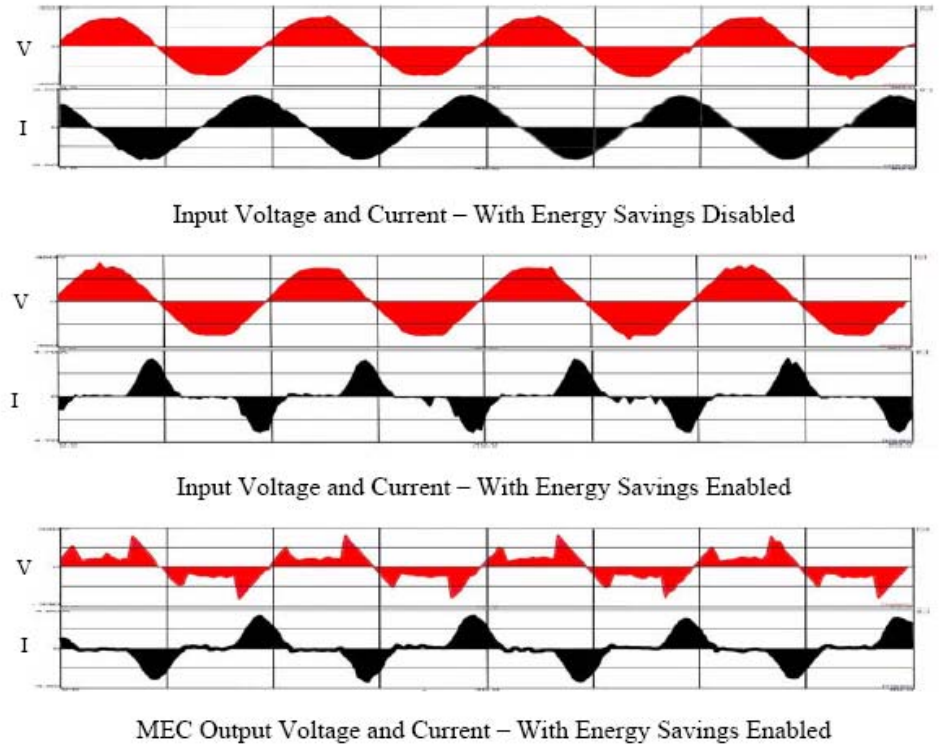

Figure 2: Current & voltage waveforms on single-phase motor

Customers of the electricity supply firms pay for kW, which is the integral of the area of the input voltage waveform multiplied by the integral of the area of the current waveform multiplied by the Pf.

As can be seen from Figure 2 above, the areas under both the voltage and current profiles are reduced when the *EnviroStart* unit is in energy saving mode.

On varying load systems such as compressors (both air and refrigeration), injection moulding machines etc, *EnviroStart* will supply the motor sufficient power to ensure the motor maintains the torque required for the job, this is achieved within 5μs of any load change. To maintain this response time *EnviroStart* systems operate at 12MHz for single phase and 48MHz for three phase *EnviroStart* units.

3 Kinross store trial installations

3.1 *General*

The purpose of the Kinross store trial installations was to obtain 'before vs. after' energy consumption data for representative single-phase and three-phase refrigeration units under comparable ambient conditions, in order to prove the MEC concept. The units selected were a single-phase chest freezer located towards the rear of the store and a three-phase walk-in freezer located behind the store manager's office.

The plan for the installation/data collection sequence was as follows:

- Friday 25/01/2008: install *EnviroStart* units and log the store ambient temperature (Δt = 90s) and current profiles (Δt = 5s) for a week with energy savings mode disabled – 'Week#1'.

- Friday 01/02/2008: retrieve 'normal operation' data, set *EnviroStart* units to energy savings mode enabled and log ambient temperature and current profile for a further week – 'Week#2'.

- Friday 08/02/2008: retrieve 'energy savings' data and disconnect *EnviroStart* units.

Figure 3, below shows an extract from the Week#1 (blue curve) and Week#2 (red curve) logger data for store ambient temperature (recorded at an interval of 1m 30s). The two sets of week-long temperature data were examined in order to identify a like-for-like interval that could be used to compare the 'before vs. after' energy consumption data. It can be seen that for the two consecutive Thursdays during the survey, the temperatures after ~ 1100h begin to diverge and differ by almost 2 °C. However, for the period from 0000h to ~ 1030h, the two sets of temperature data are essentially identical and so this interval has been selected as the basis for analysing the performance of the single-phase MEC on the in-store chest freezer.

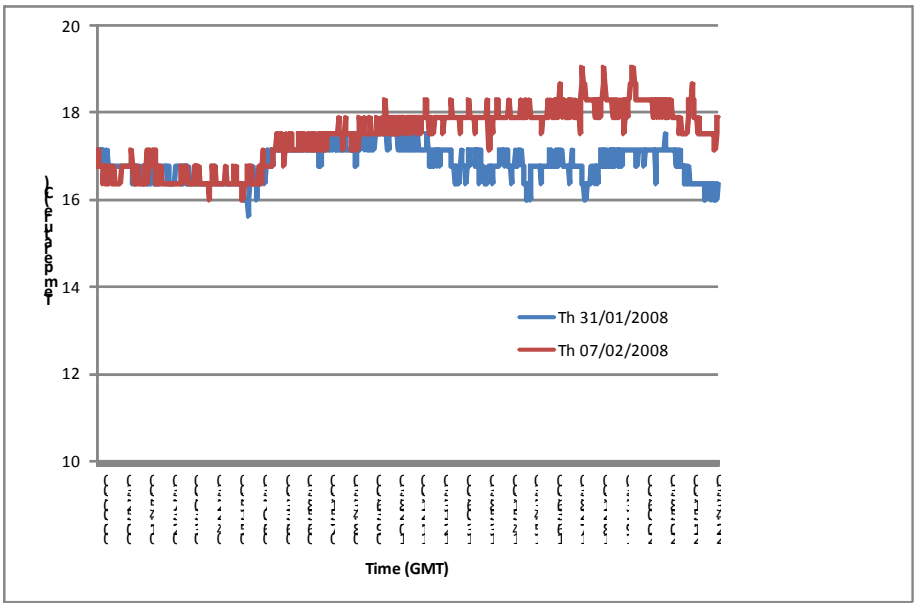

Figure 3: Ambient temperature histories in David Sands Kinross store

It was planned to adopt a similar approach for the three-phase walk-in freezer, i.e. leave a current data logger on one phase of the supply feed and compare the Week#1 and Week#2 data. However, although the Week#1 data were collected successfully, problems were encountered when the *EnviroStart* unit was switched to energy saving mode on 01/02/2008. This issue was resolved the following week as described in section 3.3 below and a faster, more sophisticated measurement technique was adopted to demonstrate the effect of the MEC unit in this case.

The following sections describe the findings for the single-phase and three-phase trials in detail.

3.2 *Single-phase chest freezer*

Figures 4 and 5 below show the installation and logging arrangement to the rear of the single-phase chest freezer unit.

Figure 4: Chest freezer *EnviroStart* MEC installation

Figure 5: Current data logger (left) and MEC unit wiring (right)

Figure 6 below shows the current consumption over a 24-hr period between Friday 25th to Saturday 26th January; these data have been extracted from the week-long survey of current measurements logged at 5 second intervals. The main features of the graph are:

- The compressor operates intermittently, several times per hour;
- The running current fluctuates around 2 ~ 2.3A;
- Occasional start-up spikes up to ~ 18A have been captured by the logger.

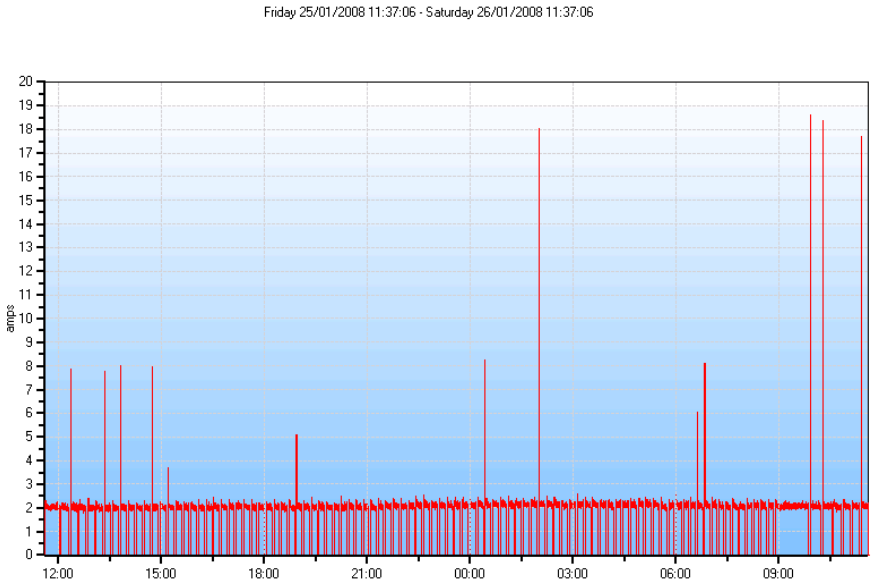

Figure 6: Chest freezer 24-hr current consumption without MEC

Figures 7 through 10 below show the effect of the MEC in circuit over four different time intervals corresponding to the early part of Figure 3 as discussed previously.

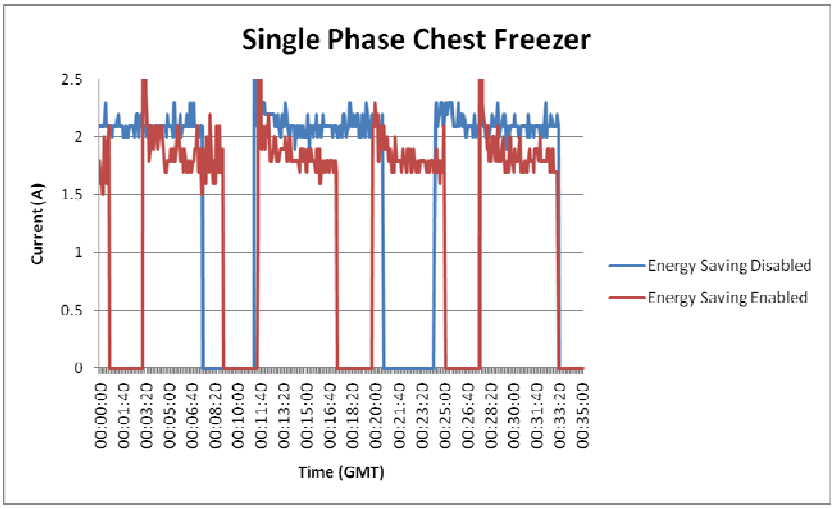

Figure 7: Chest freezer current consumption with/without MEC

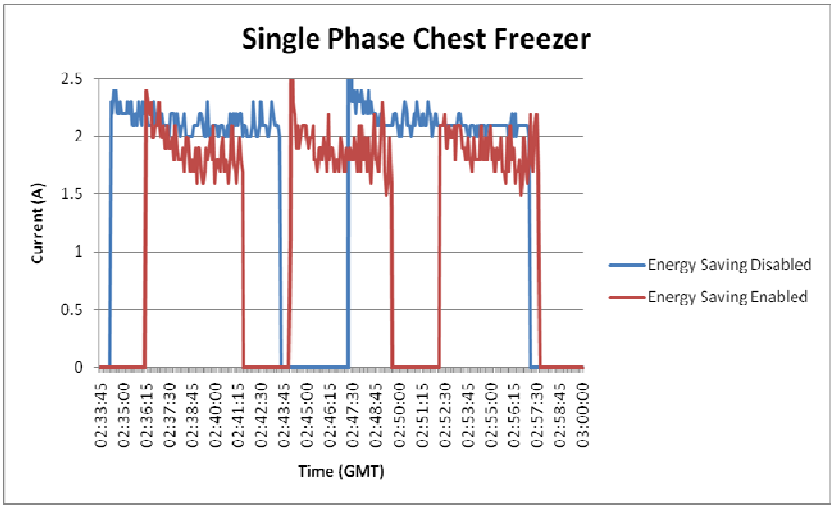

Figure 8: Chest freezer current consumption with/without MEC

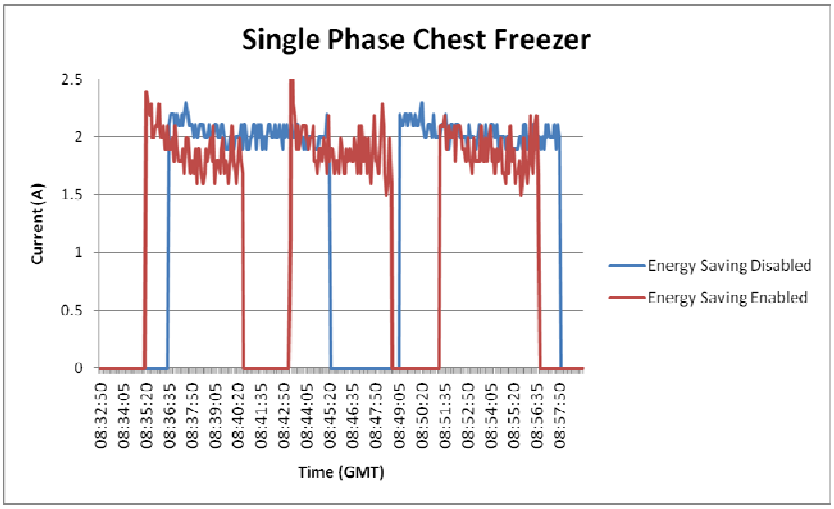

Figure 9: Chest freezer current consumption with/without MEC

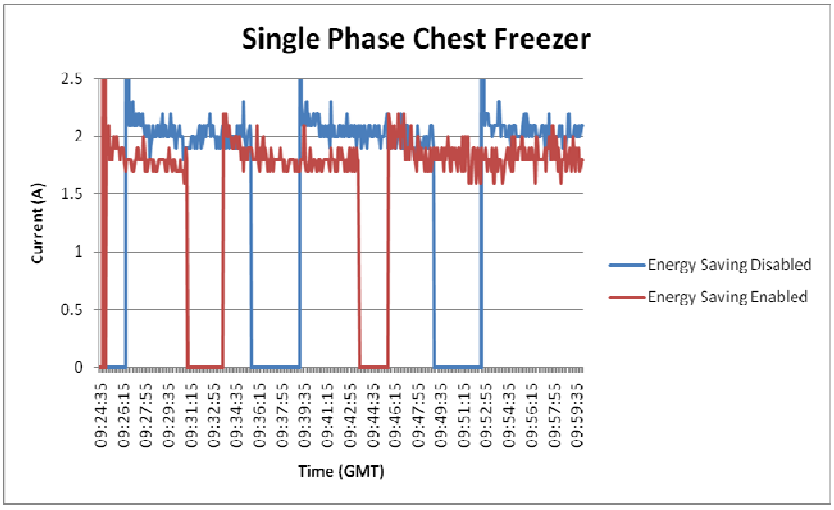

Figure 10: Chest freezer current consumption with/without MEC

According to the single phase audit sheet (dated 27th November 2007), the expected kW savings for a chest freezer are ~ 25%. The data plotted in Figures 7-10, indicate a drop in the mean current from ~ 2.1A to ~1.75A, equating to a saving of ~ 17%. However, the overall power saving is actually greater than 17% because the *EnviroStart* unit also reduces the voltage supply (as discussed previously in Section 2); it is the combined reduction in both current and voltage integrals that produces a saving level in the region of ~ 25% overall (in kW).

3.3 Three-phase walk-in freezer

Figure 11 below shows the current consumption for the walk-in freezer over a 24-hr period between Friday 25th to Saturday 26th January; these data have been extracted from the week-long survey of current measurements logged at 5 second intervals. The main features of the graph are:

- The compressor operates intermittently, several times per hour;
- The running current fluctuates around 7 ~ 8A;
- Occasional start-up spikes up to ~ 44A have been captured by the logger.

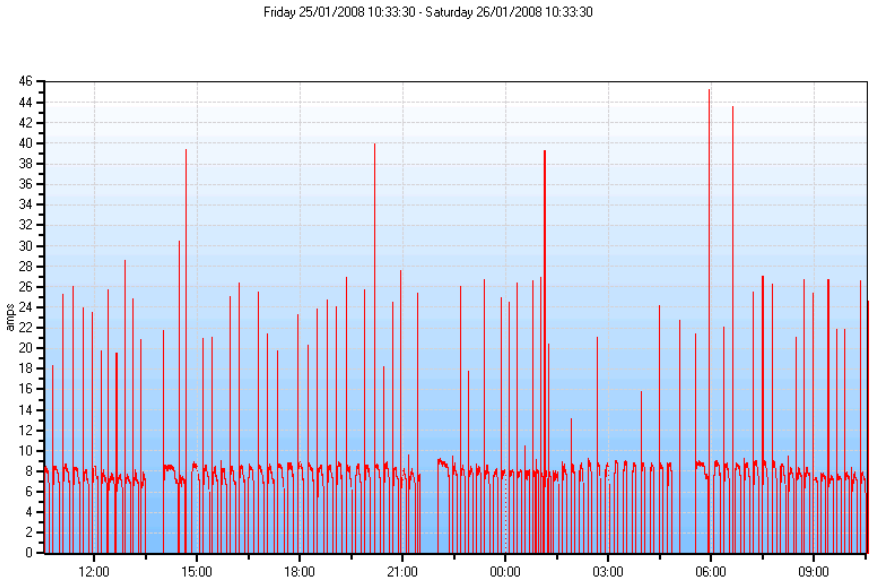

Figure 11: Walk-in freezer 24-hr current consumption without MEC

As mentioned in section 3.1 above, some initial problems were encountered when the three-phase MEC was switched into energy saving mode; these took the form of excessive current fluctuations, particularly at the start-up and ramp-down of the compressor motor. As these problems could not be resolved on site at the end of Week#1, the *EnviroStart* unit was left connected but with energy saving disabled for a second week. It was planned to return to the site the following week with a three-phase network analyser ('*Circutor*') to collect more detailed diagnostic information on the instabilities and determine the nature of the problem.

However, on returning to the site the following week (08/02/2008) it was found that the *EnviroStart* MEC unit had been disconnected and a new compressor unit installed; following a discussion with Vertex it was established that staff in the store had reported that the existing unit had been making excessive noise during operation and so the unit had been replaced.

It was then assumed that the previous problems with the *EnviroStart* operation had probably been associated with the fact that the compressor was approaching the end of its life. The *EnviroStart* unit was re-connected to the new unit as shown in Figures 12 and 13 below; following installation, the three-phase *Circutor* analyser was connected in order to gather comparative data with the energy saving function alternately enabled and disabled at various saving levels.

Figure 12: Three-phase *EnviroStart* MEC installation on walk-in freezer

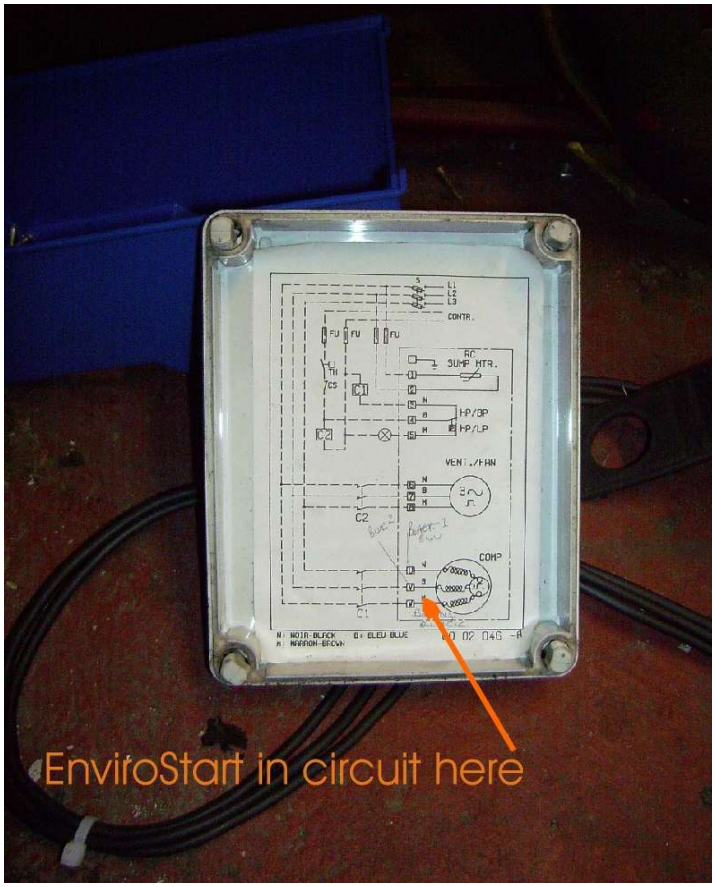

Figure 13: Location of *EnviroStart* MEC in three-phase freezer circuit

Figure 14 below shows the variation in apparent power as measured with the *Circutor* three-phase network analyser. The graph shows the power profile during a total of four compressor cycles; the rightmost curve shows the power consumed in the absence of the *EnviroStart* unit while the three curves to the left were obtained with the MEC unit in circuit and operating at various energy-saving settings. It can be seen that the difference in average apparent power (after the ramp-up period) is greatest between the third and fourth compressor cycles; the graph shows a drop from ~ 6.4 kW to ~ 5.3 kW. This decrease is equivalent to an energy saving of around 17% and is achieved with the *EnviroStart* operating on its default energy-saving settings.

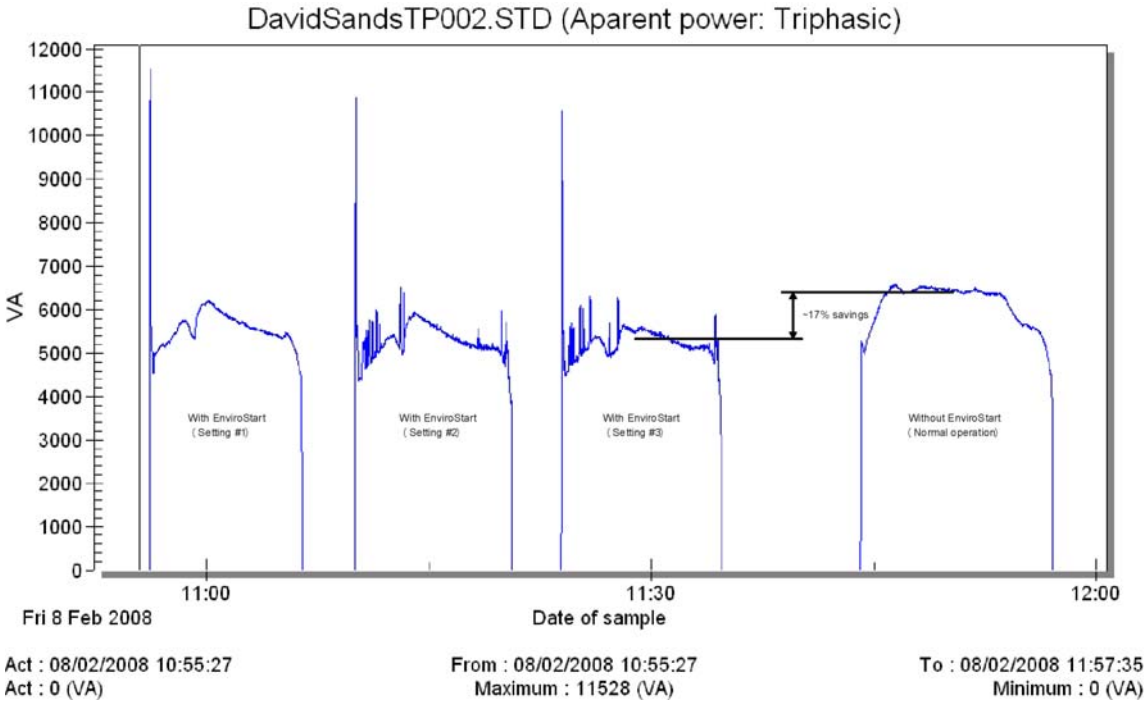

Figure 14: Circutor data for apparent power (three-phase walk-in freezer)

4 Estimates of savings & ROI

4.1 *Single-phase chest freezer*

Assuming a savings level of 25% and a unit cost for electricity at the Kinross site of £0.068/kWh, the initial survey indicated a payback period of 2.44 years for this application, based on the capital cost of the MEC unit only (i.e. no installation costs).

4.2 *Three-phase walk-in freezer*

The initial survey of the site predicted a savings level of 8% for this application and a payback period of 1.22 years (again based on capital costs only). However, the measured savings during the trials were ~ 17% and so the payback period will be reduced proportionately to around 0.6 years.

5 Conclusions

- Trials of *EnviroStart* MEC units have been conducted on both single-phase and three-phase refrigeration units in the David Sands supermarket in Kinross;

- Energy-saving levels of 25% and 17% have been estimated for the single-phase and three-phase freezer applications, respectively;

- Estimates of payback period based on the capital cost of the MEC units alone are 2.44 years and 0.6 years for the single-phase and three-phase units, respectively. However, for the overall payback time to be estimated, the cost of the installation works should be included.

6 Appendix : Motor Energy Control FAQs

Q. How does the EnviroStart Motor Energy Control, (MEC), work?

A. The MEC is an extended Soft Start with some very smart software which enables it to identify when the motor to which it is attached, is running at less than full power. During these times it is possible to reduce both the voltage and the current supplied to the motor without reducing the motor speed. In effect EnviroStart is always providing sufficient, but not too much, torque, continuously adjusting the power to just the right level, analogous in many ways to the cruise control you may have on your car.

Q. What motors is it possible to fit the EnviroStart Motor Energy Control on?

A. It is possible to fit the MEC to any three phase synchronous AC induction motor, (also known as a squirrel cage motor), and any slip-ring motor, (including motors with DC rotor injection start systems).

The single phase systems can be fitted to any AC Induction motor whether with or without capacitor start and with or without capacitor run systems. It is unimportant how new or old the motor is.

Q. Can EnviroStart Motor Energy Controls and Soft Starts be fitted to High Efficiency motors?

A. The simple answer is yes. EnviroStart systems work just as well with high efficiency motors as they do with lower efficiency or older motor types.

Q. What savings can I expect when I fit an EnviroStart Motor Energy Control?

A. This is a very complex question because there are so many aspects to what creates effective savings. Primarily on three phase systems the thing to examine is how much the motor is loaded; that is how much current is it drawing when measured against the full load current specified for that motor. If the motor is running at greater than 75% loaded on average, then it is unlikely that you will get any reasonable savings levels. Below this 75% level the savings increase steadily to peak at around 20% when the motor is around 40% loaded. (Other factors come in to play here such as the line condition, the age and quality of the motor, the ambient temperature etcetera). We have achieved savings of over 35% on certain applications where everything was favourable to savings and the motor was lightly loaded for a great part of its operational time.

On single phase systems the savings that can be achieved are greater because of the inherent simplicity of the motor structure. Typically savings of between 30 - 40% are achievable on applications such as bottle coolers, refrigeration systems and similar. Again loading is the key measure of the likelihood that the system will be positioned to make energy savings.

Q. How long is the warranty of the EnviroStart systems?

A. All EnviroStart units are supplied with a full two year warranty. This does not mean that after this time we will ignore any problems that you have should they arise. We are striving to be the supplier we would like to have supplying us and as such will always respond to a Customers legitimate problems howsoever they are caused.

Q. What is the expected lifetime of the EnviroStart units?

A. All EnviroStart systems are manufactured within the UK to very exacting standards within ISO 9001 qualified facilities. They meet the rigorous standards levelled on them by the various international inspection bodies such as CE and UL and we generally recognise that their lifetime expectancy is around ten years. (The empiric calculations as defined by the IQAB indicate that the MTBF, (Mean Time Between Failure), for our systems, is greater than 100,000 hours, or a little over eleven years).

Q. Does EnviroStart change the motor speed?

A. Not in any way. The EnviroStart Soft Start and Motor Energy Control units are fixed speed controls which do not change the speed of rotation. Rotation speed is determined by the number of poles within the motor and the supply frequency of the current provided to drive the motor. As EnviroStart does not change the frequency of supply and cannot change the number of poles in a motor it is not possible to change the synchronous rotational speed.

Q. How many starts can I allow the system to make per hour?

A. This is a function of the ambient temperature in which the control is operating as well as the size of the motor being started and the load on that motor. The limits are defined on the specification sheets but, because we oversize all of the power components within the EnviroStart units, the number of starts is typically twice that of the competition units.

Q. What is the maximum operating temperature for the EnviroStart units?

A. All EnviroStart's are designed to operate continuously at up to 40DegC without any degradation or de-rating. Above that point there are derating's which have to be applied. For details of these please review the specification sheets associated with the system you are using.

Q. Can the EnviroStart be used in conjunction with a BMS or PLC control system?

A. The Soft Start and Motor Energy Control EnviroStarts have all been designed with ease of operation and application in mind. The control circuits for the "start and stop" function and the "emergency run" function have been designed to allow simple closing of a circuit or alternatively either NPN or PNP, (pull low or pull high), zero-volt drive which will allow any form of PLC to be directly coupled to EnviroStart without interface circuitry of any kind. Additionally we have established a "System Ready" output so that we can feedback ready capability to a PLC control circuit.

Q. Does the EnviroStart radiate or generate harmonic currents?

A. All systems do generate some level of harmonic current. EnviroStart however is designed to minimise the generation of detrimental harmonic currents. Overall the contribution of EnviroStart can be considered to be near zero.

Q. Can EnviroStart be used near other sensitive electronic systems such as PLC controls and BMS systems?

A. Because EnviroStart does not radiate or generate harmonic currents there will be no effect of fitting it close to any other system. Of course with larger motors there will be the effects of induced currents and stray magnetic fields around the feed and supply cabling so normal precautions should be observed in these circumstances.

Q. How environmentally friendly is EnviroStart?

A. EMS (European) are a company dedicated to the reduction of pollution and elimination of waste. The EnviroStart systems have been designed with recyclability in mind so that most of the components within the system are either recyclable or are already using recycled materials. The heatsink and the casing are both made from recycled materials, no toxic components are used in the manufacture and, of course, the Motor Energy Control is designed to save energy which again is environmentally as well as economically friendly.

Q. Can the EnviroStart units be placed outside or in harsh environments?

A. All EnviroStart units meet the expectations of IP43 which means that whilst they will withstand a few drops of rain they will not tolerate a direct shower or a downpour so, if you want to place the units external to a building they should be within another waterproof cabinet which meets the needs of IP55 or greater.

In tropical environments EnviroStart can be provided with full conformal coating to the PCB to meet the needs of very high humidity atmospheres and reduce the possibility of solder bond or component corrosion as a result of high relative humidity.

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