Using Sinusoidal Waveform Technology to Improve Overall Motor Efficiency
A Technological Breakthrough for Motor Controllers

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The combination of high electricity prices, limited generation capabilities and the economical situation requires new type of electrical controllers to improve overall motor efficiency. Users are seeking controllers that will carry out more than just one or two tasks in the complicated electrical network. After years of research, a new controller was developed using sinusoidal technology, introducing multifunctional efficiency to induction motors – reduced voltage starting, harmonic filtration, power factor correction, motor protection, increased motor life expectancy plus improved energy efficiency of the motor. In addition, it allows regenerative energy to be transformed back to the network. All the above results in overall energy efficiency of the site, eliminating peak charges and reduces CO2 emission.

This paper browses through each one of the above issues, discussing the available solutions and explains how the multifunction controller with sinusoidal technology provides the solution. It will debate the differences between the multifunction Motor Controller and other solutions, such as variable speed drives, soft starters, power factor capacitors etc. It will explore installations in different sites worldwide from various industries, such as quarries, mining, food & beverages, cement, recycling, plastic, rubber and others and concludes with the savings and efficiency results.

***Index Terms*—Energy conservation, Harmonic distortion, Induction motors, Life Cycle Costing, Motor economics, Motor protection, Reactive power.**

I. Introduction

The electrical network includes many different parameters, each one with its own characteristics. Today's technical people need to have knowledge in variety of fields and to endeavor to improve the electrical network from all aspects. There are many different solutions in the market covering a large variety of technologies. This places two challenges in front of the decision maker:

1. What parameter is most important to my network and what solution or solutions to choose?
2. Improving one parameter may worsen another. For example, motor soft starter reduces the current peaks and voltage drops but adds significant amount of harmonics which may lead to downtime and failures.

II. Existing Situation

A. Motor Starting

For the motor, the best way to start is direct online (DOL), which means apply full voltage to the motor. However, this causes extreme current peaks and voltage sags that may activate protection equipment. Moreover, sometimes there is a need to reduce the mechanical stress of connected equipment, such as belts or gears.

There are different solutions to start a motor, each one has its pros and cons:

- Star/Delta – low cost solution which provides two voltage levels to the motor. The main problem is that sometimes the low voltage level (230v in 400v network) is too low to start the motor. It also has technical problems such as the need to break the star before connecting the delta.
- "Soft Starter" – reduced voltage starter which cuts the waveform in order to reduce the RMS voltage. The major disadvantage of this solution is that it creates harmonics which harms all equipment and may lead to faults and downtime.
- Variable Speed Drives – controls the motor speed by creating a new waveform, which allows the motor to start smoothly. This creates a huge amount of harmonics which reduces network efficiency and power quality. Adding special harmonics filters reduces certain amount of the harmonics, but a significant level remains. The filters add to the cost, which makes variable speed drives much more expensive than other solutions.

B. Motor Life Expectancy

A motor is relatively reliable equipment. However, the major costs related to motor reliability are the maintenance and downtime costs. These costs may accumulate to a significant percentage of the motor life cycle cost (LCC), as it includes many cost factors: repair costs (labor and parts) and the downtime costs - lost revenues, lost labor cost, other machines that cannot operate, etc.

According to the US Department of Energy (DoE), typical maintenance and downtime costs of a motor are 35% of its entire life cycle cost, while energy consumption is 45% of the costs and the rest is initial and other costs.

Selecting high quality equipment and providing good timely maintenance reduces downtime.

C. Energy Efficiency of the Motor

Efficiency is the ratio between the amount of mechanical work that the motor performs and the electrical power consumed. Motor efficiency is usually represented by a percentage from 0% to 100%. In practice, 100% efficiency is not possible due to motor losses. According to the principle of energy conservation, the total input and output energy must be equal. This means that the losses are wasted energy expressed as motor heat.

The motor efficiency depends on two major parameters:

- Motor design – the materials, construction, rated power etc.
- Operating conditions – the motor load, power quality and temperature

The effect of motor load on motor efficiency is shown in Fig. 1 below (note that the load is measured by means of power and not current, as the current never reaches zero). It shows that the motor is most efficiency at approx. 70-80% load and when the load is low, the efficiency is reduced dramatically.

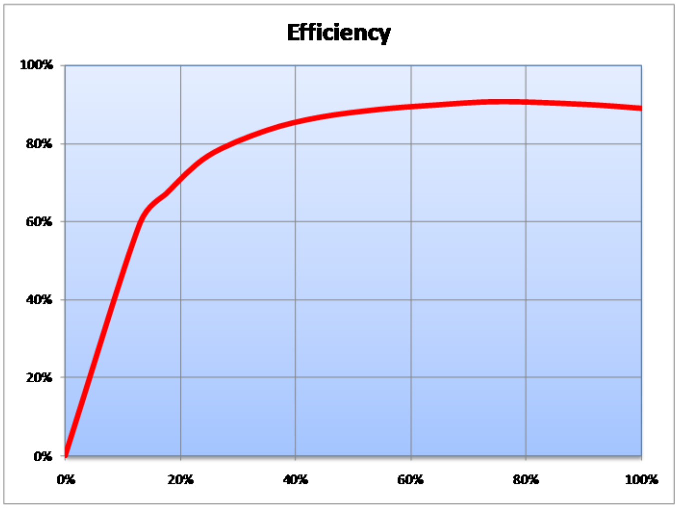

Fig. 1. Motor Efficiency vs. Motor Load

The motor efficiency for specific motor is given. Improving the efficiency can be done by replacing it with a high efficiency motor, which is a complicated and costly process

D. Network Losses

The network losses are conduction losses derived from the resistance of the electrical conductors and the transformer losses. Reducing these losses is done by better infrastructure (higher cable cross-section, use of copper rather than aluminum etc.) and reduction of currents.

1) Conductors Losses

The major parameters that affect the conducted losses are the wire cross section, wire length, ambient temperature and harmonics (which cause skin and proximity effects).

Measuring of conduction losses in complex electrical infrastructure is not a trivial task and therefore they are often ignored. However, conduction losses are usually the major source of losses in the entire facility. Common figures for such losses are 10-15% from the electricity bill. It is complicated to measure the losses for each load separately, but facility wide losses of up to 30% were measured. Even though this figure seems to be non realistic, it can be easily understood as explained hereinafter.

If the conductor length and resistance are known, losses can be calculated according to:

$P_{losses}=I^2R$, $R=r_m*Length$, r_m is the resistance per centimeter.

The resistance can be measured using a high current loop tester, which is not commonly available. A good alternative is to use the voltage drop analysis as follows:

Where:
V_S=Voltage at the transformer secondary
V_L=Voltage at the load
$V_\%$=Voltage drop in % = $100\%-V_L/V_S$

$$P_{LOSSES}=(V_S-V_L)\times I=V_\%\times V_S*I=V_\%\times S\ (kVA)=V_\%\times P/PF$$

Different standards provide different limits on voltage drops and state different values from 2% to 5%. This means that for a power factor of 0.5 and voltage drop of 5%, the losses are 10% of the active power.

2) Transformer Losses

Transformer losses include the winding resistance, Hysteresis losses, Eddy currents, magnetization and mechanical losses. In addition, in the presence of harmonics, the skin and proximity effects create additional winding losses.

Transformer losses depend on transformer design (e.g., copper vs. aluminum), transformer load (no-load losses are fixed), transformer size (larger transformers are more efficient than smaller ones), ambient temperature and harmonics (harmonics dramatically increase transformer losses and requires the use of special K-Transformers).

Typical transformer losses in low harmonics conditions and 80% load are estimated to be between 1.5% to 4%. The losses are proportional to the kVA consumption but increase the kW charges, which means reducing the kVA consumption will subsequently reduce the kW consumption.

E. *Harmonics and Harmonics Effects*

Harmonics are waveforms at higher frequencies that are integer multiplications of the fundamental. Fig. 2 shows a pure sinusoidal waveform with 5th order harmonic current and the distorted waveform.

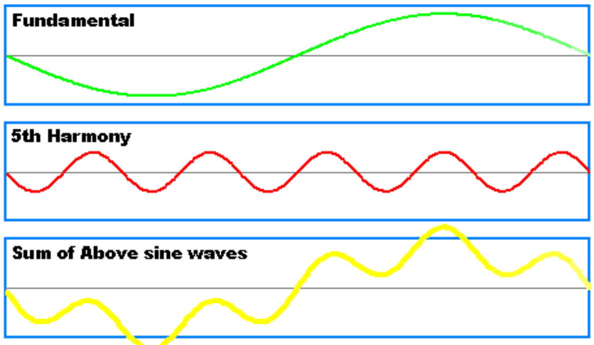

Fig. 2. Harmonic Distorted Waveform

Some of the implications of harmonics are:

- Increased losses throughout the network – conductors, loads, transformers and more.
- Overheating that reduces equipment and infrastructure lifetime and may even start fires.
- Negative force in motors from counterclockwise (CCW) harmonics (the 5th harmonic order is the most dominant in the industry and works CCW to the fundamental, thus creating a negative force that breaks the motor).
- Unexplained breaker tripping due to extreme overheating.
- Controller malfunction and other unexplained phenomena due to distorted waveforms.

Harmonics issues are among the most difficult to solve in the electrical field. The two most poplar solutions are:

- Passive filters – use of capacitor and reactor combinations to absorb specific harmonics (usually the 5th), may require adjustment of the specific filter to the site. Moreover, may require re-tuning after changes in the load.
- Active filters – injection of current in negative polarity to each harmony provides significant filtration but is extremely expensive. Usually used on smaller network with sensitive equipment only.

F. *Power Factor*

1) *What is Power Factor and how is it related to Efficiency?*

There are three types of power definitions in an AC electrical network:

- Active power, or real power – the power that is capable of working and is measured in kW (kilo-watts) and represented by the letter P.
- Reactive power – power that flows to the motor and returns to the network without performing any work, however still requires "transportation", meaning sufficient cable cross-sections and associated heat. Reactive power is measured in kVAr (kilo Volt-Ampere Reactive) and is represented by the letter Q.
- Total power, or apparent power – a combination of the active and reactive power, measured in kVA (kilo Volt-Ampere) and represented by the letter S.

The three types of powers are related to each other as shown in Fig. 3 below:

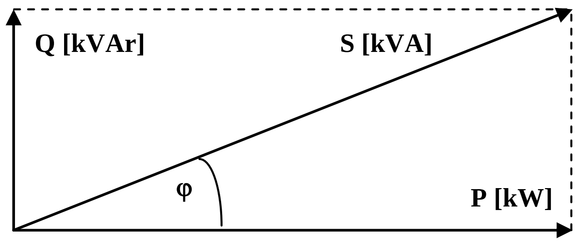

Fig. 3. Power Triangles

The phase between the S vector and the P vector is called φ (phi) and the ratio between P and S is equivalent to Cos (φ) or Power Factor (PF). The Power Factor also represents the ratio between the active and the total Power. Since reactive power does not perform any work, the PF indicates the percentage of useful energy from the total energy, and it is best to have it as close to unity as possible. Low PF means low efficiency and high losses.

Fig. 4 shows the PF vs. motor load. The PF, which is related to the motor's internal efficiency, as well as to the efficiency of the entire network, is reduced when the motor load is less than 70%.

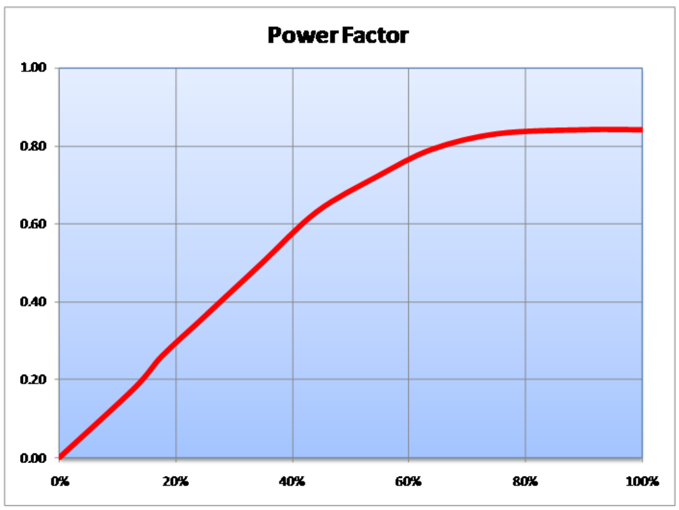

Fig. 4. Power Factor vs. Motor Load

2) *Existing Solutions*

The most common solution for low power factor is power factor capacitors. Installing central automatic capacitor bank near the main cabinet automatically connects and disconnects capacitor banks to meet the utility requirements.

The problem is that this improves the power factor for the utility. The power factor in the facility is still low, resulting with excessive losses. Installing stand alone fixed capacitors throughout the facility will improve the overall power factor. This is difficult to implement and manage, and it is not possible when using soft starters and variable speed drives.

G. *Motor Protection*

The electrical network must be protected against motor over-current using fuses or breakers. However, it is also useful to protect the motor against bad network conditions and to disconnect it from the network in such conditions.

Such protection can be from simple integral to other electrical controls to dedicated equipment which constantly monitors the motor health.

III. THE NEW GENERATION OF MOTOR EFFICIENCY CONTROLLERS

A. *The Frank Nola Patent*

As can be seen from Fig. 1 and 4, when the load on the motor is partial, both motor efficiency and network efficiency are reduced. In 1977 Frank Nola, a NASA engineer, patented a system to take advantage of this fact to improve the motor efficiency and its power factor. Nola's idea was to reduce the motor voltage to a single phase motor, thereby reducing its full rated power, increasing its power factor and reducing its wasted power. Following the first patent, Nola registered subsequent patents to his original idea with regard to three phase motors and improved performance. In 2000, Nola received the NASA Marshall Center Patent Award.

B. *SinuMEC – Sinusoidal Motor Efficiency Controller*

Power Electronics Systems introduced the SinuMEC – Sinusoidal Motor Efficiency Controller, which utilizes patented transformation technology, using a specially designed power transformer, electro-mechanical contactors and a sophisticated controller.

This new generation of motor efficiency controllers provides the benefits of Nola's concept without introducing harmonics correcting the main disadvantages of the original invention).

The unique architecture enables pure sinusoidal voltage control, while the use of simple components makes the apparatus very reliable.

In addition, due to the proprietary design, the overall size is several times smaller than conventional full transformation, providing a *cost effective solution* and *very low self losses*.

C. *Economical and Environmental Benefits*

While some equipment provides one or two benefits only, the SinuMEC provides many different benefits. Some of the benefits can be quantified, while others, such as motor protection, are only valued when failures happen.

The benefits of the SinuMEC is the multifunctional operation including:

1) *Motor Starting*

The SinuMEC provides reduced sinusoidal voltage to the motor according to user defined periods to allow smooth motor startup (no need to use dedicated motor starters) without any harmonics (which are the main drawback of soft starters as they cause failures and mishaps), with typical startup current of only 2x nominal.

2) *Motor Life Expectancy*

SinuMEC reduces the motor operating temperature at up to 10ºC and reduces its operating stress (both voltage and mechanical) which improves its lifetime, reduces downtime and reduces maintenance costs. Common figures are 7% improvement of motor life and up to 50% reduction in maintenance costs and downtime.

3) *Energy Efficiency of the Motor*

The SinuMEC reduces the motor's internal losses, optimizes the motor's efficiency and saves up to 20% of the energy consumption (kWh):

By reducing the supplied voltage to the motor, the SinuMEC dynamically changes the motor's effective full rated power, according to the load. For example, when the motor is loaded at 20%, its efficiency (Fig. 1) is 70%. Reducing its supplied voltage by 25% will reduce its effective rated power by 44%, which will provide equivalent load of 35.6% (20%/56%) and new efficiency of 84%.

4) *Energy Efficiency of the Network*

The combination of improved power factor and reduced losses provides up to 50% reduction in motor current. As the losses are linear to I^2R, the result is up to 75% reduction in network losses.

For example, 35% reduction of current reduces the network losses by 58%. Assuming typical value of 12% network losses, this means additional kW saving of 7%.

5) *Harmonics*

In addition to the fact that the SinuMEC does NOT create any harmonics, it includes a series reactor which filters out existing harmonics. The filtration is both for the motor itself and for the network.

The amount of filtration and the harmonics order which are filtered depends on different parameters, such as the harmonics spectrum and the network impedance which may vary the harmonics filtration results. A common figure is 40% reduction of harmonics, but some installations reached 60% reduction.

Harmonics are one of the most common causes for energy losses, electrical network failures and may even start fires. Reduction of harmonics reduces the risk of fire and has significant influence on the overall losses.

6) *Power Factor*

Similar to motor efficiency, reduction of the voltage reduces the motor's effective full rated power. For the same motor with 20% load, the power factor will change from 0.30 to 0.55.

Unlike central power factor correction (PFC) systems that improve the PF for the utility company only, the SinuMEC improves the PF also for the facility itself and the utility company. The facility benefits directly from the power factor correction which is more efficient. Moreover, the SinuMEC reduces the amount of capacitors required by central PFC systems which reduces investment in infrastructure, capacitor losses and harmonics amplifications (which is typical to capacitors).The SinuMEC can improve as high as 60% of the power factor, which provides saving in investment of equipment and energy losses (the improvement of power factor in the facility provides saving to the customer, not only the utility).

7) Motor Protection

Enhanced motor protection is included in the SinuMEC, which protects the motor against bad network conditions while protecting the network from motor overload.

8) Reduction of CO2 Emissions

The SinuMEC is a green product which helps to protect the environment directly and indirectly. The saving of energy directly reduces the CO2 emission that is created when generating the energy. Indirect savings are derived by improving the reliability of the motor so there is a reduction of the CO2 emission used by the service cars, and a reduction of the CO2 involved with manufacturing of replacement parts and power factor capacitors.

D. Air Conditioning

Due to the law of energy conservation, there is no such thing as "lost" energy. The "lost" energy is converted into thermal energy (heat). If a facility is air-conditioned, every "lost" watt will be cooled. Air conditioners work on the concept of heat exchange, which allows them to work at an efficiency higher than 100%. The Coefficient of Performance (COP) is the ratio between consumed energy to cooled energy. Modern air conditioners have a COP between 2 and 3, which means 0.5W to 0.33W of energy for each 1W lost energy. In other words, if the facility is fully air conditioned, all losses should be multiplied by 1.33 to 1.5.

E. Utility Charges

Utilities, like energy users, waste a lot of energy in their transmission and distribution network. In order to reduce their losses they encourage energy users to consume the energy efficiently. This is done by defining their charges based on efficiency parameters, depending on their needs. The most common charge is low power factory penalties. Other common charges are peak demand and capacity charges (kVA charges).

The SinuMEC can reduce utility charges by increasing the power factor and reducing the peak demand and kVA.

IV. Other Solutions

A. Variable Speed Drives

Variable speed drives can provide energy savings by reducing the speed of motors, which reduces the motor work (as work is distance over time). In cases where the speed cannot be changed, then variable speed drives do not save energy, and they **increase the energy consumption** due to their high internal losses (at least 5%) and high harmonics pollution. Moreover, the harmonics created by variable speed drives may cause significant losses throughout the entire facility, which makes it very complicated to measure the net saving.

The SinuMEC provides saving to fixed speed applications, where variable speed drives are applicable to variable speed applications.

B. Soft Starters

Soft starters provide graduated voltage levels to the motor to provide smooth starting. Soft Starters reduce the mechanical stress significantly, but create voltage stress to the motor. The operator needs to find the balance between the two by fine tuning the starting process.

The SinuMEC reduces **both** the mechanical and voltage stress from the motor.

C. Power Factor Capacitors

Power factor capacitors (PFC) improve the power factor and reduce the reactive energy. There are fixed capacitors with fixed reactive ratings and automatic banks which connect and disconnect capacitors. The ultimate solution is installing an automatic capacitor bank near each load. However, this is not economical. In practice, an automatic bank is installed at a central point which compensates the reactive energy for the utility company, and fixed capacitors are sometimes installed near the loads to provide improvement to the facility. The problem with fixed capacitors is that you have to measure each place to specify the capacitor. In addition, it is very hard to manage. As a result, most installations do not have distributed power factor correction. The consequences are significant losses on the conductors.

The SinuMEC reduces the reactive energy that the motor itself consumes while PFC compensates it by adding reactive energy in negative polarity. Changing the motor's reactive consumption using SinuMEC is more efficient, more reliable and simpler than capacitors compensation,

D. Active and Passive Harmonics Filter

Passive harmonics filter includes reactors with or without capacitors which filters out harmonics. Active harmonics filter injects harmonics current in reverse polarity. Passive harmonic filter can filter out up to 60% of the harmonics while active filters can reduce more harmonics (up to 90%), but generates significant losses and carries a high price tag.

The SinuMEC includes a passive harmonic filter that can filter out up to 60% of the harmonics.

E. High Efficiency Motors

High Efficiency Motors are motors with better design and more material (copper, iron etc.). The result is a more efficient motor. However, standard motors are relatively efficient with more than 90% efficiency factor, so high efficiency motors are only 2-3% more efficient than standard ones.

The SinuMEC increases the efficiency of all motors – standard and high efficiency, by up to 20%.

V. INSTALLATIONS

A. Mines & Quarries

Electric motors consume 90% of electricity in mines and quarries. The SinuMEC provides excellent benefits to typical motors in quarries and mines: conveyors, crushers, bucket elevators, sifters and vibrators, which consistently operate at variable or partial load. These sites are usually large, which makes the conduction losses even more dominant than in smaller facilities, increasing the economical benefits from installing the SinuMEC.

SinuMECs are installed in different quarries on variety of loads and exhibit improvement of all parameters. For example, A SinuMEC on a *conveyor* provides an 18% reduction in the kWh, reduces the current and total power by 48%, the conduction losses by 73% and the reactive power by 58%. The conveyor startup current is limited to 1.76 of nominal. When comparing the maintenance costs for the year before and after the installation, 60% reduction of direct repair costs was measured (plus reduced downtime, less labor costs etc.).

B. Food & Beverages

There is huge variety of processes in the food & beverage industry. The SinuMEC fits many different loads, such as mixers (e.g., chocolate mixers or sugar pan stirrers), flakers, palettizers, bucket elevators and more.

An example from different SinuMEC installations in food factories includes a SinuMEC at a Unilever factory on the flaker machine used for manufacturing cornflakes. The benefits are reduced voltage starting, improved motor reliability, reduction of 11% in kW, reduction of losses by 60%, filtration of harmonics, improvement of power factor by 38% and protection of the motor from failures.

C. Cement & Concrete

The cement & concrete manufacturing process includes many electrical motors, such as crushers, grinders, mills, bucket elevators, conveyors and vibrators. The SinuMEC provides excellent benefits to these motors, particularly in the primary part of the process where the load on the crushers and grinders vary as the loading varies. Bucket elevators and conveyors which are designed to withstand hard startup processes benefit from the SinuMEC during normal operation as they remain partially loaded after startup and during the remainder of their work.

In one installation of the SinuMEC on a bucket elevator, used to elevate the clay at cement factory, the SinuMEC provided exceptional energy saving: 25% reduction in the active energy, 67% reduction in network losses, 25% improvement of power factor in addition to harmonics filtration, motor protection and reduced startup current.

D. Recycling

The recycling industry uses different motors which typically have variable loads. These motors are designed to operate properly while fully loaded with material, but work with partial loads most of the time and include granulators, shredders, balers, and bottle perforators. In addition to dedicated recycling facilities, such loads exist in many industrial sites such as granulators in plastic industry, balers and granulators in pulp and paper industry etc.

On a 37kW motor in granulator at a plastic factory, this example of the SinuMEC shows the following results: startup current reduced to as low as 1.2 times nominal current, the wear of the belt was reduced and energy saving was achieved – 15% reduction of active energy, 70% reduction in network losses and 57% improvement in the power factor.

E. Escalators

Escalators need to be ready to operate at full load capacity, which is one or two persons per stair. Normally, the load on the escalator is less than 50% of full capacity, even during rush hours. Since the motor of the escalator is never fully loaded, the SinuMEC can continuously operate in "Save Mode", providing maximum savings through increase of life expectancy, harmonics filtration, improvement of power factor and energy saving.

The SinuMEC is installed on escalators in both public transportation and retails stores. It provides consistent results of reduced startup current, reduced harmonic pollution, 15% to 20% reduction in active power, 40% to 50% reduction in current, 64% to 75% reduction in network losses and increased motor lifetime.

F. More Industries

The SinuMEC is recommended for AC induction motors running at fixed speed and carrying variable or partial loads. In every industrial site there are motors which fit these criteria.

Examples of best-fit motors include: granulators, grinders, shredders, mills, pumps (vacuum pumps, hydraulic pumps), conveyors, bucket elevators, mixers of viscous material, presses, and in some cases, compressors and fans.

Two more examples of interesting installations include:

- A SinuMEC is installed on a water pump in process industry facility. Among many benefits, the operating temperature of the motor was measured by the site personnel using an infra-red thermal camera. While the SinuMEC was bypassed, the motor temperature was 58.2ºC. When the SinuMEC was active, the motor temperature was down to 50.3ºC, providing 8ºC temperature reduction. This reduction has a significant effect on the operation reliability and maintenance of the water pump.

- A SinuMEC installed on a HVAC fan at a paper facility in the US. Due to the fan's high inertia, during the startup process the motor turns into generator mode and generates energy back to the network. All installations of soft starters failed and direct online startup was the only possible solution. The SinuMEC is based on transformers which transforms the reverse energy flow and delivers the excess energy back to the network to provide additional saving. The use of the SinuMEC reduced the huge wear of the fan's v-belts to almost zero. The savings in maintenance costs was 2.4 times more than the savings on energy and was the major reason to use the SinuMEC.

VI. Conclusion

The SinuMEC is Sinusoidal Motor Efficiency controller which improves reliability and reduces energy related operating expenses. This multifunctional motor controller provides a complete, all around motor improvement solution to AC induction motors running at fixed speeds and carrying variable or partial loads. SinuMEC allows voltage control while maintaining the waveform undistorted providing significant benefits; harmonics-free motor startup, reduced maintenance and downtime, reduced energy consumption, reduced conduction losses, harmonics filtration, power factor correction and motor protection.

Installation of the SinuMEC in various applications, such as conveyors, sifters, granulators, flakers, mills and escalators, provides significant economical and operational benefits for complete motor operation and maintenance.

VII. About the company

Power Electronics Systems (2006) Ltd. is a global provider of energy-efficiency solutions leveraging decades of expertise in voltage regulation and control technologies. Our voltage control solutions provide the right voltage s to enable electricity savings in commercial and public lighting systems and improve efficiency of electric motors in industrial applications while contributing towards a greener environment. The Lighting Energy Controller (LEC) significantly reduces electricity costs for commercial and public lighting, and the Sinusoidal Motor Efficiency Controller (SinuMEC) improves overall efficiency of electric AC motors. Companies using our products see immediate business benefits with direct electricity savings of up to 35% and reduced total cost of ownership of up to 50%. With over 18,000 units already installed in enterprises around the world, our products are proven effective for financial savings while implementing a green strategy.

VIII. About the Authors

A. *Shimon Limor*

Electrical Engineering graduate from SUNY of Buffalo (state university of N.Y.) in 1973, Mr. Limor became the Chief Engineer and Manager of the Eilat oil terminal division of the Eilat Ashkelon pipe line company until 1976. Mr. Limor continued as a consultant and design engineer until the year 1980 when he established Power Electronics.

Since 1980, Mr. Limor has lead Power Electronics with major product developments such as:

- Thyristorised soft starters
- Variable speed drives
- Sinusoidal motor and lighting controllers

Mr. Limor remains today as part of the management of Power Electronics and is responsible for future product developments and groundbreaking technological developments.

B. *Amir Broshi*

Mr. Amir Broshi began his career while studying for his B.Sc in Engineering at the Technion in Haifa Israel. Upon completion of his degree, Mr. Broshi served 5 years in the Israeli Defense Forces managing R&D teams working in the signal corps, attaining the rank of Captain. Mr. Broshi joined Elspec, a world leader in power quality solutions, immediately after completing his tour of duty, putting him to work as an R&D manager for software development. Mr. Broshi moved on to the Marketing Department, as a Sales Engineer, pushing local sales to new levels. An MBA from the University of Derby aided him in his next post at Elspec, developing the relatively new market for power quality as a Product Manager; bringing Elspec's powerful R&D department to focus on this important market. After more than 10 years at Elspec, Mr. Broshi joined Power Electronics Systems to lead the company’s Sinusoidal Motor Efficiency products as Marketing and Product Manager.

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