Thought leadership

Energy efficiency, for a better tomorrow driven by drives

Abstract

Why is energy efficiency a priority for us all? Skeptics have their doubts about the viability of energy efficiency. They point out that energy efficiency is expensive in our times where energy costs are falling, and ask for the proof that the benefits of improving energy efficiency outweigh the costs. We should not save energy at any price, but there can be no doubt that energy efficiency pays. This article explains exactly how AC drives improve efficiency, the advantage of choosing ideal components over pre-bundled packages, and total cost of ownership considerations.

Why energy efficiency?

Skeptics have their doubts about the viability of energy efficiency. They point out that energy efficiency is expensive in our times where energy costs are falling, and ask for the proof that the benefits of improving energy efficiency outweigh the costs. In the industrial sector where electric motors account for 30% of global final energy use [1], they argue that it requires significant investment to upgrade motor efficiency class or install AC drives to optimize existing motors for energy efficiency. At the rate of development today, will the investment break even before the technology is obsolete? Or they argue that energy efficiency competes with renewables in a detrimental manner. Or – when based in Germany and dependent on the energy supply to run a business, I get a tax break on my energy bill anyway. So why spend money reducing consumption? It will cost me more in the long run since I will no longer qualify for the rebate [2].

Fortunately there are also heavyweight proponents of energy efficiency, who know without a doubt that energy efficiency does pay. The German chancellor Angela Merkel, in the context of maintaining economic growth despite the Brexit vote in June 2016 recently pointed out, **"We must concentrate on efficiency and growth"** [3]. The International Energy Agency (IEA) [4] and the European Union have set ambitious targets for energy savings, and regard cutting back consumption as a vital first step in achieving these targets, following the principles of the Efficiency First concept.

An energy source in its own right

According to the IEA, we should prioritize energy efficiency as the "first fuel", and this is the foundation of the Efficiency First concept. As an energy source, energy efficiency is broadly defined in two categories: demand side or supply side. Investments in energy efficiency either contribute to avoiding energy consumption (for example, motor efficiency performance standards) or to avoiding energy losses (for example, legislation to regulate power distribution).

Energy efficiency as a fuel can be difficult to visualize or quantify, but nonetheless it dominates the energy market. In 2013, the IEA demonstrated its significance by showing that energy savings from efficiency measures exceeded the output of every other fuel in 11 IEA countries from 1974 to 2010 [5]

AC drives have a role on both demand and supply sides of the equation. They primarily act to reduce electricity consumption drawn by motors under torque loading. AC drives can also be configured to run in regenerative mode where they feed braking energy back into the line power, instead of it being lost as heat.

Figure 1: Energy savings from Efficiency First

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[1] *World Energy Outlook*, International Energy Agency, November 2016

[2] The Renewable Energy Sources Act (EEG), Germany, 1 April 2000

[3] Daily Mail, UK, 30 June 2016 http://www.dailymail.co.uk/news/article-3667663/Germanys-Kohl-tells-EU-dont-pressure-UK-Brexit-vote.html

[4] The International Energy Agency is an independent agency with 29 member nations, founded by the nations in order to evaluate and forecast the development of energy consumption globally. Read more here: www.iea.org

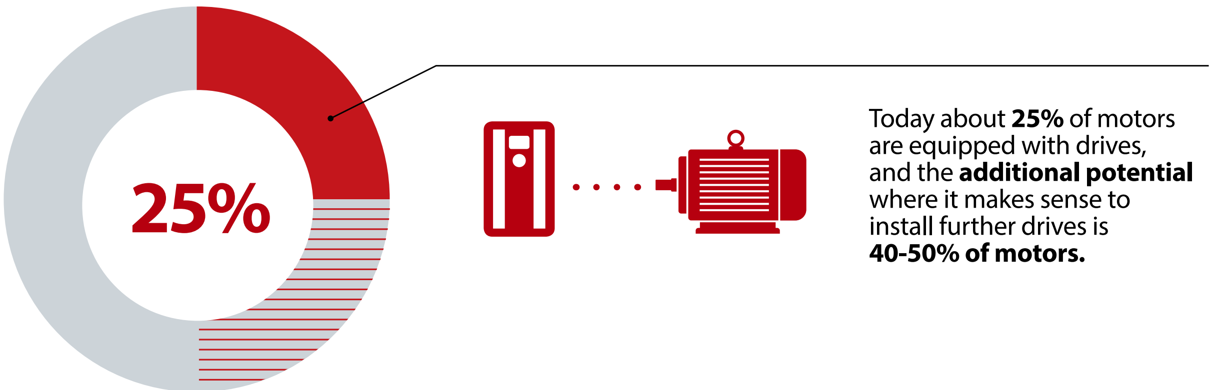
[5] *Energy Efficiency Market Report 2013*, International Energy Agency, October 2013 https://www.iea.org/publications/freepublications/publication/EEMR2013 free.pdf

Where are the best opportunities?

The European Union (EU) is engaged in a broad range of initiatives aimed at achieving its 2020 energy efficiency targets. It enforces them via the Energy Efficiency Directive (EED), which states: *The 2012 Energy Efficiency Directive establishes a set of binding measures to help the EU reach its 20% energy efficiency target by 2020. Under the Directive, all EU countries are required to use energy more efficiently at all stages of the energy chain from its production to its final consumption.* [6]

Potential energy savings arise from a range of opportunities at consumer and industrial level, some more worthwhile to pursue than others. The EU has already identified motors and variable speed control of motors using AC drives as huge opportunities for saving energy. Today about 25% of motors are equipped with drives, and the potential where it makes sense to install further drives is 40-50% of motors.

Figure 2: Potential for improving motor efficiency using drives



The achievable energy reductions in generalized form are:

- 10% by improving motor efficiency
- 30% by implementing speed control using AC drives
- 60% by optimizing the system[7]

Motor efficiency measures are already in place, with additional measures currently in review. To date, the EU has focused on improving motor efficiency, but the other opportunities are not yet in scope.

The greatest prizes lie in speed control using AC drives, and system optimization, so let us take a closer look at these.

Speed control using AC drives

Where are the greatest benefits to be won in variable speed control of motors using AC drives? There are numerous reasons for adjusting the speed of an application:

- Save energy and improve system efficiency
- Match the speed of the drive to the process requirements
- Match the torque or power of a drive to the process requirements
- Improve the working environment
- Reduce mechanical stress on machines
- Lower noise levels, for example from fans and pumps

Depending on the application one benefit or another is predominant. However, speed control is proven to bring significant efficiency advantages in many different applications.

The AC drive acts in differing ways at different stages of operation:

- Start-up current: Three-phase induction motors require a high start-up current. An AC drive reduces start-up current and enables speed control.
- Number of startups: The AC drive also contributes to energy savings by reducing the number of startups. For example, for pumps, motor startups account for 5-10% of overall energy consumption.[8]

[6] European Commission https://ec.europa.eu/energy/en/topics/energy-efficiency/energy-efficiency-directive

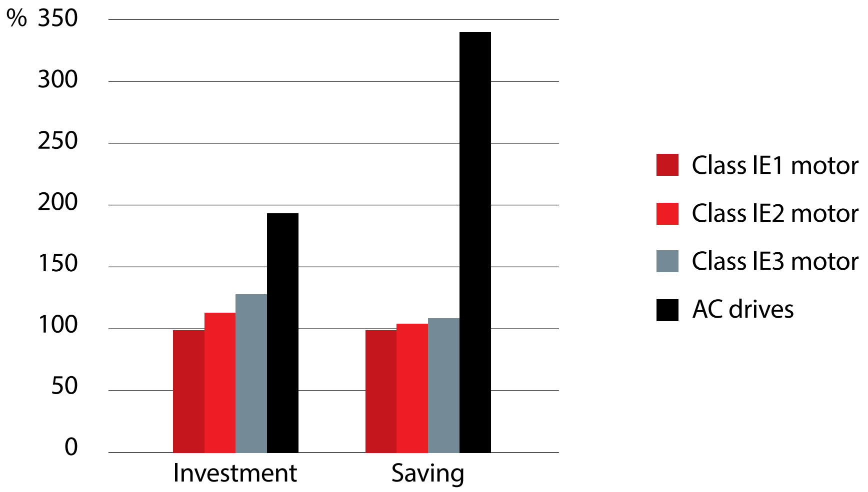
[7] *Energy Efficiency with Electric Drive Systems, ZVEI* - German Electrical and Electronic Manufacturers' Association, April 2015

[8] *Handbook of energy conservation,* The Working Group under the PSO - Research and Development Project 336-055, March 2006 http://euroec.by/assets/files/danfoss/Handbook_Energy_AQUA_202.pdf

- Constant load torque: The load does not vary much with the speed. This applies to conveyor belts, hoists or mixers. Speed control enables process optimization, energy savings, favorable transmission ratios, and reduced mechanical wear and tear.
- Quadratic load torque: Many but not all pumps and fans have a quadratic load torque. Power consumption is a cubic function of the motor speed, which means speed control almost always leads to significant savings. For example, 20% less speed results in approximately 50% reduction in energy consumption.

The comparable economy of investing in AC drives as opposed to high efficiency motors is shown in Figure 3. The investment in an AC drive is higher than in an energy-efficient motor. However, the benefit is often considerably higher, meaning that after the initial payback time, the AC drive is the most economic means to generate energy efficiency. It is more advantageous even than an IE3 class motor. This interesting observation demonstrates that certain investments are more valuable than others, and leads us to the next topic, system optimization.

Figure 3: Cost/benefit comparison of motors of various efficiency classes, and AC drives [9]



Pre-assembled or adapted assignment?

Pre-assembled drive packages firmly link the drive to the motor, offering maximum savings for a specific theoretical situation. This is a safe selection but inflexible. No alternative components will do, and this can become a nasty trap in the form of potentially limited availability in delivery bottlenecks or export.

In contrast, the adapted assignment where drive and motor are combined on a case-to-case basis remains flexible to customer requirements and technology trends. It demands a once-off expense and the result is the ideal optimization for energy efficiency and high performance, tailored to the application, where components are easy to replace. For example, any local motor can be retrofitted, worldwide. Using an adaptable AC drive, capable of optimizing many different motor technologies, it is easy to retrofit to a different motor technology. This ability is a great advantage in reducing downtime costs. An adaptable drive, when combined with diverse motors is able to reach system efficiency equal to that achievable with the majority of dedicated packages.

To optimize operation of the "new" high-efficiency motor concepts such as permanent-magnet or synchronous reluctance motors, an AC drive is always required. In fact, without the existence of AC drives, these motor concepts would not have been developed.

Efficient components do not necessarily create an efficient system

System optimization comprises a multitude of different energy-saving approaches. Put simply, to evaluate the efficiency of a system, first measure the efficiency of the components, then multiply. Choosing the most efficient components is not enough, however. They do not always combine to create the most efficient system.

A good example of this is the very compact fan, where the motor is directly mounted inside the center of the fan and acts as its hub. Unfortunately this placement results typically in a disturbance of the airflow which reduces the efficiency of the whole system. The further inside the fan the motor is positioned, the more compact the device gets and the more the disturbances increase.

[9] Cost: ErP Lot 30 Tasks 2 – 5, last updated August 2014

Saving: Regulation (EU) 640/2009, guidelines:
https://ec.europa.eu/energy/sites/ener/files/documents/20141211_GuidelinesElectricMotors%20cover.pdf; and *Energy Efficiency with Electric Drive Systems, ZVEI* - German Electrical and Electronic Manufacturers' Association, April 2015

The typical components in a power drive system are the AC drive, motor, transmission and the load machine. For some components, IE classes (International Efficiency) and even statutory minimum values are partly defined. However, they do not give an indication of the efficiency under partial load. In the standards motor efficiency is only defined for full load. In practice, motors run most of the time at part loads, where constant mechanical and electromagnetic losses cause motor efficiency to deteriorate. The degree of deterioration depends on the motor torque and speed.

The entire drive train

The starting point in improving energy efficiency is to establish the current state of the planned or existing system. This involves calculating the energy consumption, clarifying which processes are suitable for speed control, and pinpointing where reasonable savings could be made. This process will also highlight synergies. Once the initial state is established as a baseline, then the effect of any optimization steps taken will be quantifiable. By documenting the initial state, operators are equipped to verify that theoretical savings have been achieved in practice, and whether the potential for savings has been fully exploited, after implementing the system optimization.

Analysis of the system layout, length of piping, pneumatics, the energy sources used, power losses, central or decentral control, availability of spare parts and their storage - all these factors influence the overall lifetime system efficiency. Consider also the total electromagnetic interference, and whether internal or external filters are required. Here it is vital to concentrate on actions which are cost-effective and sensible.

With the advent of efficiency legislation Ecodesign Directive in the EU, machine builders have to pay more attention to the overall efficiency of their systems and equipment. For their own survival they have to carefully maintain the technological edge in the global market while remaining competitive in cost and effort. A regulation must therefore always ensure that the expense and effort required are in equilibrium with the commercial benefits.

Save energy, but not at any price

Opportunities to save energy await us in almost all sectors, and in applications as diverse as building services, conveyor belt systems and chemical processes. However not all opportunities are equal. Some are dramatically better than others.

The challenge lies in identifying the potential and in finding the (economically) optimum implementation. To assess and compare different measures for improving efficiency, it is vital to pay special attention to the benefits each method brings. Always apply this principle: Save energy, but not at any price.

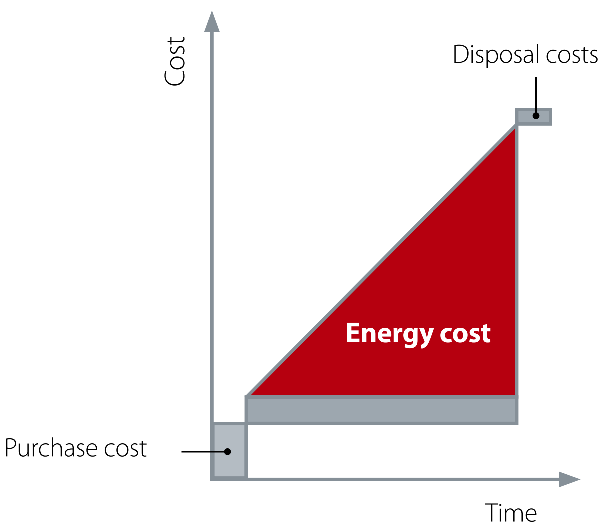
To ensure that energy efficiency does pay, it is therefore necessary to examine all aspects - technical, commercial and logistical –in the perspective of the entire system lifetime, before making an investment decision.

From cradle to grave

To make an informed decision on an energy efficiency investment, use a recognized method to analyze overall cost over the system lifetime, from cradle to grave. Some alternatives are Life Cycle Costing (LCC) which calculates total costs within a life cycle, and Total Cost of Ownership (TCO) which calculates total costs over a period. The basic idea of both concepts is to consider not only the purchase costs, but also the running costs such as energy, repair and maintenance costs.

Over the entire lifecycle, energy costs often account for most of the running costs, as shown in Figure 4.

Figure 4: Total cost of a system over its lifecycle, including initial investment, running costs and disposal costs.



Total cost of operation (TCO) over an application lifetime:

- **Purchasing costs 10%**
- **The remaining 90%:**
  Energy
  Operation and maintenance costs:
  - Downtime
  - Maintenance and repair
  - Wear and replacement
- **Disposal costs**

Measured over the lifetime of a machine or plant, initial costs usually account for only 10% or less of the total cost of ownership (TCO). To perform a thorough assessment of system optimization, management of the remaining 90% of lifecycle cost factors has by far the greatest influence:

- Energy
- Downtime
- Maintenance and repair
- Wear and replacement
- Disposal costs

Therefore a device with a high purchase cost and low energy consumption may turn out to be the most economic over its total service life than a device which is more affordable initially, but consumes a larger amount of energy in operation.

When analyzing overall cost, consider also product availability. When a device breaks down during use, costs will arise, for example due to a loss of production. To minimize production downtime, the operator requires storage space for one or several replacement devices. Establishing the storage space involves decisions on the size of the storage space required, which in turn depends on how quickly the product manufacturer can deliver new devices when required. These are examples of just some of the factors to be considered.

One of the biggest issues when it comes to investment in energy efficiency is still the initial purchasing cost, even though payback times are often less than 24 months.

Product availability is another element of the equation. The failure of a device in operation can incur costs due to production downtime. Therefore a spare parts stock plan, based on lifetime and replacement part delivery time, is an essential element of a system optimization strategy. Components, such as variable speed drives, which are globally sourceable and which possess broad compatibility with diverse motor technologies and control systems are valuable elements in planning for optimal productivity.

This is why

Energy efficiency is documented to save resources and save money. It is rightly prioritized as the first fuel. When we make energy supply decisions based on this principle, society has the most to win.[10]

However, introducing energy efficiency measures requires investment. Sometimes the costs outweigh the benefits, and therefore not all potential energy efficiency measures are viable or wise. Not all legislative decisions support energy efficiency in practice, and not all investment decisions act to save energy in the long run. To stay on track and ensure that energy efficiency does pay, requires assessment of all the relevant factors when making every individual decision:

- Every measure has side effects. Weigh the side effects up against the advantages.
- Consider lifetime cost. Low purchase costs seldom mean automatically low operating costs.
- Consult experts where necessary to clarify technical advantages and disadvantages.

Only then can we make good choices that enhance our industries and our society, keep us in the energy-efficiency race, and ultimately create a better tomorrow for our future generations.

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Anna Hildebrand Jensen, November 2016

[10] *Efficiency First: A New Paradigm for the European Energy System*, European Climate Foundation, June 2016

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