Projektinfo **04**/2012

Detailed information on energy research

Getting things moving with little energy

Efficient drive technology for industrial machines

BINE Information Service

47 per cent of the net electricity consumed in Germany is used by industry. Particularly in automation technology, robot arms would not move without drive energy and heavy components would remain at a standstill in the production. A potential study recommends new solutions for energy optimised system operations. The intention is to increase the energy productivity of the electrical and pneumatic drive technology by up to 50 per cent.

Drive technology has a considerable relevance for the energy turnaround: more than two thirds of industry's electricity requirements are used to provide mechanical energy, whereby around 17 billion kilowatt-hours are used alone for providing compressed air. That corresponds to 7 % of the total electricity consumed for industrial purposes in Germany. The term "drive technology" encompasses diverse applications ranging from engines consuming several 100 kilowatts to miniature applications with a low number of watts or very small compressed air requirements.

In many industrial enterprises, increasing energy costs and a heightened environmental awareness mean that there is an urgent requirement to increase the energy efficiency in the drive and handling technology. The energy consumption and costs can be considerably reduced by simple means. However, existing potential is often not being utilised.

A systematic contribution to the rational use and saving of energy in electrical and pneumatic drive technology is provided by the "EnEffAH" research project (energy efficiency in production in the drive and handling technology field). Three research

This research project is funded by the:

Federal Ministry of Economics and Technology (BMWi)

institutes and three industrial companies combined forces in 2008 to research energy efficient automation. The effective choice of the right technology and efficient operation are essential for energy saving, functional machines. Their research is focussing on drive technologies that use compressed air or electricity as energy sources and are used in handling tasks such as in robotics.
Pneumatic drive technology uses compressed air as the drive medium and is distinguished by its environmentally friendly and simple construction. Pneumatic systems have a particular advantage over electrical drive systems in terms of "holding" tasks because the latter heat up very rapidly and, without additional locking mechanisms, require a constant electricity supply. In improving the efficiency of both technologies, the project is adopting a "bottom up" approach, i.e. in regard to how the energy is used in the product, whereby what is not used does not need to be generated and distributed. At the same time, the researchers are investigating the entire causal chain for the individual energy sources from the generation to the distribution.
In terms of all applications using compressed air, a maximum possible economic savings potential of up to 50 % of the overall energy consumption can be expected in individual cases. The energy consumption aspect is closely related to the economic efficiency, since 70 % of the life cycle costs for compressed air stations are spent on consuming energy. Without regular controls, leaks in poorly maintained systems cause up to 30 % of the compressed air consumption, which in individual companies can quickly add up to energy costs amounting to tens of thousands of euros each year.
Until now the efficiency of electrical drives has been optimised for operations with constant rotational speed (e.g. with pumps), but not for start-stop operations, such as occurs with positioning or pick-and-place applications. One example is the production of body parts for vehicles. Recovering braking energy and its intermediate storage provides considerable savings potential here. There are diverse application areas for electric motors. They are used not only as drive assemblies for compressors, centrifuges, pumps and ventilators but also for linear axes in automation technology. Considerable savings are also possible with larger electric motors used as drive assemblies. In addition to using highly efficient motors, significant potential for improvement is seen, for example, in the use of frequency-variable electric drives (up to 50 %).

Choice of suitable technology

Many applications in drive and handling technology can, in principle, be realised both pneumatically and electrically, whereby an increasing standardisation of the individual components makes the exchange of technologies possible. It cannot be generally said whether electrical or pneumatic drives use less energy; they have to be checked in individual cases using suitable calculations. The energy consumption of electrical drives is essentially a quadratic function of the desired force and increases linearly with the holding period. The stroke length of the drive is irrelevant in this regard. With pneumatic drives, on the other hand, the energy consumption does not depend on the holding period. This reflects the functionality of the powerless holding. The consumption is also only linearly dependent on the desired force.

Pneumatic and electrical drives

	Pneumatic	*Electrical*
Advantages	· Durability and simple construction · Loadability and high overload capacity · Low power/weight ratio and high power density · Continual peak force · Powerless holding · Centralised heat production that is mostly usable	· Efficient conversion of electrical energy into kinetic energy · Possible to use braking energy (energy recovery and storage) · Highly dynamic through rapid force generation · Highly flexible through specifying the precise movement · High load stiffness · Control system not susceptible to disturbances
Disadvantages	· Loud noise (exhaust air capture) · Condensation (drying) · Air consumption costs for the entire system with active and process air and pneumatic tools	· Decentralised heating of components, almost no use possible, partial cooling of control cabinets required

Fig. 1 *Comparison of pneumatic and electrical technologies*
Source: EnEffAH project consortium

This is how compressed air can work more efficiently

Phase in the energy-based causal chain	*Measure*	*Applicability*	*Savings up to ...*
Provision	Compressor specification and network control	20 %	20 %
	Centralised heat recovery	50 %	96 %
	Decentralised compressors	25 %	15 %
	Lowering the network pressure	50 %	15 %
Treatment	Drying compressed air		
	Refrigerant dryer	60 %	2 %
	Adsorption dryer	10 %	20 %
	Specification of compressed air treatment system	20 %	10 %
	Regular servicing of compressed air treatment system	80 %	20 %
Distribution	Optimised sizing of cables	20 %	10 %
	Optimisation of the network infrastructure	40 %	5 %
	Durability and positioning of intermediate storage tanks	40 %	10 %
	Elimination of leakages in the network	80 %	5 %
Use	Correct specification of drives and components	80 %	40 %
	Avoid dead volumes	30 %	20 %
	Identify and eliminate leakages (system/application)	70 %	20 %
	Single-acting cylinder	10 %	50 %
	Short-circuit valve	10 %	43 %
	Supply air throttling and targeted disconnection	30 %	50 %
	Optimised valve actuation	30 %	65 %

Fig. 2 *Overview of efficiency-enhancing measures in pneumatic drive and handling technology (compressed air). Source: EnEffAH project consortium*

The researchers have therefore formulated the following rules of thumb for automated machine movements:
The smaller the stroke length, the greater the force at the end position, and the longer the holding period, the more efficient the pneumatic drive technology.
The greater the stroke length, the smaller the force at the end position, and the shorter the holding period, the more efficient the electrical drive technology.
Fig. 2 and 3 summarise the most promising measures from the EnEffAH project. Each individual measure offers additional potential for improving efficiency. However, the measures mutually influence each other so that their implementation must always be examined as a whole. Some individual measures are even mutually exclusive (for example, general pressure drop

This is how electricity can work more efficiently			
Phase in the energy-based causal chain	***Measure***	***Applicability***	***Savings up to ...***
Provision	*Optimise low-voltage DC supply*	*10 %*	*2 %*
	Reduce energy consumption in standby mode	*20 %*	*5 %*
Planning	*Use low-friction mechanical components*	*10 %*	*20 %*
	Minimise moving parts	*10 %*	*15 %*
	Avoid over-sizing	*50 %*	*10 %*
	Optimise energy consumption in movement pauses	*10 %*	*4 %*
	Use efficient motors	*30 %*	*3 %*
	Use efficient servo controllers	*20 %*	*3 %*
	Minimise motor cable length	*5 %*	*2 %*
	Use braking energy	*10 %*	*5 %*
Drives & utilisation	*Adapt movement profile*	*20 %*	*8 %*
	Reduce fluctuations in control system	*10 %*	*10 %*

Fig. 3 *Overview of efficiency-enhancing measures in electric drive and handling technology (electricity). Source: EnEffAH project consortium*

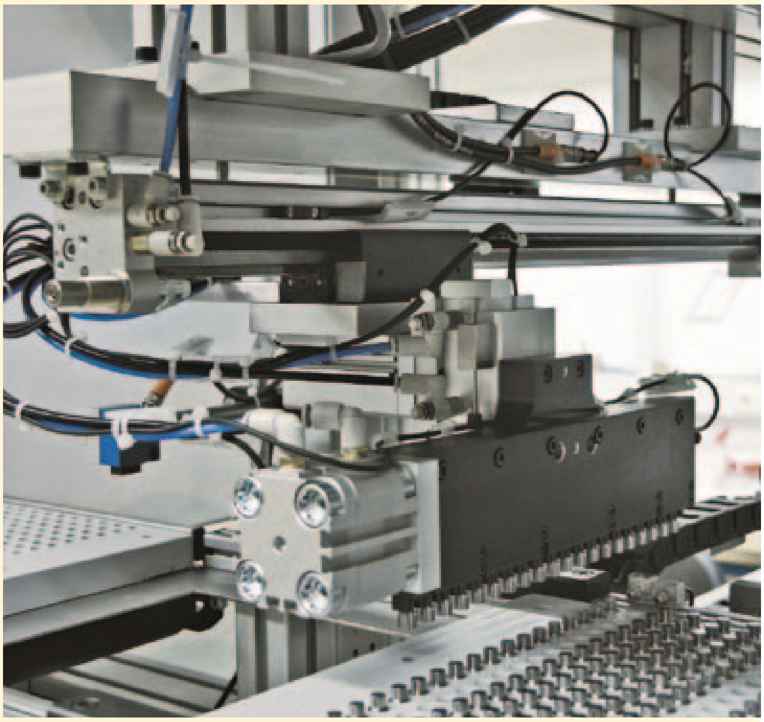

Fig. 4 *Electrical feeding system for automotive injection technology*
Source: Festo AG

and efficient sizing of drives). Because of the mutual influences it is not possible to generalise as to how the overall efficiency of a system increases based on the values presented here. The percentage efficiency increases cannot be simply added together in order to determine the overall energy savings! Furthermore, the percentage savings for the measures described for pneumatic and electrical drive and handling technology cannot be compared with one another since they use different reference values.
Centralised heat recovery takes up a unique position among the measures. The savings shown here do not impact on the drive technology. Instead, the energy gained through recovering heat provides an additional benefit that can be realised in other company areas (process heat for heating or providing air conditioning).

Efficiency favourites

The researchers from the EnEffAH project particularly favour these measures:

- Efficient sizing of components
- Reducing moving parts
- Reducing friction in the system
- Use of operating strategies (pneumatics): Single-acting cylinders, short-circuit valves; targeted disconnection of the compressed air inlet
- Avoiding dead volumes (pneumatics)
- Efficient compressor control with splitting systems or speed-controlled compressor (pneumatics)
- Recovering heat from the compressor (pneumatics – up to 96% of the energy used can be additionally utilised as heat)
- Reducing energy consumption in standby mode (electric drives)

Becoming an efficiency leader

The researchers recommend that industry practitioners take three steps to achieve energy efficient drive and handling technology.
The first step, in the form of "first aid", requires little expenditure and provides considerable benefits.
With compressed air systems, the most important measure – which fortunately can be implemented on almost all systems – is the identification and elimination of leakages. This can be carried out by the company's own personnel or – if they do not have any spare capacity or the necessary expertise or equipment is not available – the work can be conducted by external service providers. In addition, regular servicing of the compressed air treatment components with a justified outlay will provide immediate energy savings.
With electric motors, the potential energy efficiency can be improved without any major interference in the existing system by optimising the movement profiles of the drives in energy terms and by reducing fluctuations in the control system.
As a second stage, all employees should be made more aware of the need for energy efficiency. Obstacles need to be removed. This is a prerequisite in ensuring that the measures implemented also lead to success in the long term. The increased awareness should also be conveyed to suppliers (e.g. in the specifications) and customers (e.g. through the marketing).
The third step can transform the company into a market leader in energy efficiency if all measures are sensibly implemented in accordance with the benefits and costs. In an average company, all the researched measures are economic. Nevertheless, in each individual company it should be checked as to which measures promise the best cost-benefit ratio and should therefore be tackled first.

Efficiency is not automatic

In 2011, the total turnover of the German automation industry increased by more than 17 % to almost 48 billion euros. Exports increased by almost 13 % and achieved an all-time high with more than 30 billion euros, whereby Germany has a 10 % share of the global market. In 2011, the turnover with drives increased by more than 17 per cent to more than 10 billion euros. This has created 16,000 new jobs in the automation industry and the sector now employs a quarter of a million people in Germany. In automation, the focus is now on technologies that increase energy efficiency. The savings potential for the existing technology amounts to 88 billion kWh per year and thus corresponds to the electricity produced by fifty-eight 400 MW-class coal-fired power plants. This has been calculated by the Zentralverband Elektrotechnik- und Elektronikindustrie (ZVEI).
Whereas energy efficiency has long played a considerable role with power and processing machines, it is relatively new in handling technology. Until now there have been no guidelines available for mechanical engineering companies that make it possible to compare the various pneumatic, mechanical and electro-mechanical solutions. For this reason, they always face the dilemma of having to keep both the investment and operating costs down. Pneumatically controlled handling technology is often deployed where there are no rapid movements or high cycle rates and large weights. In terms of drives, it is seldom questioned whether there are even better alternatives. Although electrical axes frequently work substantially more efficiently, they are considerably more expensive to procure and much more complicated to commission. Pneumatic and electrical systems are therefore not in competition with each other but are complementary.
Most money is frequently wasted through over-sizing. For example, pneumatic systems are still frequently designed to be larger than required, particularly with rapid movement sequences and higher loads. The applications should be considered in terms of their overall economic efficiency, particularly in terms of the flexibility, reliability and energy efficiency. The most energy efficient solution can only be determined by comparing the technologies neutrally, whereby the client's handling requirements must always determine the respective solution.

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and Technology (BMWi)
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Project number
0327484A-E

Imprint

ISSN
0937 - 8367

Publisher
FIZ Karlsruhe · Leibniz Institute
for Information Infrastructure
Hermann-von-Helmholtz-Platz 1
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Links and literature (in German)

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Supported by:
Federal Ministry of Economics and Technology
on the basis of a decision by the German Bundestag

Concept and design: iserundschmidt GmbH, Bonn – Berlin, Germany · Layout: KERSTIN CONRADI Mediengestaltung, Berlin, Germany