Over the last few years, the electrotechnical components of pumping installations have increasingly gained the interest of customers. Often it is the electrotechnical equipment which decides on a product's success on the market. This development is expected to continue in future, and customers will focus more and more on the control of process variables by means of pump speed and the energy saving going with it. Depending on the type of pump and on the application, energy costs may account for about 80% of the life cycle costs.

Speed Control Saves Energy

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Why speed control?

Pumping systems are often designed for the maximum demand, which, however, is seldom required. Process-geared adjustments are often achieved with conventional control methods using throttle valves or by-pass lines. Sometimes, this results in very high energy losses. If, however, the pump is optimally matched to the plant requirements by electronic speed adjustment, the motor input power can be reduced considerably.

Positive side effects of reduced speed are the decrease in wear and noise. Different speeds may also become necessary due to process conditions, for example in heating or air-conditioning systems or in water supply installations, if there are changes in demand.

Speed control of asynchronous motors

Thanks to its robustness, no-maintenance design and low production costs, the asynchronous motor has become the "workhorse" among the electric drives, even though continuous speed control cannot easily be implemented.

Fig. 1 shows how the **speed n** of an asynchronous motor can be influenced.

Pole pair number p
(by special pole-changing motors for two up to four speeds at maximum)

Slip s
(by voltage reduction via phase angle control, rotor circuit resistors in the slip ring rotor motor)

Frequency f
(by frequency inverter)

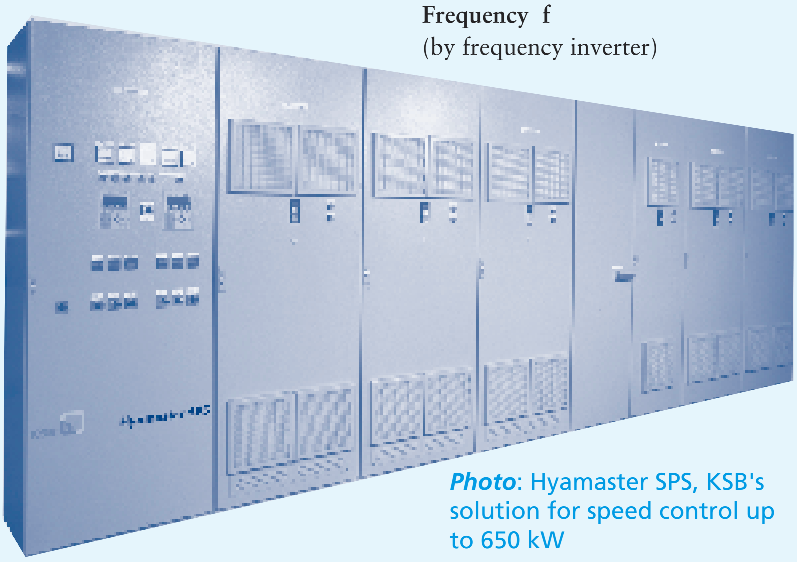
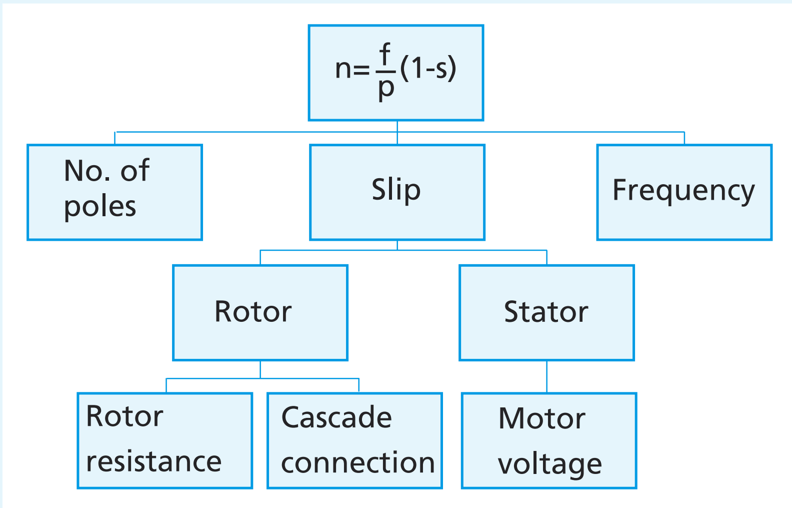


Photo: Hyamaster SPS, KSB's solution for speed control up to 650 kW

Fig. 1: Methods of influencing the speed of an asynchronous motor



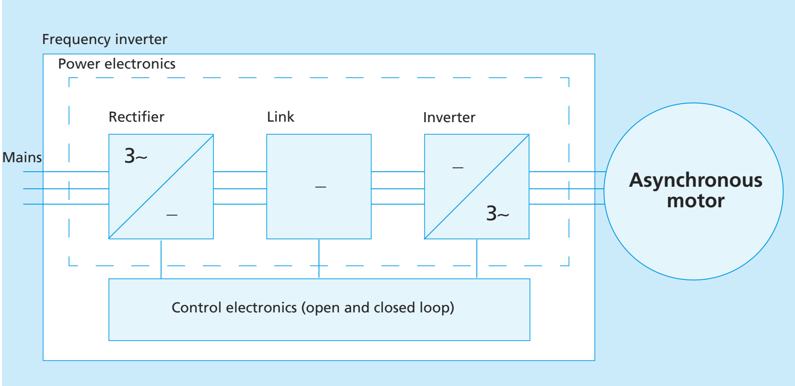


Fig. 2: Frequency inverter structure

The most simple technical solution of speed control is the pole-changing asynchronous motor. It allows, however, no more than four pre-set speeds so that continuous process control is not possible.

Today, motor voltage adjustment at constant supply frequency is almost exclusively effected by means of electronic three-phase a.c. choppers. The constant mains voltage supplied to the terminals of the three-phase a.c. chopper is reduced via a so-called phase angle control by *triacs*. The speed can only be varied in a very narrow range, and so the scope for process control is also limited. Because of the poor efficiency, this method of adjustment should only be used for powers below 1 kW.

The most comfortable speed control method is a frequency inverter, which cannot only change the amplitude but also the frequency. The asynchronous motor with frequency inverter has become a standard solution for industrial drives and is widely used today whenever flexible, low loss speed control is required.

The use of frequency inverters for pump control has the following advantages:

- Infinitely variable speed adjustment
- Availability of higher speeds than with direct mains operation
- *Reactive power compensation* is not required
- Motor can be started with limited *rated current*
- No star delta stages
- Noise reduction
- Reduction of wear
- High start-up / stopping frequency possible
- PI controller already integrated
- Throttle controls are not required
- Energy savings
- Easy connection to bus systems
- Power range from 100 W to several MW

Structure and function of frequency inverters

Most frequency inverters work according to the same basic principle. The frequency inverter converts the a.c. components of the mains into d.c. components and subsequently "chops" them into a three-phase system of variable frequency and amplitude by means of electronic power semiconductors.

The power section of a frequency inverter consists of the rectifier, a link and the inverter, as is shown in Fig. 2. The rectifier in the mains rectifies the alternating voltage of the mains. The link decouples the rectifier and the inverter and serves as energy store. The inverter in the motor converts the d.c. components of the link via electronic switches into a new three-phase voltage system of variable frequency and voltage. An electronic control system monitors and controls the power section.

There are two types of inverters. Which type is chosen depends on the respective power class. The so-called constant-voltage d.c.-link inverter has d.c. voltage in the link with a capacitor as energy store. If the power exceeds 200 kW, it is recommendable for economic reasons to use the constant-current d.c.-link inverter, which has a coil as energy store and thus generates direct current in the link.

Behaviour of the asynchronous motor run via a frequency inverter

Most asynchronous motors are designed for a mains frequency of 50 Hz or 60 Hz. To operate such a motor with a frequency inverter, some particularities must be taken into consideration:

1. Magnetization should remain at a constant level.
2. The maximum current must not exceed the rated current.
3. The permissible insulation voltage must not be exceeded.

To observe the first rule, the U to f ratio is kept constant so that the motor is optimally utilized. If the speed is to be changed by modifying the frequency of the electric supply mains, voltage must change too in the way shown by the characteristic curves in Fig. 3. The voltage / frequency ratio can, however, be

Triac: Bi-lateral triode thyristor (functions like two antiparallelly connected silicon controlled rectifiers).

Reactive power compensation: The reactive power generated by the reactive current does not contribute to the useful service output. For this reason and to relieve the electric generator it is compensated by means of capacitors in the immediate vicinity of inductive consumers.

Rated variable (voltage, current): Variable specified by the manufacturer of an electric machine for a set of defined operating conditions.

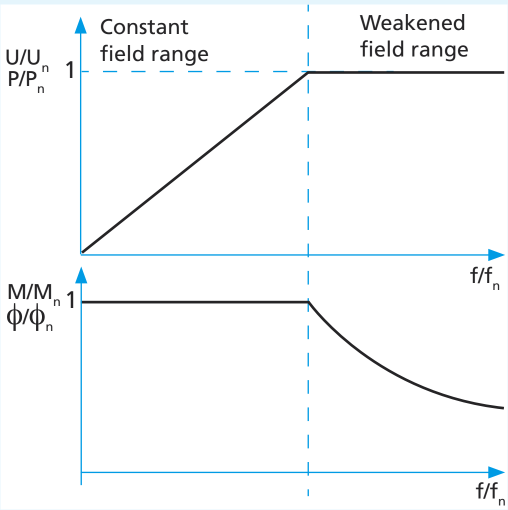


Fig. 3: Characteristics of an asynchronous motor operated via a frequency inverter

kept constant only until the motor voltage has reached the mains voltage. If frequency is increased beyond this level, voltage must necessarily be kept constant at its peak level. This means that the motor is undermagnetized in the upper speed range. It is then operated in the so-called "weakened field range".

Often, a U/f characteristic matched to this special load characteristic is used for the square pump torque.

Saving energy

Electric drive systems account for approximately two thirds of industrial power consumption in Germany. Pumping systems outnumber other drive applications by far. Half of the total energy consumed by electric motors goes into driving pumps.

Fig. 4 illustrates the power saved in a pumping system with speed control compared with throttle control.

Looking at the life cycle costs of a 3 kW in-line pump, for example, the following data are found: initial cost approx. DM 1,900, energy costs over 10 years approx. DM 28,000. Depending on the load profile, approx. DM 600 / kW of installed drive power can on average be saved in annual energy costs. The pay-off period for higher initial cost is approx. 2.6 years.

If only 30 % of the pumps deployed in industry in Germany were equipped with speed control, the energy saved would total 16 TWh per annum. This corresponds to approx. DM 2.4 billion on the basis of present industrial power prices in Germany (source: report of the German Central Association of Electronic Engineering and the Electronics Industry (ZVEI)).

State of the art and outlook

Today, system integration is of special importance with regard to most different aspects. Mechanical engineers, process engineers and drive specialists must cooperate in the planning and development of new drive concepts which include all components and interfaces. New drive concepts will lead to greater efficiency of the total system and thus save costs.

Up to now, the term "drive" has always designated a motor supplied via a frequency inverter. But drive systems are normally used in complex processes in which a certain task must be fulfilled under changing conditions. Fig. 5 shows a drive system with the pertinent process.

Practical applications

At present, these functional units are frequently physically separated. But increasingly smaller electronic and electrotechnical assemblies provide more and more scope for integrating components, so that there is a strong trend to combining different assemblies in a single physical unit.

Fig. 4: Energy saved by speed control compared with throttle control

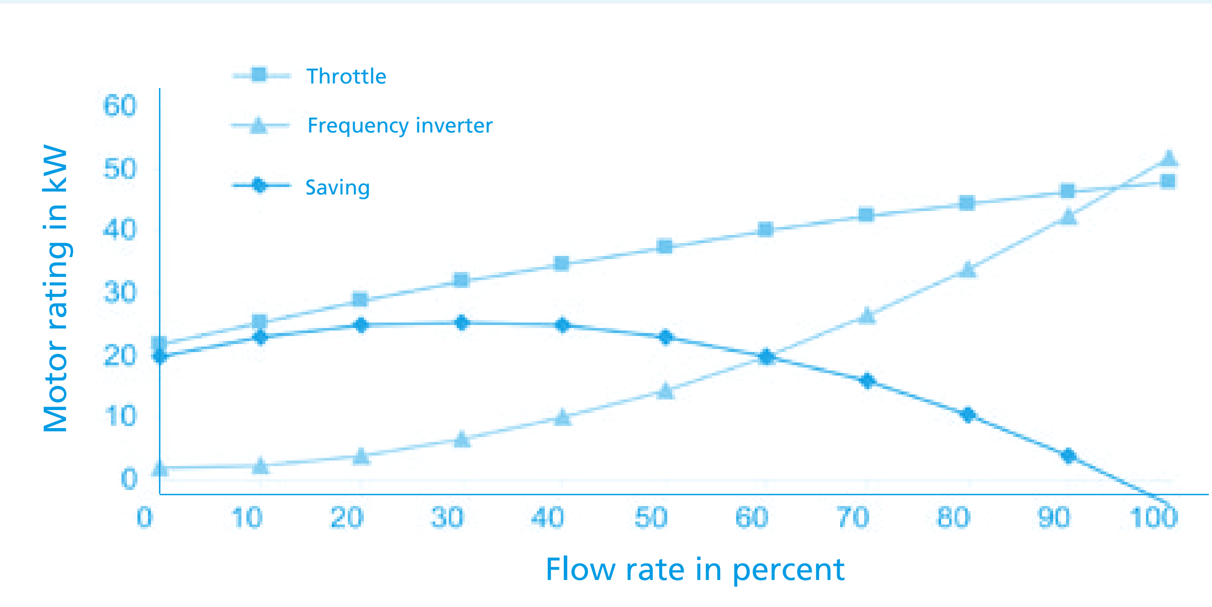


Fig. 5 shows which assemblies are integrated. As a consequence, the complete process is reduced to three elements, i.e. the technical process, the process instrumentation and the integral drive.

The drive consists of a conventional asynchronous motor which, however, is equipped with a frequency inverter with integrated electronics. This produces an integral speed-controlled drive system perfectly suited to open- and closed-loop control.

This solution has the advantage that all relevant functions (motor protection, control, etc.) are integrated and that disturbing *interferences* of the motor cable are reduced due to the position of the frequency inverter immediately on the motor.

Further benefits for the customer are the little space required and reduced wiring costs. In the next issue, we will present the "Hya Drive“, the latest generation of KSB integral motors.

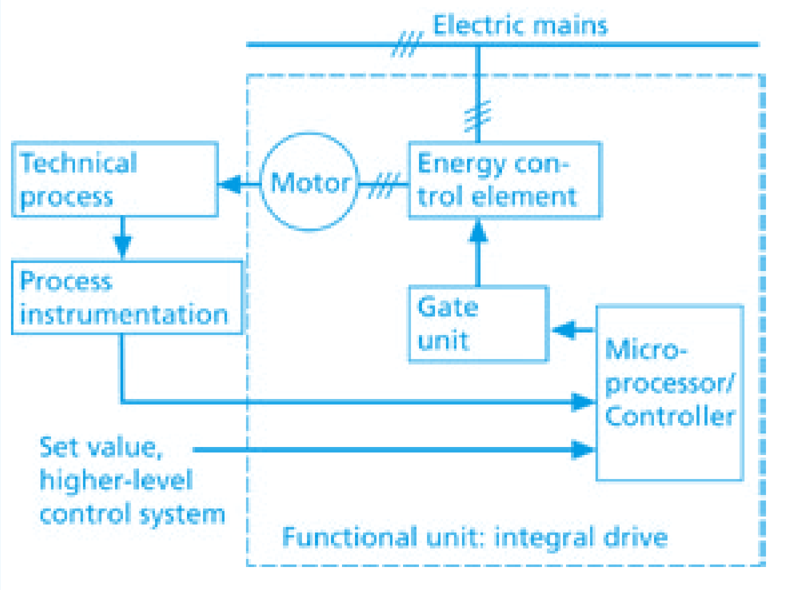


Fig. 5: Components of an integrated drive system in a process.

Interference: Any electromagnetic phenomenon which has a disturbing impact on the functioning of a apparatus, a plant or a system.

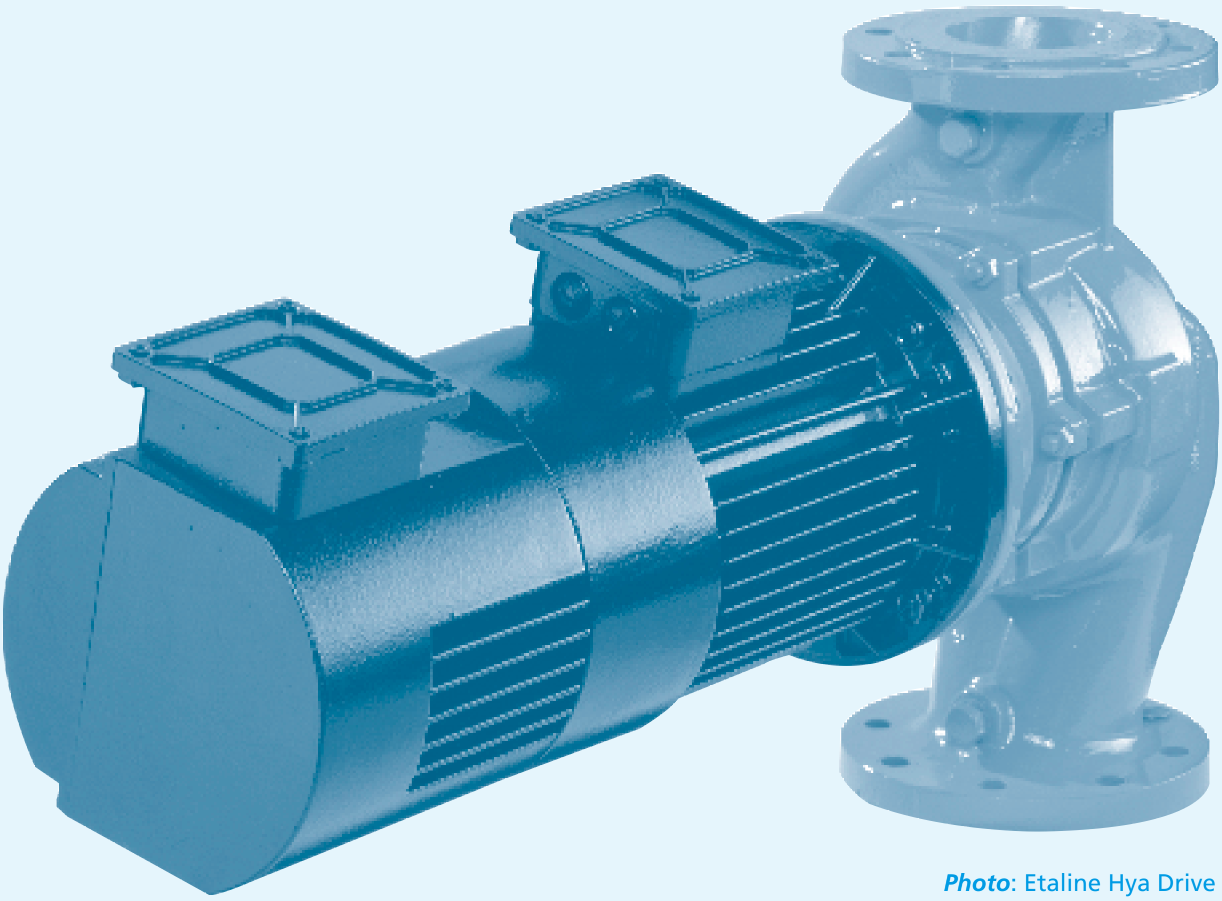


Photo: Etaline Hya Drive