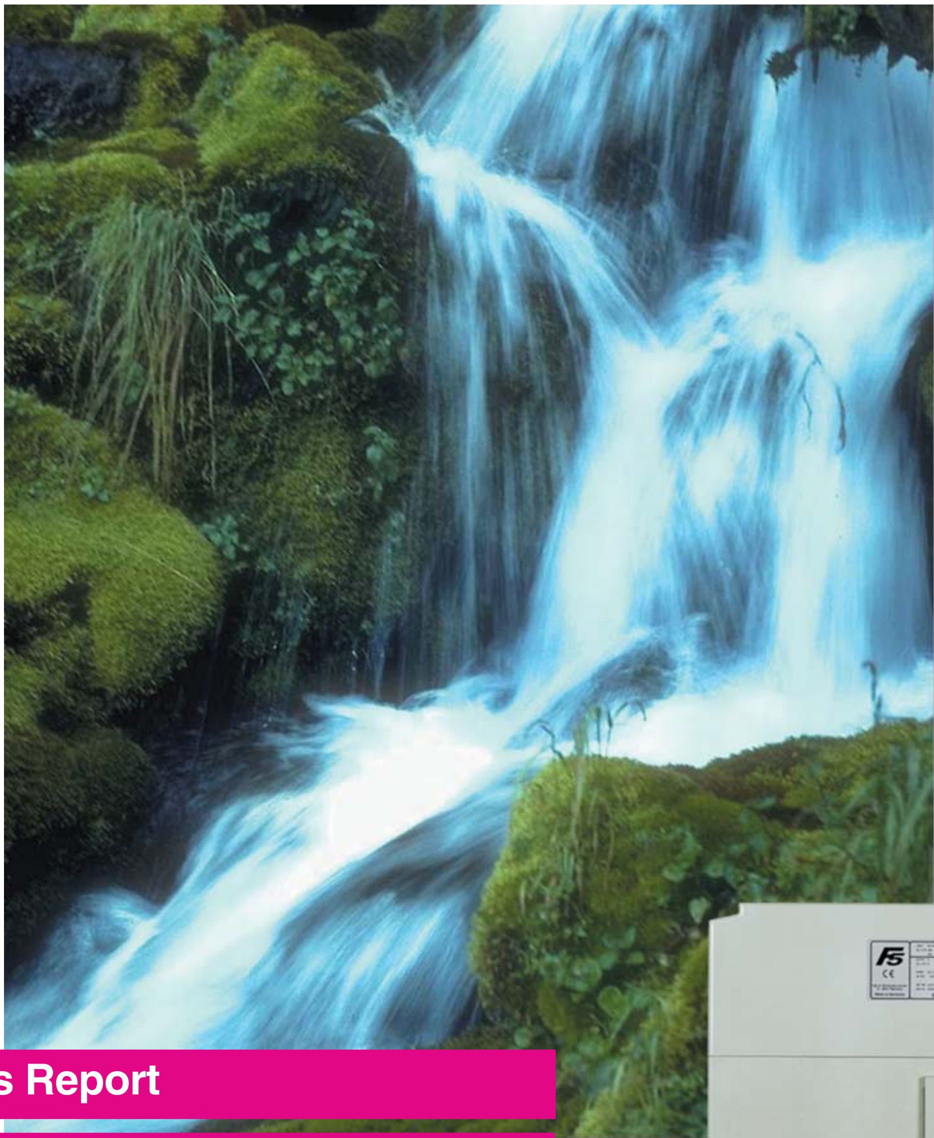
COMBIVERT



Applications Report

Frequency Inverter KEB COMBIVERT

the **System Solution for Pumps and Fans**

with economical und ecological advantages

TÜV CERT
DIN ISO 9001

KEB
ANTRIEBSTECHNIK

B 1

Today about half of the power consumption of industrial countries is used for drive purposes. Most drives are equipped with three-phase asynchronous motors. Over 50% of the energy used here is for pumps and fans.

Current Practice

Although rotary pumps and fans are ideal actuators to fit onto variable operating conditions with speed control, today a major part of these applications is still solved with choke, twist, bypass or discontinuous stopping and starting.

In the future, traditional ways must be broken away from in order to find the optimal technical and commercial solution for precise applications.

Intelligent Solutions . . .

- realize optimal operational performance
- minimize the energy costs with optimal-system total efficiency.
- minimize the preparation costs (power supply company and stand-by set) by reducing the electrical starting points and minimizing the switching cycles
- realize minimal maintenance charges by gentle operation of the equipment (minimal pressure fluctuation, no impact from reverse flow checks, no surges in the pipe mains, minimize leaks by softly starting the aggregate)
- minimize the investment costs by optimizing the energy storage (about 1/3 of the volume without speed control), so that Technical Inspectorate is rarely needed
- offers a variable system with minimal modifications and/or retrofit costs
- makes it possible for an open system with connection possibilites to superior control technology
- reduce noises
- offer optimal reliability

B 2

For economical and ecological reasons careful use of energy resources is required more now than ever.

Rotary pumps and fans must also be layed out in systems with variable power output onto the maximal required drive power. The total system should reach its optimal efficiency in the typical working point. The targeted efficiency in the total operating range is essentially dependent on the control and/or regulating processes used. If for example, the flow volume or pressure must be changed, it is current practice to reach the new working point by adapting the system curve and/or the machine curve of the pump/fan, with the help of an additional mechanical actuator (as described above).

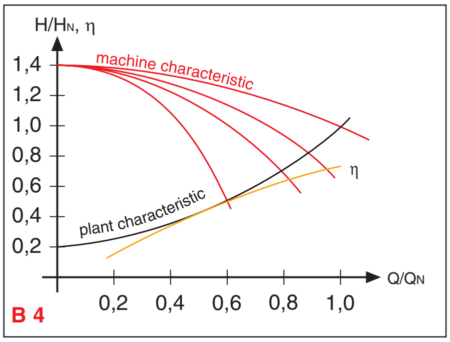
In comparison the energetic and inexpensive speed control of the drive machine optimally adapts the machine curve of the pump / fan onto the new working point.

Each control process is compared on the following pages with a flow control.

B 3

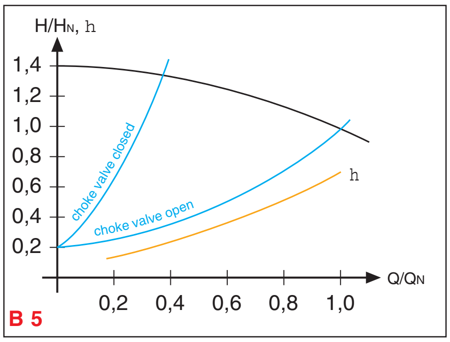
Flow Control with a Twist Valve (B4)

Twist valves change the flow on the suction side of the pump / fan. In changing the machine curve, new working points are set in the system curve with reduced drive power (delivery head H and less volume Q). However, the efficiency is also reduced.



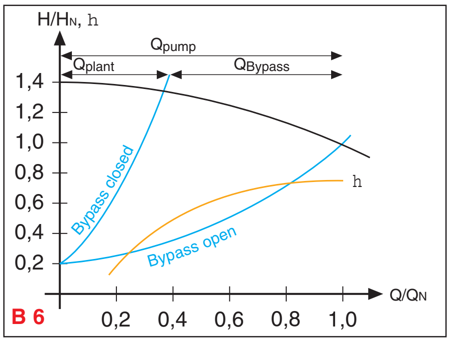
Flow Control with a Choke Valve (B5)

With the help of fittings (slider, valve etc.) the system curve is changed. The resulting increased current losses are transformed into heat energy. This means that the choke valve control is an absolute loss control and with it even more energetically unfavorable than the twist valve control.



Flow Control with a Bypass (B6)

With the help of a bypass a component current of the conveying current is branched off and fed back to the suction side of the pump / fan. This control process is exclusively suitable for axial pumps / fans with increasing flow volume and decreasing power demand. In radial pumps / fans with increasing power demand at increasing flow amounts, the attainable efficiency is worse than all the other control processes described here.



H	– *delivery head ~ the pressure p*
Q	– *quantity*
h	– *efficiency factor*
P	– *power*
n	– *speed*
Index $_N$	– *rated value (at mains frequency)*

Affinity Laws:

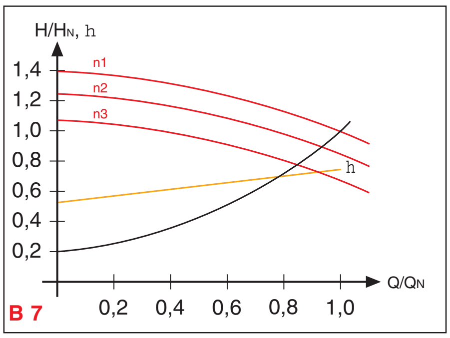
$$\frac{Q_1}{Q_2} = \frac{n_1}{n_2} \; ; \; \frac{H_1}{H_2} = \left(\frac{n_1}{n_2}\right)^2 \; ; \; \frac{P_1}{P_2} = \left(\frac{n_1}{n_2}\right)^3$$

Flow Control with ON/OFF Regulation

Storage tanks are needed in this process in order to compensate the discontinuous behaviour of these 2-point controls (e.g. pressure tank or collecting basin). As soon as the storage tanks are no longer available due to technical reasons, then considerable investment costs are necessary. Another substantial disadvantage is the high number of alternations. These unnecessarily uphold the entire system.

Flow Control with Speed Adjustment (B7)

Only the delivery head in the actuator is produced in the total working range by the speed adjustment, without negatively influencing the efficiency by an unfavourable flow (twist valve). The machine curve is shifted on the system curve according to the affinity laws.



Conclusion

The speed control is the only process that realizes the minimal delivery head needed with an optimum efficiency. The PQ-diagram clarifies the energetic advantages of the speed control. Only with flow volumes > 95 % of the rated amount are the electrical losses in the frequency inverter larger than the losses in the mechanical process. The power demand of the pump/fan is calculated with the following formula:

$$P = \frac{Q \quad H \quad g \quad r}{h}$$

g ≙ *drop acc.* *r* ≙ *specific density*

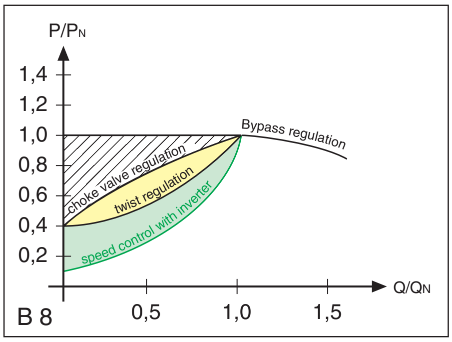
The differing control processes influence the power demand only with the quotients

$$\frac{Q \quad H}{h}$$

The bypass control works alone in the working range "larger equipment nominal conveyor current"

$$(Q_{pump} = Q_{bypass} + Q_{equipment} \leq Q_{Npump})$$

and it is difficult to compare it to the other control processes, because of the main reason for its use (decreasing power demand with increasing flow amount). Just as the ON/OFF regulation it is listed only for the sake of completeness.

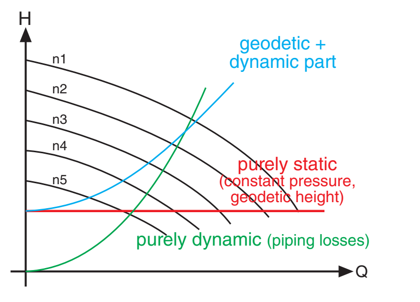


Power reduction

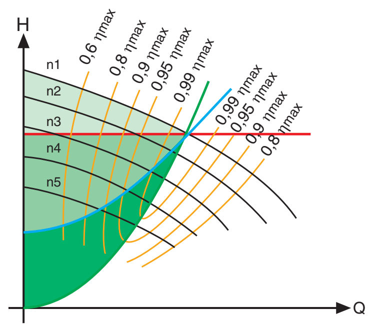
- through throttle valve
- through twist valve
- through speed control

Advantages of Speed Control with Dynamic Set Value

Pumps and fans must often be driven onto so-called "control technical curves", e.g. in the water supply - control of constant pressure with variable volume or heating equipment - in which the quantity quadratically increases the pressure to compensate the pipeline losses. Control engineering curves are not influenced by the pipeline geometry which specifies the system curves. For this reason they can vary to a large extent. As described the twist (B10) and the speed control (B11) are the only processes, which produce the needed pressure in the working machine. The energetic balance of the controls is only differentiated by the efficiency factor. The following identifying fields clarify once again the advantages of the speed control in the partial load range. Especially in systems with pure dynamic characteristics (only flow resistances) does the actuator work in every operating point with optimal efficiency.

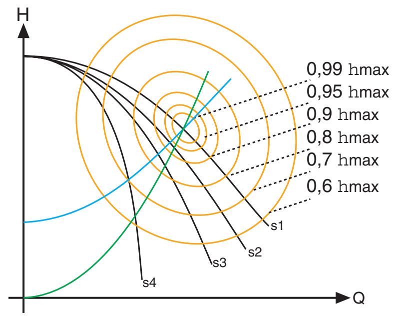


B 9



B 11

Characteristic field of a rotary pump with speed adjustment



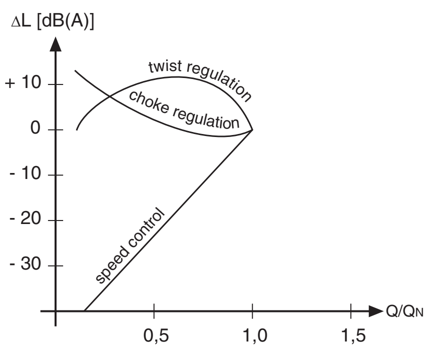
B 10

Characteristic field of a rotary pump with spin changes

- through control onto constant pressure
- through control onto dynamic pressure setpoint value (with geodetic part)
- through control onto dynamic pressure setpoint value (without geodetic part)

Inverters Minimize Process Noises (B12)

With the speed control of the working machines, a considerable reduction of the turbulence-induced noise is possible in the subload range. Using the KEB COMBIVERT inverter the typical whistling noises of three-phase asynchronous motors are reduced to a minimum.



B 12

Speed Control with Inverters Saves Investment Costs

The optimal operating behaviour and the minimal operating costs of speed controlled equipment is well known. The theory, that the use of inverters does not automatically mean more investment costs is valid today for a number of applications. The much improved price-power-ratio of the new inverter generation and the intelligent solutions connected with savings of conventional technology must be displayed here.

No Installation of the Supply on Excessive Starting Currents

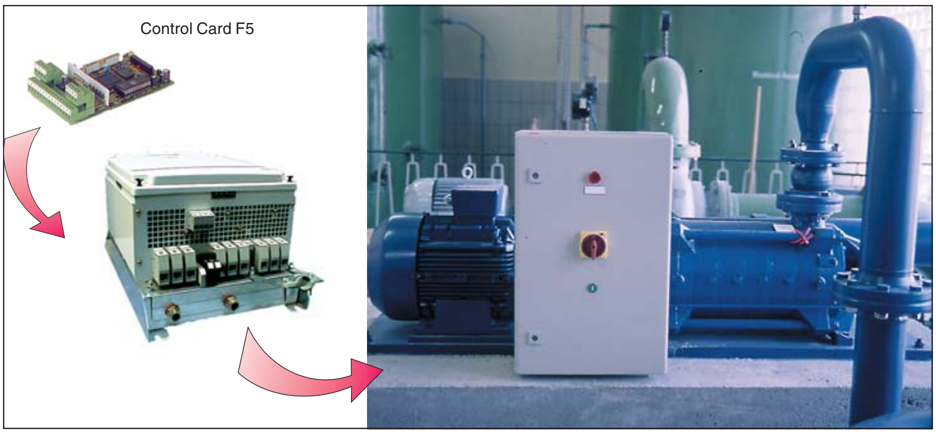
Inverter fed pumps/ventilating motors need substantially less starting currents than machines operated by the mains. Therefore, the overdimensioning of the supply can be done without. A considerable saving potential is represented by the frequently needed emergency generator. Despite the system-limited non-sine formed current drain from the mains, the inverter operation can be installed with 20 - 50% less generator power. Additionally the provision fees of the power supply company correspondingly decrease.

Compensation Equipment is Unnecessary

Three-phase asynchronous motors principally need inductive reactive power. The power supply companies require larger consumers to install compensation capacitors, so that the mains must not be dimensioned onto the reactive power. A max. of 50% of the active power may be taken from the mains as reactive power ($\cos\varphi = 0.9$). At inverter operation the required reactive power in the intermediate circuit capacitors of the inverter is produced ($\cos \approx 1$). With an optimal compensation the investment in additional capacitors is not necessary.

Pumps / Fans with KEB COMBIVERT F-Series - Intelligence on Location

KEB power transmission offers inverters with digital control (16/32-bit-controller) in the power range from 0.37 to 315 kW. It concerns a pulse-width-modulating voltage-intermediate-circuit inverter with high clock output transistors (IGBT's) for the universal application of three-phase asynchronous motors. The advanced functions and the compact design provide the user with intelligent solutions when using pumps/fans in larger drive powers.



B 13

Frequency inverter (air- or water-cooled) asynchronous motor und pump as compact unit.

Power Features

Extensive Operating Safety with

- hardware protective functions against overcurrent, overvoltage, phase failure, short-circuit, line-to-earth fault, overload and overtemperature
- EMC-resistance according to IEC 801-4 (new IEC 1000-4)
- prototype certification
- digital noise filter of the control inputs
- large input rated voltage range 200 to 240 V and/or 380 to 480 V
- control of mains voltage fluctuations (in subload operation instead of full torque and with it optimal operating behaviour of the pumps / fans)
- blanking out of the resonance frequencies of the systems
- rotation block
- protection against water shortage in the pumps (digital input)
- variable maximum limit against "spinning" of the pumps (also stall in the pump)
- automatic restart after a mains breakdown
- automatic restart after overload
- automatic speed search at restart
- overload alert signal
- overtemperature alert signal
- PTC-evaluation logic
- programmable electronic motor protection relay
- high overload reserves according to type, up to 200% for 30 sec.
- operating- and interference messages
- diagnostic possibility with error memory

Variable System with

! adaption onto various pumps / fans

- rated speeds
- min. speed (max. acceleration onto min. speed, then moderate variable acceleration to the operating point)
- maximum speeds

! adaption onto various operational requirements

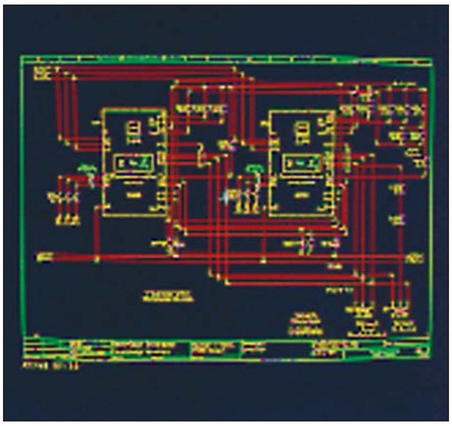
- real-time signal processing
- set value presetting internally and/or externally (0 - 10 V, ± 0-10 V, 0-20 mA und 4-20 mA)
- high automation flexibility with PLC-functionality in the inverter, with up to 8 parameter sets to define various behaviour, 4 programmable digital outputs, 2 programmable analog output, up to 4 programmable digital inputs, 2 analog set value inputs
- multi-function d.c.-braking of the drive
- continuous base load e.g. in circulating systems (through f_{min})
- automatic switch-on /off of the base load e.g. pressure dep. with pressure increase units

! coupling on current field bus systems, InterBus-S, CAN-Bus,Profibus and LON via serial RS232/485- interface

! Visualization program COMBIVIS (executable on IBM compatible PC's)

... simple starting with adapted parameter lists

... clear display of all important parameters in the working list, as well as the most important inverter process sizes with the help of a 4 channel scope function.



Your System Partner KEB Antriebstechnik

The market demands a competent partner in the field of pumps and fan automation. A complete span from inverter manufacturers to support at the planning, projecting and execution of the complete control system with linking possibilities to predominate control technology must be offered.

KEB has over 25 years of experience in power transmission which assures fully developed technology and excellent application know-how. We offer the optimal solution for your application:

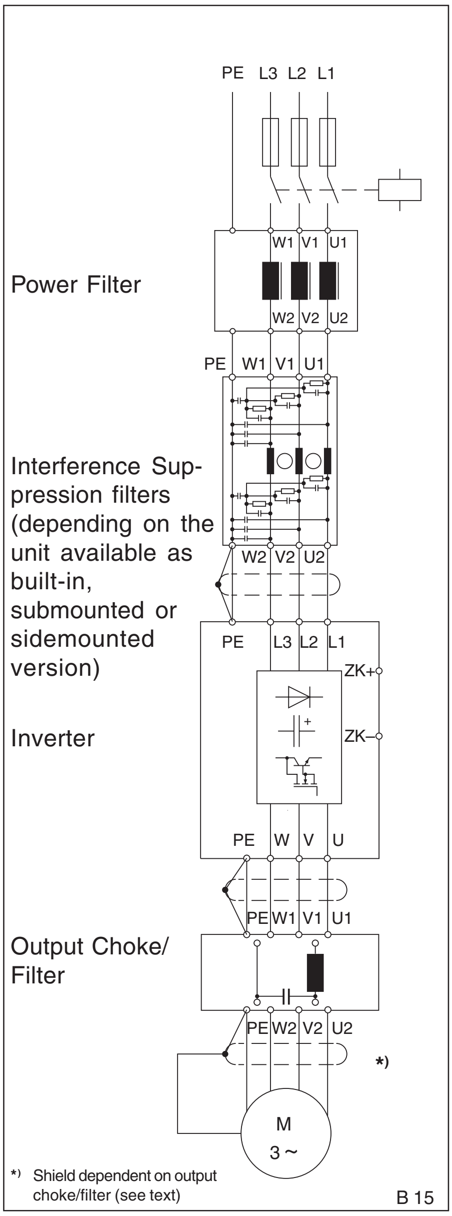
Static Inverter (see product catalogs)

Corresponding Optional Input- and Output Chokes and/or Filters

- KEB input choke / layed out according to VDE 0160 with relative terminal short-circuit voltage from u_k = 4 %, because of that a reduction of the harmonics and with it an improvement of the power factor l of about 0.6 to about 0.9 is reached. Furthermore, the mains feedback in the frequency range of 10 to 300 kHz and up to 30 dB is reduced.
- Input noise suppression filter according to EN 55011 to conform with the noise suppression degree B.
- External KEB motor chokes, a cost-effective way to reduce the voltage rate-of-rise du/dt in the motor winding, to prevent the premature aging of the winding insulation. Furthermore the use of motor chokes to reduce the motor noises with standard inverters and/or in applications with long motor lines can be indicated.
- I/O filter as combination of input interference suppression filter and output du/dt filter, which lessens the rate of voltage rise du/dt and the max. voltage peaks at the motor windings to the values specified in VDE 0530. Moreover, the compact design of this filter version is captivating.
- External sine output filter / with the use of KEB-sine filter reduces the voltage rate of rise between the output phases on sine behaviours, so that no negative effects are expected on the long-time response of the winding insulation of the three-phase asynchronous motor. The voltage rate of rise amounts to max. 500 V/ms. This is independent from the length of the motor line.
- External sine output filter plus (sine filter with HF-connection) / makes it possible for a sine-formed voltage course of the motor terminal voltage between the phases and the ground. This means next to the limitation of the max. voltage rate-of-rise, the numerous high frequency EMC-problems can be solved with these filters. This is done without exceeding the limit values for interference suppression on the lines. With this it is possible to retrofit the drive with an inverter, without changing the motor lines.

Integrated Process Controller

- quasi PID-controller in KEB COMBIVERT type F4 and PID-controller in KEB COMBIVERT F5 for controled systems with large variance and control onto floating setpoint value. Simple optimization. The manipulated variable is externally available over an analog output, e. g. for the control of further KEB COMBIVERTs.



Complete Solution, e.g. " Intelligent Inverter Full Cascade "

- Provides an optimal solution for the greatest demands on the operating behaviour and efficiency of the equipment with complete degree of freedom for the user. Suitable for up to 8 speed controlled pumps/fans.

  Equipment / Performance Characteristics:
  - 1 KEB-COMBIVERT F-series per regulated pump / fan
  - 1 PI-controller per cascade (integriert im COMBIVERT)
  - 1 sensor, e.g. pressure sensor per cascade
  - Minimal periphery for the realization of the control. There are no predominate controls (PLC, industry-PC, etc.) required, since the complete control is realized in the inverter software.
  - Variable system for various pumps / fans in a full cascade (aggregate size, zero delivery head, rated speeds, minimal speeds) free programmable operating behaviour, e.g. continuous / automatic switching on/off of the base load machine, automatic disturbance switching.
  - Optimal regulation in the entire working range with synchronous driving of the aggregate on the overall characteristic. Optimized system efficiency and material protective soft operation provides for economic efficiency (see also system description of intelligent inverter full-cascade).

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System solutions: KEB pumps / fans - CP-Mode

- A pre-programming and operator interface tailored to be applications of pumps/ fans (instruction manual and download can be retrieved from the KEB-CD as allas under KEB.de).

$$Q = \left[\frac{m^3}{Std}\right]$$

To Calculate the Energy-Savings Yourself

1. Power Demand

   The various power demands of each control process can be determined from the respective aggregate-identification field. The power may also be calculated from the power equations already named. To simplify this the corresponding standard size equation is given.

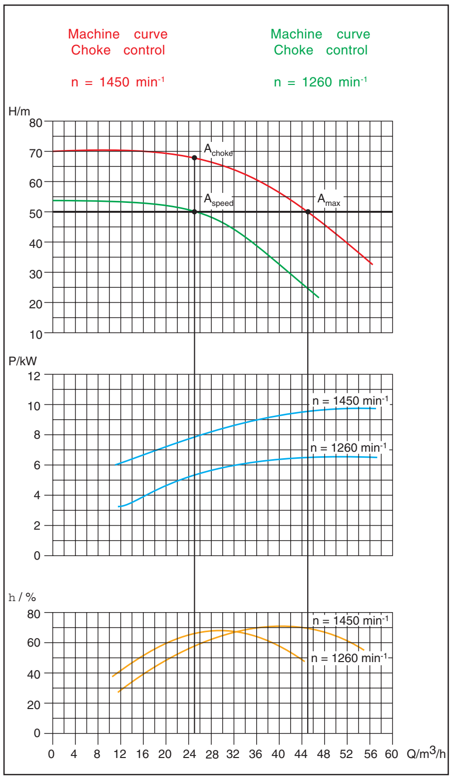
$$P = \frac{Q \cdot H \cdot g \cdot \rho}{\eta \cdot 3600} \qquad P = [kW] \qquad H = [m] \qquad g = [m/S^2] \qquad \rho = [kg/dm^3]$$

   The total efficiency results by multiplying the partial efficiency from pump/fan three-phase asynchronous motors and with speed controls from the inverter efficiency.

2. **Energy Savings**

   With the help of a daily demand curve and/or with average power demand and the operating time, the energy savings can be calculated.

$$W_S = P_S \cdot t$$



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people in motion

Calculation Example

You can find detailed amortization considerations for the use of several aggregates in the parallel operation in the product description of the "intelligent inverter full cascade".

Given: rotary pump

Rated delivery head: H_{rated} = 50 m (control on constant set value)

Rated current: Q_{rated} = 45 m^3/hr.

Specific density of the quantity: r = 1 kg/dm^3 (water)

Operating time: t = 8,760 hr./year

kWh-price: K = 0.08 Euro /kWh

max. pump efficiency: $Q_{optimum}$ = 0.7

Search: recorded power P_1 at drive current reduction onto 25 m^3/hr.

This standard equation of the power at choke control results:

$$P_{1choke} = \frac{25 \cdot 68 \cdot 9{,}81 \cdot 1}{3600 \cdot 0{,}58 \cdot 0{,}89} = 9\ kW$$

h_p – pump efficiency (see assigned field, here 0.58)
h_M – motor efficiency (dep. on the rated power and the ratio of instantaneous power to rated power, here 0.89)

and/or at speed control with KEB COMBIVERT:

$$P_{1speed} = \frac{25 \cdot 50 \cdot 9{,}81 \cdot 1}{3600 \cdot 0{,}66 \cdot 0{,}88 \cdot 0{,}96} = 6{,}1\ kW$$

h_F – frequeny inverter efficiency
(depending on the rated power and the switching frequency, here = 0.96)
h_P = 0.66
h_M = 0.88

Power savings: P_S = 2.9 kW

Energy savings: W_S = 2.9 kW · 8760 hr./year = 25.404 kWh/year

Cost savings: K_S = 25,404 kWh · 0.06 Euro/kWh = 1,524 Euro/year

Amortization time: T_A = inverter unit price (frequency inverter 11 kW)
about 2.200 Euro : 1.524 Euro » 17 months

With controls that have a pure dynamic set value or mixed forms of dynamic and geodetic parts, there are extremely larger savings and with it shorter amortization times.

Even after the liberalization of the energy market it sill pays to employ energy-saving technologies.

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