NESS
The Process Heat Company

Energy efficiency
in supplying industrial
process heat

SAVINGS WITH CONTROLLED PUMPS – SOME CASES FROM THE FIELD

Whitepaper

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PREFACE

For more than 50 years we have been developing, designing and manufacturing process heating systems for our customers worldwide. In engineering alone, around 30 highly qualified and motivated engineers from all areas of technology work on solutions for our customers on all continents.
We would like to share this experience with you. For this reason we provide you with free whitepapers for various areas in process heating.

Costs for resources as well as plant operation are constantly increasing. The topic of energy efficiency has therefore become more important than ever. Previous procedures and processes must therefore be analysed and, if necessary, improved. A sustainable, future-proof plant operation presents us with completely new ecological and economic challenges. The latter makes it particularly sensible to decide in which areas an investment is necessary.

We hope that this whitepaper will provide you with clear added value and support you in your decision-making process.

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SUMMARY

Using more efficient electric motors can cut energy consumption in process heating systems by a few percentage points. This makes sense with new systems and upgrades; but replacing existing motors is generally not financially viable.

Using frequency converters while optimising process technology at the same time can often generate energy savings of up to 60%, while improving systems technically.

Two specific case studies, one with a single major heat consumer, the other with multiple heat consumers, show how it is possible to save approx. 60% and 50%, respectively. The capital costs are relatively low, making retrofitting existing systems financially attractive.

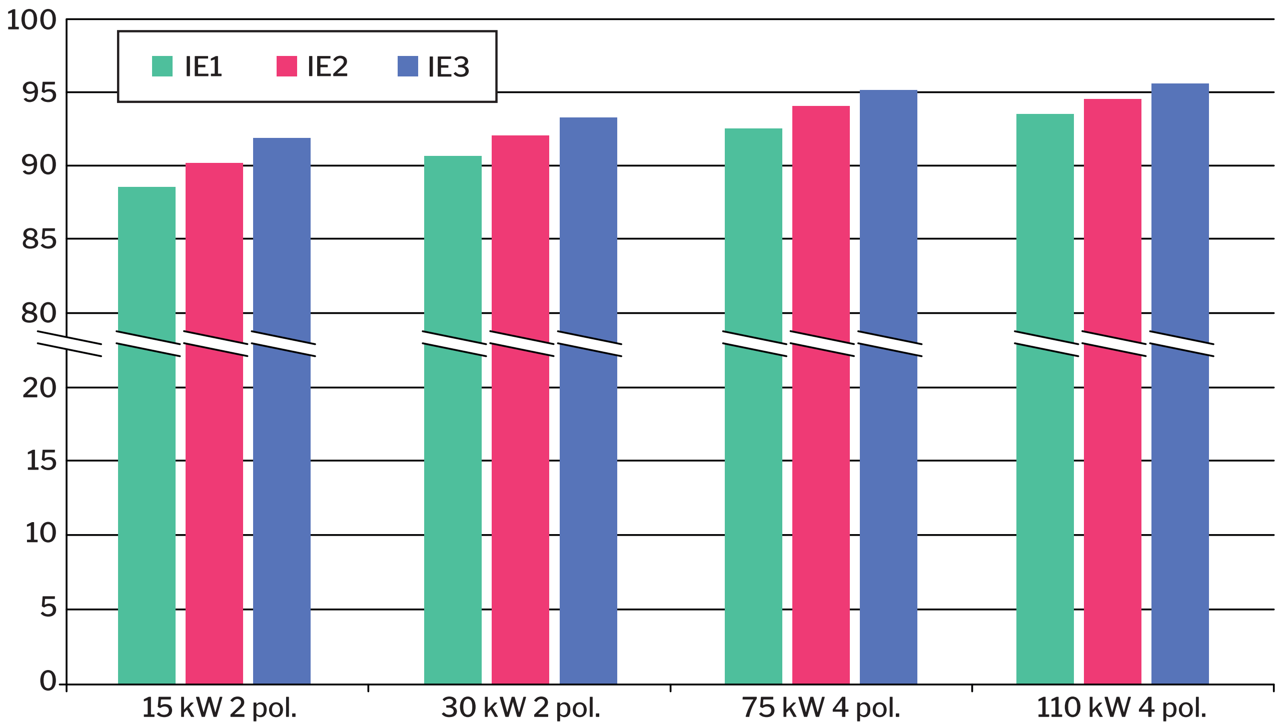
HIGHER EFFICIENCY CLASS MOTORS – A SMALL ADVANCE IN ENERGY CONSUMPTION

The pioneers in increasing the efficiency of electric motors are currently the USA and Europe. Guidelines for new installations of more efficient motors are being specially prescribed there. In the EU, for example via the Ecodesign requirements (2009/125/EC).

It applies in particular to 2 to 6-pole motors at altitudes up to 1000 m with ambient temperatures of -15°C to +40°C and maximum operating temperatures up to 400°C, but not in Ex zones. Since 2017 IE3 has been mandatory for asynchronous motors from 0.75 kW to 375 kW. Alternatively, IE2 motors can be operated with frequency converters. This certainly brings advantages in terms of power consumption.

By virtue of Regulation (EU) 2019/1781 of 1 October 2019, the following will apply from 1 July 2021:
“The energy efficiency of three-phase motors with a rated output equal to or above 0,75 kW and equal to or below 1 000 kW, with 2, 4, 6 or 8 poles, which are not Ex eb increased safety motors, shall correspond to at least the IE3 efficiency level.”

From 1 July 2023, the rules for Ex-eb motors will also be tightened:
“The energy efficiency of Ex eb increased safety motors with a rated output equal to or above 0,12 kW and equal to or below 1 000 kW, with 2, 4, 6 or 8 poles, and single-phase motors with a rated output equal to or above 0,12 kW shall correspond to at least the IE2 efficiency level“



Efficiency of three-phase asynchronous motors of various energy efficiency classes at full load (data from Siemens catalogue)

If the full-load efficiencies of three-phase asynchronous motors with four common power ratings are compared, it becomes interesting.

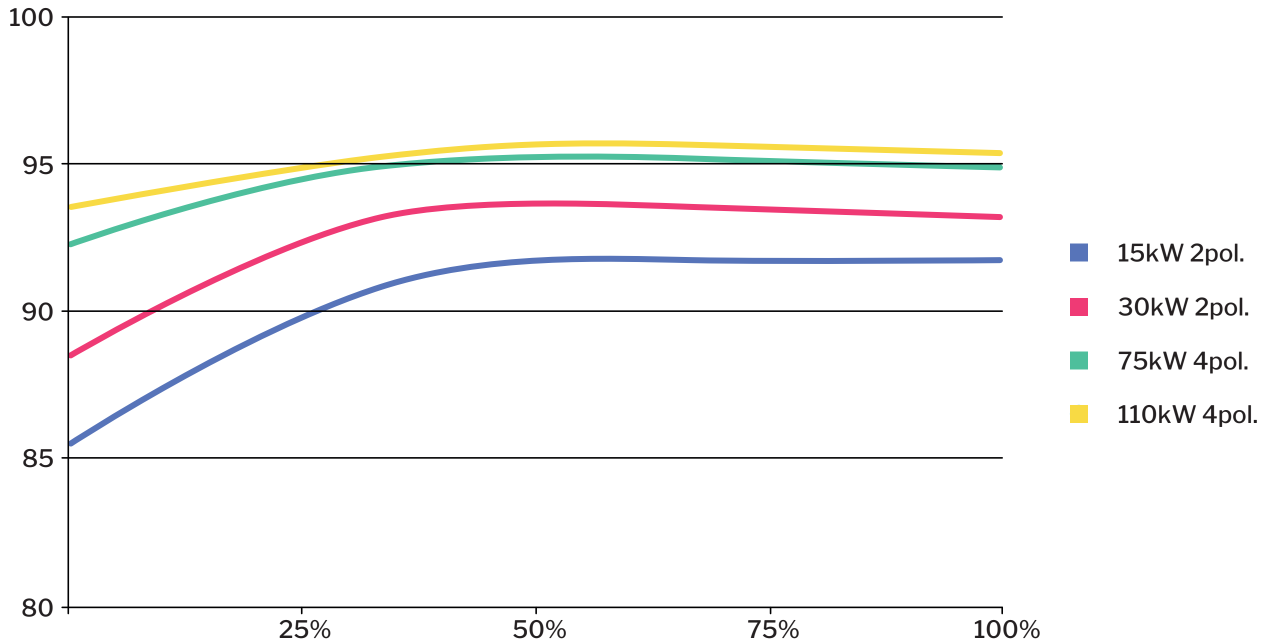
There are three points worth noting here:

- Larger motors are rather more efficient than smaller ones (IE3: 110 kW = 95.5% vs. 15 kW = 91.9%)
- The difference between IE3 and IE2 is less pronounced with larger motors than with smaller ones (91.9% vs. 90.3% at 15 kW, 95.5% vs. 94.5% at 110 kW)
- Overall, IE3 is only slightly more efficient than IE2 (around one percentage point)

So converting existing working motors from IE2 to IE3 is not financially viable, even more so with future IE4 motors, which differ in sizes for technical reasons and also need to be rebuilt mechanically.

THREE-PHASE ASYNCHRONOUS MOTORS HAVE A GOOD PART LOAD EFFICIENCY

Motors are designed to have 15-30% power reserve in hand when used at fixed frequencies. When using frequency converters, three-phase asynchronous motors often run at less than 50% of their nominal power, so it is essential that motors are efficient at part loads too, in both energy and financial terms.



Part load efficiencies of typical three-phase asynchronous motors in efficiency class IE3

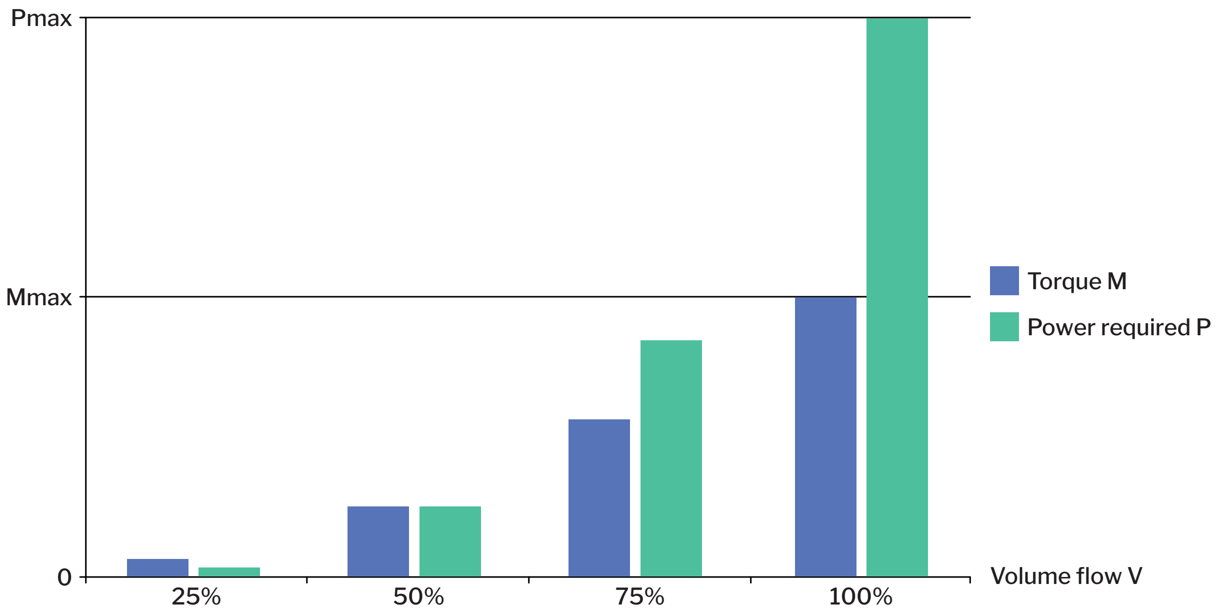
Looking at the efficiencies, the following becomes clear:

- Efficiency is more or less constant at loads between 50% and 100% of rated power
- Larger motors are actually more efficient at 75% of rated power than at full load
- Efficiency does not fall off noticeably until below 50% of rated power
- Smaller motors become much less efficient at 25% of rated power compared to larger ones
- Even smaller 15 kW motors are still approx. 86% efficient at 25% of rated power

Other types of motors, such as three-phase synchronous motors and especially reluctance motors, are more efficient at very low part loads than three-phase asynchronous ones. But they always need special frequency converters when starting, which are incompatible with those used for three-phase asynchronous motors. As the latter are efficient enough at part loads, however, there is generally no point, financially speaking, in replacing existing drive systems with three-phase synchronous motors. It is an option, however, worth considering with new investments.

OPERATING FREQUENCY CONVERTERS AND OPTIMISING PROCESS TECHNOLOGY CAN RESULT IN MAJOR ENERGY SAVINGS

Many systems are designed to run at maximum power, but are regularly used at much lower - often variable - power levels, and often variable power levels, if they are used to make different products for example.
There are extensive energy savings to be made under all operating conditions which do not require maximum power. This is particularly true of systems with pumps and fans in which resistance (torque) increases as the square of speed or throughput.



Ratio of the torque and power requirement of the pump to its throughput

The power required then increases with the cube of throughput.
At half the mass or volume flow, the theoretical energy required is then just one-eighth of that required at full load!

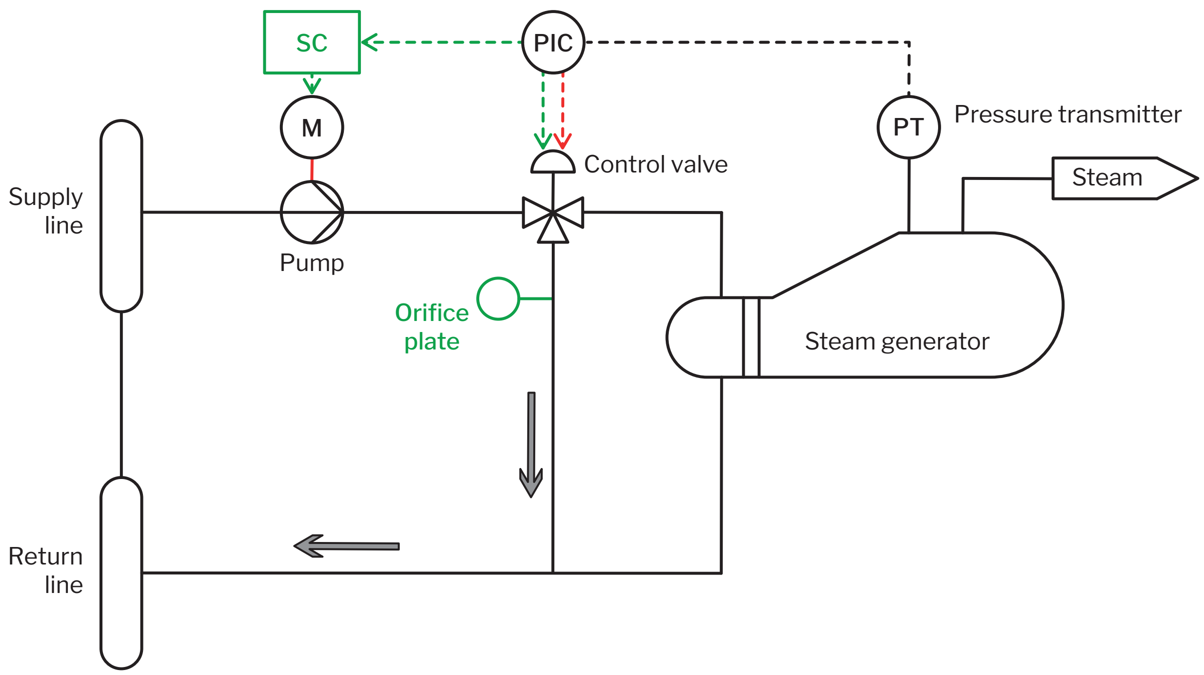
Even allowing for the fact that motors may be rather less efficient at part loads, the savings this makes possible are many times those which could be made purely by replacing motors with higher efficiency class ones. At the same time, this can also improve quality in different ways, such as control precision, noise levels or service life.

Let us now look at this in more detail, using two case studies.

CASE STUDY #1: THERMAL OIL-HEATED STEAM GENERATOR – SWITCHING FROM VALVE CONTROL TO FREQUENCY CONVERTER CONTROL

A steam generator produces saturated steam for making MDF (medium density fibre) and HDF (high density fibre) panels. It has a maximum output of 27 t/h and a maximum thermal oil volumetric flow of 960 m^3/h. Initially, this steam generator ran at a constant thermal oil volumetric flow, controlling the steam pressure using a three-way valve.

Ness Wärmetechnik modified the system, adding a frequency converter, an orifice plate for the control valve and changing the control structure. The regulator now works on the split-range method. The control valve is wide open and plays no part in regulation until the variable speed drive has reached its minimum speed.



Steam generator supply block diagram

In operation, this gave the following values. In case of HDF and MDF production, reductions of 65% and 55% respectively were achieved.

OPERATING MODE	FREQUENCY	POWER	POWER SAVING
-	50 Hz	110 kW	-

AFTER MODIFICATION	FREQUENCY	POWER	POWER SAVING
MDF PRODUCTION	31 Hz	38 kW	**65%**
HDF PRODUCTION	36 Hz	51 kW	**55%**
STANDBY	20 Hz	31 kW	**72%**

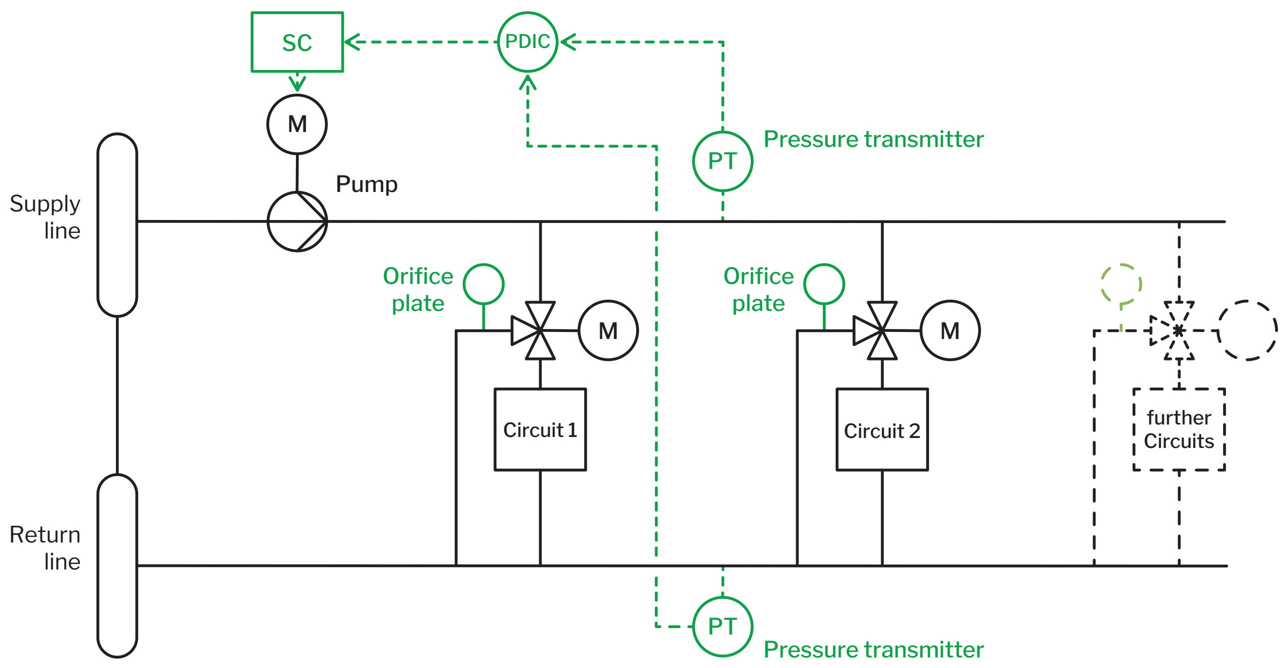
Energy consumption with thermal oil-heated steam generator pre- and post-modification

CASE STUDY #2: MULTIPLE PARALLEL HEATING CIRCUITS – FROM FIXED FREQUENCY TO FREQUENCY CONVERTER AND DIFFERENTIAL PRESSURE CONTROL

There are a number of parallel circuits heating different zones of a consumer. Each heating circuit has a three-way control valve and is controlled individually. How much heat each zone requires depends on the product.

A pump with a 90 kW motor supplies the heating circuits with hot heating medium. The heating circuit control valves allow as much heating medium into each heating circuit as is needed and return the rest unused via the system return line.

Ness Wärmetechnik restricted the unused heating medium flows in the heating circuits with orifice plates so that the pump has precisely the volumetric flow it needs at minimum rpm.



Multiple circuit supply block diagram

The pump was frequency-controlled, with the control variable being a constant differential pressure between the supply and return at the heating circuit inputs.

In the following summaries the measurement data before and after the modification.

PRE-MODIFICATION	PRESSURE	FREQUENCY	POWER	POWER SAVING
-	-	50 Hz	79 kW	-

POST-MODIFICATION	PRESSURE	FREQUENCY	POWER	POWER SAVING
MDF PRODUCTION	0.75 bar	35 Hz	33 kW	**58%**
HDF PRODUCTION	0.7 bar	36 Hz	34 kW	**57%**
STANDBY	0.7 bar	27 Hz	21 kW	**73%**

Energy consumption in multiple circuit supply (90 kW motor) to an HDF/MDF press

Post-modification, the energy consumption could be reduced by more than 50% for both main products.

The system has also gained a degree of freedom: the adjustable differential pressure. Using the right differential pressure upstream of the control valves can enable the system to be controlled with more precision: it can be selected such that all control valves are in the range of 10-90%, with none of the valves at 100%. This circuit would not get enough heat otherwise.

This modification also has the benefit that there are now virtually no unused heating medium flows. What this means is that, with new systems, the heater volumetric flow does not now need to be designed for the theoretical maximum total flow for all loads. It is sufficient to design it to meet the maximum consumption actually expected at any time, saving, again, on capital and energy costs.

With existing systems which have a limited volume flow of heating medium available, this can be used optimally to increase output or expand the heat consumers.

RECOMMENDED APPROACH WITH NEW AND EXISTING SYSTEMS

With any pump and fan application, it is advisable to consider whether a suitably designed frequency converter could save significantly on energy.

If a process pump has to run at a constant frequency, the savings to be made are just a few per cent. Using a frequency converter is generally worth considering, in particular with new systems. The system can then be run up to the exact working point required, so the otherwise necessary overdesign and safety margins do not result in additional long-term costs.

This may be worthwhile, even with existing systems. Alternatively, pump impellers may be optimised retrospectively.

Using frequency control offers disproportionately more savings. Wherever systems run at variable output and a meaningful control variable can be found, as in the case studies above, savings of more than 50% can be made while at the same time improving system quality (control, precision, noise, service life, etc.). This is worthwhile in just about all cases, in both new and existing systems, as the capital costs are not high. But it is essential to have process know-how, because this will affect how the system operates, and unwanted side-effects must to be avoided.

New systems should be fitted with high efficiency class motors (IE3/IE4). For smaller drives, IE4 reluctance motors with special frequency inverters are available: these are the most efficient at part load, but are incompatible with three-phase asynchronous motors and frequency converters, so spares, service and maintenance costs should also be taken into account when making the decision.

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