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Optimizing pump speeds saves energy

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Abstract

There is potential for savings just about everywhere, because all planning and dimensioning are done so that pumps are over-dimensioned, to be sure that they work in extreme conditions. This means that they cannot be driven at ideal efficiency which in turn leads to lost energy. With variable speed drive (VSD) control even over-dimensioned machines can be driven more efficiently.

When pumps are operated in parallel and their control is based on VSDs, there is a potential for energy savings of up to 60 per cent. The biggest savings can be achieved in environments where fluctuations of the flow are remarkable. These findings come from a study done at the department of Energy and Environment at the Lappeenranta University of Technology (LUT) in Finland.

ABB has developed an intelligent package of control software for VSD. Using this software, which is available for ABB's industrial drives, interconnected VSDs can ensure the optimal pump operating arrangement in terms of pump efficiency at any operating point, without using an external programmable logic controller (PLC).

This paper describes the technical back round, simulations and test results when optimization was fully utilized.

Key words: *energy, control, efficiency*

Introduction

Water works are designed to work without a second thought, which means that once they are in operation, nobody is interested to reconsider after, say, 10 years how the works could be made more efficient. The current trend in many countries were public water works are sold to private investors may lead a growing interest in energy savings. The more the energy consumption (and the underlying need to move liquids) varies, the more reasonable it is to consider applying some kind of control method.

There is energy saving potential in quite a lot of applications, but an energy analysis is always a prerequisite in order to define when overhauling the old systems is purposeful. It is, however, difficult to make such an analysis, because in a system there are always components that don't easily fit in an analysis and at the planning stage of a system it has not been necessarily thought how all the components fit together.

Sometimes energy saving components get stripped from the system already on the drawing board, because they necessarily increase the price of the investment. However, with long-term investments the payback time of this kind of equipment makes the acquisition often worthwhile.

Affinity laws

Affinity laws in Table 1 show the proportion of speed (n), flow (Q), head (H) and power (P). Speed and flow are proportional. The power needed is proportional to the cube of the speed or flow. If the speed is 1/2 of the original, the power needed is only 1/8 compared to original power consumption. Naturally with half speed the flow is only half, so the time needed to pump the same volume is double. The energy needed is still ¼ compared to start.

Table 1: Affinity laws

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

Affinity laws itself do not take static head into consideration. The calculation above is applicable only to systems with zero static head. To adopt system curve to efficiency speed approach, we need to define Specific energy.

Specific energy Es

Specific energy [Wh/V] is calculated below:

$$\text{Specific energy} = \frac{\text{Energy used}}{\text{Pumped volume}} = \frac{\text{Pin}}{\text{Q}}$$

Below in Figure 1 there is a comparison between 3 different system curves and their Specific energy curves. On the graph on left hand side it is clearly stated that with lower speeds the energy consumption is smaller with A and B-type of system curves having low static head.

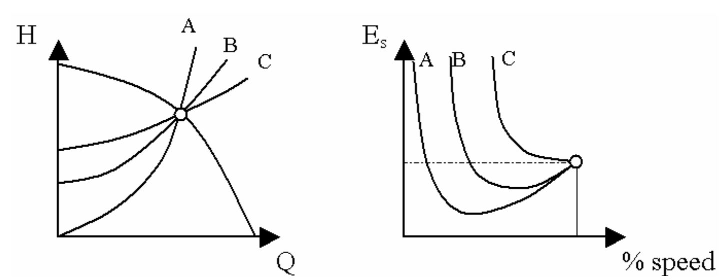

Fig. 1: Specific energy curves with 3 different system curves A, B and C (Europump and Hydraulic Institute: Pump Life Cycle Costs, 2001)

Software solution

We set out to measure the differences in energy consumption in three applications with three flow control methods. The simulations were done with Matlab v 6.1 and Simulink software. Three different control methods were used in the simulations: throttling, standard VSD control and optimized VSD control.

In throttling one pump is controlled by valve and the others with on/off control. In this model all the pumps that are on are driven with the same speed of rotation (max RPM) and the yield of only one pump can be controlled at a time.

In standard VSD control one pump is equipped with a VSD and the other pumps work with on/off control. The yield of the VSD controlled pump can be adjusted by controlling the speed of the pump and this pump is on all the time. The other pumps are either on (operate at nominal speed) or off. The pumps are taken into use when the VSD controlled pump cannot generate the necessary flow anymore.

With optimized VSD control each pump has its own VSD. The required flow is divided evenly on all the pumps and thus the rotational speed of the pumps is the same. This model differs from the standard VSD model so that the pumps are taken on and off in an optimized way. Thus pumps are not added only after the pumps that are on cannot produce the required flow anymore, but this happens already before the maximum rotational speed is reached. The VSDs are preprogrammed to optimize energy consumption of the pump station.
The optimized VSD control technology is based an invention for which ABB has filed a patent application. When several pumps are driven in parallel and the flow fluctuates, all pumps are used at the same speed. The number of required pumps is deduced separately. When pumps are operated at the same speed, they run much closer to their optimal efficiency, especially when another pump is taken into use. This means also that energy consumption stays at an even level and energy will be saved. The rotation speed is used as the basis for switch-over points where new pumps are taken into operation.

Simulations

The first industrial example is quite typical of industrial pumping where new control technology can be applied. The actual measurement results from the pumping facility were used as a basis for the simulations. In simulations it is necessary to simplify some things, but the results are directive in themselves – also in respect to savings in energy.

At the paper mill of UPM-Kymmene Oyj in Jämsänkoski APP22-65 centrifugal pumps made by Ahlstrom are used to pump chemically treated water to desalination.

In the simulations it was found that in this case control by throthling takes considerably more energy than other control methods. Optimized VSD control is by far the most energy efficient method. The difference between optimized and standard VSD control is almost 45 %. The consumption of specific energy is almost threefold with throttling in comparison to optimized control (table 2)

Table 2. Energy consumption at Jämsänkoski, chemically treated water

	Energy consumption		Flow	E_s
	[J / 24 h]	[%]	[m^3]	[J/m^3]
Throttling control	177114.33	0.0	2254	78.58
Standard VSD control	102786.49	- 42	2257	45.54
Optimized VSD control	57050.08	- 68	2256	25.29

The second industrial example corresponds to a real-life situation at the paper mill of UPM-Kymmene Oyj in Jämsänkoski where mechanically treated water is pumped with APP51-300 centrifugal pumps made by Ahlstrom. The water is pumped from the community water works to the paper mill. With this model it was difficult to draw the system graph because of scarce background information.

The duration curve of this model does not spread out so evenly during the day as pictured in the study, but it fluctuates momentarily quite strongly. The duration curve is adjusted to make the simulation easier.

Table 3 presents the energy consumption with different control models. The table also presents the flow pumped within 24 hours and the specific energy (Es) calculated for each control method. The percentage column tells how much less energy is consumed in comparison to throttling control. The mechanical water treatment pumps are controlled by choking, but if standard drive control were applied, over 50 per cent of energy could be saved and with optimized drive control over 60 per cent could be saved.

Table 3. Energy consumption at Jämsänkoski, mechanically treated water

	Energy consumption		Flow	E_s
	[J / 24 h]	[%]	[m^3]	[J/m^3]
Throttling control	7998814.78	0.0	32585	245.48
Standard VSD control	3796801.81	-53	32595	116.48
Optimized VSD control	3107893.77	-61	32594	95.35

Measurements

The third model is based on the test equipment at the Energy and Environmental Technology department at Lappeenranta University of Technology. The duration curve has been chosen so that it is an evenly rising line. Thus special attention could be given to energy consumption in proximity to those points where the next pump becomes operational. The pumps in the laboratory are DC-80/260 centrifugal pump manufactured by GA Serlachius and LP 100-125 centrifugal pump made by Ahlstrom. The controlling of the motors was done by two ABB ACS 800 drives.

With the university's test equipment different amounts of water were pumped while observing how much energy was consumed. With the simulation software such cases could not be simulated where different sized pump were used in parallel. Thus only one of the laboratory's pump models was used in this model.

Also here throttling control takes up the most energy. By using standard VSD control energy consumption could be reduced by appr. 40 % and by using optimized VSD control by over 50 %.

The biggest difference in power consumption is close to the point where new pumps are taken into use. By optimized drive control the power consumption can be reduced remarkably by taking the second pump into use already well before the first pump reaches its maximum yield.

Table 4. Energy consumption, LUT's test equipment

	Energy consumption		Flow	E_s
	[J / 24 h]	[%]	[m^3]	[J/m^3]
Throttling control	150185.94	0.0	1803	83.30
Standard VSD control	90173.67	- 40	1797	50.18
Optimized VSD control	70852.49	- 53	1795	39.47

The share of energy costs related to pumping is very remarkable in the whole life cycle costs. According to the simulations and measurements it is possible to reduce energy costs by over 60 per cent in certain cases. Energy costs represent usually 50 – 85 per cent of life cycle costs. This means that the energy costs of pumps could be reduced at best by over half. However, it has to be taken into consideration that changing the control method also affects many other aspects of life cycle costs.

Optimizând viteza pompei se econonomiseste energia

Rezumat

Exista posibilitatea economisirii energiei în toate aplicaţtiile în care proiectarea, aproximând necesarul de putere, vine cu soluţii supradimensionate. ABB a dezvoltat un pachet inteligent de softuri pentru conducerea centralizată a pompelor la oricare punct de exploatare, fără folosirea unui automat programabil local (PLC). Solutia garantează utilizarea pompelor în exploatare în condiţii de maximă eficienţă