Optimizing pump speed with ABB drives save energy

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Abstract

The objective of this paper is to show how the application of optimized pump control can save energy. This is done by means of computer simulation with four case studies.

Optimized pump control is an innovative control method which reduces energy consumption. It is based on the use of variable speed drives (VSDs) and all the pumps that run in parallel in a system are equipped with a VSD.

The study found that in specific cases the use of optimized pump control can result in energy savings of almost 70%. It must be stressed, however, that the potential for energy savings is highly dependant on case-specific factors such as the static head, pump dimensioning and system and duration curves.

The information presented in this paper is extracted from a M.Sc. thesis [1].

Keywords

Energy saving, Drives, VSD, Optimized pump control

Introduction

Variable speed drives offer the potential for energy savings in many situations where machines are used. This is because machines are generally over-dimensioned at the planning stage in order to ensure that they can accommodate unexpected loads. As a result they cannot be driven at their ideal efficiency level, which means that energy is wasted. VSD control allows even over-dimensioned machines to be driven more efficiently.

Pump stations are usually built to last for 10 – 20 years, and are commonly designed to provide overcapacity. In the public sector the established view is that excess energy consumption is a ‘lesser evil’ than the cost of upgrading old systems. This approach is not necessarily correct, however. If energy savings can be made, then the cumulative savings at a facility whose service life is measured in decades will be considerable. In terms of the entire lifecycle cost, a new investment – whether it is a new pipeline or a new control method - is likely to pay for itself very quickly.

Waterworks are designed for reliable operation and once they are running there is usually no interest in reviewing the design after a number of years to check whether they could be operated more efficiently. In many countries, however, there is currently a trend for public waterworks to be sold into the private sector, and this may lead to increased interest in energy savings.

The variation in flow through the system is a major factor in determining whether or not a more sophisticated control method should be applied: the greater the variation, the more justification there is for upgrading the control system. There is potential for energy savings in many applications, but an energy analysis should always be undertaken to establish whether it would make sense to overhaul existing systems. The task of producing an energy analysis can, however, be a difficult one: there are always components in the system that are not easily accommodated in the analysis, and the system may have been upgraded or otherwise altered since it was originally planned.

In some cases energy saving components are removed from the system at the drawing board stage because they increase the investment cost. With long-term investments, however, the payback from this kind of equipment often makes the initial investment worthwhile.

1 ABB drives

ABB drives brings together a world leading and recognised brand - ABB - the number one supplier for variable speed drives (VSDs) and a product range that is simply the widest available from any manufacturer. ABB drives is a reference for drives users the world over that signifies reliability, simplicity, flexibility and ingenuity, throughout the lifecycle of a drive.
ABB drives are used to control the speed and torque of a standard induction motor, the workhorse of the industry. ABB drives extends the motor speed range from zero to high above the rated speed, increasing the productivity of the driven process. When a low capacity is enough, the drive reduces the machine speed and saves energy.

ABB LV Drives Jüri factory is situated in the greater Tallinn area, about 12 km outside the city of Tallinn. The factory was initially opened in 2005 and with the new expansion the factory space is increased by 30%, from 2000 m² to 3000 m². The Jüri facility currently manufactures all the ACS800-67 windmill cabinets, including the power cabinet for ABB LV Drives. An interesting side note is that 80% of the world’s market share of windmill cabinets is manufactured in the Jüri factory. The testing facility has been in use since May 2007, therefore the Jüri factory has complete quality control of the cabinets. The regenerative drives, the ACS800-11 is also manufactured and tested at Jüri. These drives can be used in a wide range of motor control applications where improved network power quality is essential. They are ideal for controlling pumps, fans, compressors and conveyors in sectors such as water and wastewater, HVAC, building automation, mining, gas, oil and chemicals, and marine.

2 Throttle, standard and optimized pump control

The project was undertaken at the Lappeenranta University of Technology (LUT) Department of Energy and Environmental Technology. It set out to quantify the differences in energy consumption in four specific applications with three different flow control methods. The simulations were done with Matlab v 6.1 and Simulink software, and the results were verified with actual measurements. The three control methods were: throttle control, standard pump control and optimized pump control.

Throttle control: one pump is throttled and the others are on/off controlled. All the pumps that are on are driven at the same speed of rotation (max RPM), and the yield of only one pump can be controlled at a time.

Standard pump control: one pump is controlled by a VSD and the others are on/off controlled. The drive controlled pump is on all the time and its yield can be regulated by adjusting its speed. The other pumps are either on (operate at nominal speed) or off. They are taken into use when the drive controlled pump can no longer generate the necessary flow.

Optimized pump control: each pump has its own VSD, and the required flow is divided evenly between all the pumps. As a result their rotational speed is the same. This case differs from the standard model in that the pumps are switched on and off in an optimized way. Where standard pump control adds extra pumps after those that are already running can no longer produce the required flow, the optimized control model adds extra pumps before the maximum rotational speed is reached. The VSD is parameterized to select the scenario which results in the lowest energy consumption at any given time. Optimized pump control technology subject to a patent application has been patented by ABB.

With optimized pump control, when several pumps are driven in parallel and the flow fluctuates, all the pumps are operated at the same speed. The number of pumps required is calculated separately.

A major drawback of standard pump control is that when pumps are operated in parallel and an extra pump has to be added, this pump has to be started at a relatively high speed in order to generate the required head. Energy is wasted because this “new” pump is only used to increase the flow a little, and yet it runs at quite a high speed. Unless they are optimized to run at the same speed, the pumps are operated at fairly low efficiency. When the pumps are operated at the same speed the system as a whole consumes less energy. The rotation speed is used as the basis for the switch-over points where new pumps are taken into operation.

3 Cases

The applications chosen for the study represent different aspects of pumping, and the results were produced by computer simulations. In the first case study, which is based on laboratory-scale equipment at Lappeenranta University of Technology (LUT), actual measurements were also performed to verify the accuracy of the simulation tool. The second and third cases are based on real-life industrial uses, the fourth on a city waterworks.

3.1 LUT laboratory

The first case is based on test equipment at the LUT’s Department of Energy and Environmental Technology. The chosen duration curve was a steadily rising line, meaning that special attention could be paid to energy consumption around the point where an additional pump is started up. The laboratory equipment comprises two centrifugal pumps with the motors controlled by two ABB industrial drives. In the simulation tool, two identical GA Serlachius DC 80/260 pumps were used.

The LUT laboratory test equipment was used to pump different amounts of water while observing how much energy was consumed. In this way it could be shown that the theoretical assumptions about the advantages of optimized pump control could be reproduced in a test environment. For the laboratory set-up used in this part of the study, the simulation results show that throttling consumes the most energy. Energy consumption could be reduced by approximately 40% by using standard pump control and by over 50% using optimized control in the specific laboratory set-up (Table 1).
Table 1. Energy consumption simulation, LUT test equipment

<table>
<thead>
<tr>
<th>Type of pump control</th>
<th>Energy consumption</th>
<th>Flow</th>
<th>$E_s$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>J/24 h</td>
<td>%</td>
<td>m$^3$</td>
</tr>
<tr>
<td>Throttle</td>
<td>150 185</td>
<td>0.0</td>
<td>1803</td>
</tr>
<tr>
<td>Standard</td>
<td>90 173</td>
<td>-40</td>
<td>1797</td>
</tr>
<tr>
<td>Optimized</td>
<td>70 852</td>
<td>-53</td>
<td>1795</td>
</tr>
</tbody>
</table>

The biggest difference in power consumption is close to the point where the new pump is taken into use. Optimized pump control produced a significant reduction in power consumption by taking the additional pump into use well before the operating pump reached its maximum yield. As mentioned earlier, actual measurements were performed and these support the simulation results.

3.2 Paper mill, chemically treated water

The first simulated industrial example is typical of real-life industrial pumping situations where new control technology can be applied. It is taken from a Finnish paper mill, where Ahlstrom APP22-65 centrifugal pumps are used to pump chemically treated water to a desalination unit. An energy analysis of the pumping facility was used as the basis for the simulations. In both of the industrial cases, a lack of background information made it difficult to draw the system curve.

The simulations, which relied on simplified system and duration curves, showed that in this case throttle control uses considerably more energy than the other control methods. Optimized pump control is by far the most energy efficient method. The difference between standard and optimized pump control is over 45%. The consumption of specific energy with throttling is almost threefold that used with optimized pump control (Table 2).

Table 2. Energy consumption at a Finnish paper mill, chemically treated water

<table>
<thead>
<tr>
<th>Type of pump control</th>
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<th>Flow</th>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>J/24 h</td>
<td>%</td>
<td>m$^3$</td>
</tr>
<tr>
<td>Throttle</td>
<td>177 114</td>
<td>0.0</td>
<td>2254</td>
</tr>
<tr>
<td>Standard</td>
<td>102 786</td>
<td>-42</td>
<td>2257</td>
</tr>
<tr>
<td>Optimized</td>
<td>57 050</td>
<td>-68</td>
<td>2256</td>
</tr>
</tbody>
</table>

3.3 Paper mill, mechanically treated water

The second simulated industrial case corresponds to a real-life situation at a Finnish paper mill, where Ahlstrom APP51-300 centrifugal pumps are used to pump mechanically treated water.

In this case the mechanical water treatment pumps are controlled by throttling. Standard pump control would cut energy consumption by over 50%, and the reduction would be over 60% with optimized pump control (Table 3).

Table 3. Energy consumption at a Finnish paper mill, mechanically treated water

<table>
<thead>
<tr>
<th>Type of pump control</th>
<th>Energy consumption</th>
<th>Flow</th>
<th>$E_s$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>J/24 h</td>
<td>%</td>
<td>m$^3$</td>
</tr>
<tr>
<td>Throttle</td>
<td>7 998 814</td>
<td>0.0</td>
<td>32585</td>
</tr>
<tr>
<td>Standard</td>
<td>3 796 801</td>
<td>-53</td>
<td>32595</td>
</tr>
<tr>
<td>Optimized</td>
<td>3 107 893</td>
<td>-61</td>
<td>32594</td>
</tr>
</tbody>
</table>

3.4 Energy-efficient pumping at waterworks

This case study is based on the waterworks serving a Finnish city. This facility naturally forms part of the city’s infrastructure and the pumping needs are different from the two industrial examples.

The simulated pumping system is based on Ahlstrom PPN-2 centrifugal pumps, which can be considered typical for a public waterworks. Water for the city is supplied from a water tower, and so there are big differences in elevation within the system. The water has to be pumped up to the water tower, an operation which consumes a lot of energy. The tower is therefore filled at night in order to take advantage of lower electricity tariffs.

The addition of VSDs to control the pumps at the waterworks would not provide any significant savings, as the pumps are already operating efficiently (Table 4). In this case the simulations used a system curve different from the type of curve normally found in a system with a water tower. The duration curve, however, is based on actual information from the waterworks.

The pumps at the waterworks in question are on/off controlled, and no speed control is used. This is possible because variations in water consumption rates are balanced out by the water tower. In general, water towers are now no longer built because modern pressurizing stations can maintain the system pressure at a steady level.

Table 4. Energy consumption at a Finnish waterworks

<table>
<thead>
<tr>
<th>Type of pump control</th>
<th>Energy consumption</th>
<th>Flow</th>
<th>$E_s$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>J/24 h</td>
<td>%</td>
<td>m$^3$</td>
</tr>
<tr>
<td>Throttle</td>
<td>3 805 198</td>
<td>0.0</td>
<td>13163</td>
</tr>
<tr>
<td>Standard</td>
<td>3 460 264</td>
<td>-9.1</td>
<td>13161</td>
</tr>
<tr>
<td>Optimized</td>
<td>3 475 395</td>
<td>-8.7</td>
<td>13163</td>
</tr>
</tbody>
</table>
4 Lifecycle costs in focus

Even though the simulations were partly based on modified duration and system curves, this is not thought to have affected the results to any significant extent. The simulations clearly show that for the specific cases studied, major energy savings are possible. This potential was verified in the tests performed in the LUT laboratory. Throttle control is the least energy efficient method of pump control, and the addition of VSDs can increase system efficiency. In some cases, however - especially when the pumps are regularly run at nominal speeds and the flow does not fluctuate - the addition of VSDs will not produce significant savings. For each case the energy savings that can be achieved depend on variables such as the static head of the system, pump dimensions, and system and duration curves. Case-specific analysis should always be performed to evaluate how much energy can be saved.

Energy costs usually represent 50 – 85% of lifecycle costs in pumping installations. The study indicates that energy costs can be reduced by over 60% in certain specific cases, which results in a considerable reduction in overall lifecycle costs. It must be kept in mind, however, that changing the control method also affects many other aspects of lifecycle costs.

References