A New Generation of Intelligent Electronically Controlled Circulator Pumps

Niels Bidstrup  
GRUNDFOS Management A/S  
Poul Due Jensens Vej 7  
DK-8850 Bjerringbro  
Email: nbidstrup@grundfos.com

Abstract:  
The energy saving potential by using electronically controlled circulator pumps is huge. New investigations have showed that the energy consumption of small circulator pumps in household central heating systems in EU is approximately 40 TWh/year. A new generation of intelligent electronically controlled circulator pumps are now entering the market.

This new generation can save up to 55% energy compared to non-controlled circulator pumps and save up to 35% energy compared to existing electronically controlled circulator pumps on the market. The energy savings are achieved by using new motor technologies and built in intelligent functions, which continuously adjusts the pump pressure to the demands from the heating system. New built in adaptive functions may result in even further energy savings.

Background  
The use of electronically controlled circulator pumps for water based heating systems is increasing. Substantial electrical energy savings are made possible by using electronically controlled circulator pumps instead of standard non-controlled circulators. A study under the SAVE II programme have showed that small circulator pumps (P1<250 W) in household central heating systems in EU consumes approximately 40 TWh/year, comparable to all washing maschines in EU [Bidstrup et al, 2001].

Apart from the fact that electronically controlled circulator pumps saves energy it can also improved the control performance of the heating systems because it delivers a suitable differential pressure both at full load as well as at partial load operation [Bidstrup, 1999].

This paper describes functionalities and energy savings by using the new generation of circulator pumps, which are entering the market now.

Electronically controlled circulator pumps  
Figure 1 shows the trend in the development of electronically controlled circulator pumps starting from the first wet-runner with integrated frequency converter, denoted 1st generation, on to the 3rd generation.

With the introduction of pumps with integrated frequency converter, it became possible to operate the pump at different impeller speeds, which made it possible to realize other relations between flow and differential pressure than those given by a fixed speed pump. This offers the possibility of choosing relations between flow and differential pressure, which improves the conditions for the control valves, thus minimizing hydraulic loses and saving electrical energy. These relations are realized by preprogrammed control curves in the electronically controlled circulator pump.
Fig 1. Trend in the development of electronically controlled circulator pumps

Constant pressure control

Constant pressure control is recommended if flow resistance in the distribution and supply system (pipe, boiler, heat exchanger etc.) is low. Figure 2 shows the differential pressure across the circulator when constant pressure control is selected. A1-A3 are different operating points.

The differential pressure across the circulator is constant and independent of the flow. Due to the low flow resistance in the distribution system the differential pressure across the control valves is nearly constant and optimal control performance is obtained both at full load as well as at partial load operation.

Different setting of constant pressure is possible and selected manually or by an external signal (e.g., bus or infrared communication).

Proportional pressure control

If flow resistance in the distribution system is not negligible Proportional pressure control is recommended. Figure 3 shows the differential pressure across the circulator when Proportional pressure control is selected. Again A1-A3 are different operating points. The differential pressure across the circulator increases when flow increases.

The proportional pressure control compensates for the flow resistance in the distribution and supply system with the result that the differential pressure across the control valves is nearly constant and a good control performance is obtained both at full load as well as at partial load operation.

Different slopes of the proportional control curves can be selected to fit the pump to the resistance in the actual heating system, in which it is installed.

Since the introduction of proportional pressure control it has proven its efficiency and has become an accepted control method in industry.

Fig. 2. Constant pressure control

Fig. 3. Proportional pressure control
Permanent magnet motors
The new generation (3rd generation) of electronically controlled circulator pumps is based on a permanent magnet motor. This reduces losses in the motor and thereby results in a significant increase in efficiency.

Figure 4 shows a rotor with permanent magnets. These types of circulator pumps are wet runners, which means that the rotor is running in the circulated fluid. The permanent magnets are encapsulated to protect them against the fluid.

For more information on circulators with permanent magnet motors and how they are controlled see (Rasmussen et al, 2002).

System Adaptation
To obtain further energy saving the new generation circulator pumps have built in adaptive functions. These adaptive functions select control curve settings depending on the system and the operating conditions. Two examples of adaptive functions are automatic set point control and automatic night setback.

Automatic set point control
The proportional pressure control methods introduced in 2nd generation electronically controlled pumps can be improved with respect to energy savings if the pump selects the setting of the control curve after installation and thereby adapts to the system where it is installed. This functionality is denoted automatic set point control. The method is showed in figure 5.

The automatic set point control automatically adjusts the setting of the proportional control curve. The method is based on an observation of maximum flow. The pump operates on control curve A (A1-A3). If more flow is required than at point A3 the pump will follow the maximum curve to operating point B3.

From now on the pump will operate on the proportional control curve B (B1-B3) until a new maximum flow is observed and an even lower proportional control curve is selected. Finally the pump has found the lowest possible control curve for the system, where it is installed, and extra energy savings are achieved.

Automatic night setback
In heating systems with night setback the thermostatic valves will open due to the reduced room temperatures. A 2nd generation electronically controlled pump will misinterpret this as an increased heat demand and it will speed up to compensate for that. This will result in an unnecessary increase in power consumption and can also result in flow noise. The new generation circulator pumps have a built in adaptive function, which reduce the speed when the heating system is at night set back. This functionality is called automatic night setback and is shown in figure 6.

Based on measurements of the flow temperature the circulator pump detects the night set back from the heating controller and changes the setting to a fixed minimum speed. In figure 6 this implies that the pump will operate in the operating point B1 instead of A3. When the heating system returns to day operation the pump returns to control curve A (A1- A3)

If the pump is connected to a building management system it is also possible to force the pumps in minimum speed via an external control signal.
Comparison of annual energy consumption
To compare the annual energy consumption of non-controlled, 2nd and 3rd generation electronically controlled circulator pumps, measurements have been performed by three independent test centres.

The calculation of the annual energy consumption in the test was based on the following load file, which is an accepted load profile in industry and is used to label the pumps according to the German Blue Angel labelling scheme [Blauer Engel], which came into force primo 2002. The load profile is displayed in Table 1.

The load profile shows that the pump only runs at full speed for a short percentage of the time during a year and runs below 50% flow most of the time. With such a load profile it is evident that the pump operation should be optimized at partial load.

The results from the comparative tests are shown in Figure 7.

<table>
<thead>
<tr>
<th>FLOW [%]</th>
<th>TIME [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>6</td>
</tr>
<tr>
<td>75</td>
<td>15</td>
</tr>
<tr>
<td>50</td>
<td>35</td>
</tr>
<tr>
<td>25</td>
<td>44</td>
</tr>
</tbody>
</table>

Table 1. Load Profile

The energy savings by changing from a non-controlled pump to a 3rd generation pump is 2569-1148 = 1421 kWh/year or 55%. This is a substantial saving and the pay back time for this change is also low. The energy savings by changing from a 2nd generation pump to a 3rd generation pump is 1783-1148 = 635 kWh/year or 35%.

It is estimated that the energy saving potential in EU by changing pumps in this size alone from non-controlled pumps to 3rd generation pumps is 3.3 TWh/year comparable to the electricity consumption of 700,000 single family houses.

Conclusions
The energy saving potential by using electronically controlled circulator pumps is huge. Small circulator pumps in household central heating systems in EU consume approximately 40 TWh/year. Energy savings of 10 TWh/year is possible with these small pumps. For the new generation of electronically controlled circulator pumps the energy saving potential is even larger. Comparative tests at three independent test centres have shown energy savings of 55%, with the new generation of electronically controlled pumps, when compared to non-controlled circulator pumps.
The energy savings in the tests are mainly due to the high efficiency motors with permanent magnets and built in intelligent functions. The effect of the new adaptive functions is not incorporated in these comparative tests, which means that the saving in a specific system may be larger.

References

Bidstrup, N., Energy savings by using electronically controlled circulator pumps, in proceedings from District Heating Control, Zlin, Czech Republic, October 1999.

Rasmussen, K. F., Thorup, N., Permanent Magnet Motors find its way to circulator pumps, submitted to EEMODS, Treviso, Italy, September 2002

Blauer Engel

BE THINK INNOVATE