

Soft Starters vs. Variable Speed— or Both?

Juan Sagarduy, Jesper Kristensson, Sören Kling and Johan Rees

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Management Summary

In water applications, centrifugal pumps are driven by an induction motor directly fed from the network. Flow regulation is accomplished by a few different means, namely:

- **Throttling**—A highly inefficient method, as hydraulic losses increase dramatically when the flow is strangled by a valve.
- **Variable-frequency drives (VFDs)**—Recommended as an effective means of saving energy—that ensure flow regulation by controlling the rotational speed of the motor shaft.
- **Alternatively, on-and-off pump operation following a precise duty cycle**—The pump is not operated continuously; rather, it is activated when needed for pumping the target water volume and is disconnected for the rest of the time.

Given that many different hydraulic systems recommend the use of either frequency converters or cyclic control (soft starter technologies), the question must be asked—Which one of these solutions is the most cost-effective in reducing energy consumption and providing the most satisfactory payback time?

Introduction

Energy efficiency is key for customers seeking products and systems, and something that suppliers work hard at in improving their product offerings. In fact, the general view held is that the investment linked to the purchase of electrical equipment—as well as the downtime cost incurred from installation and commissioning—is offset by a decrease in electricity consumption due to energy-efficient operation.

Low-voltage solutions in the form of frequency converters and soft starters are especially suitable for maximizing energy savings in water pump and waste applications.

By reducing the applied voltage, a soft starter allows smooth starting of AC motors. During pump stop, water hammer—i.e., a pressure surge or wave resulting when a fluid in motion is forced to stop or change direction suddenly—in the hydraulic system is avoided by a controlled decrease in torque enabled by a dedicated algorithm in the soft starter. Water hammer commonly occurs when a valve is closed suddenly at an end of a pipeline system and a pressure wave propagates in the pipe.

As throttling is highly inefficient, which one of the two technical solutions—variable-speed or cyclic control—is the most cost-effective in reducing energy consumption (Fig. 1). In fact, the nature of the hydraulic system in which the centrifugal pump is to operate is the determining factor in

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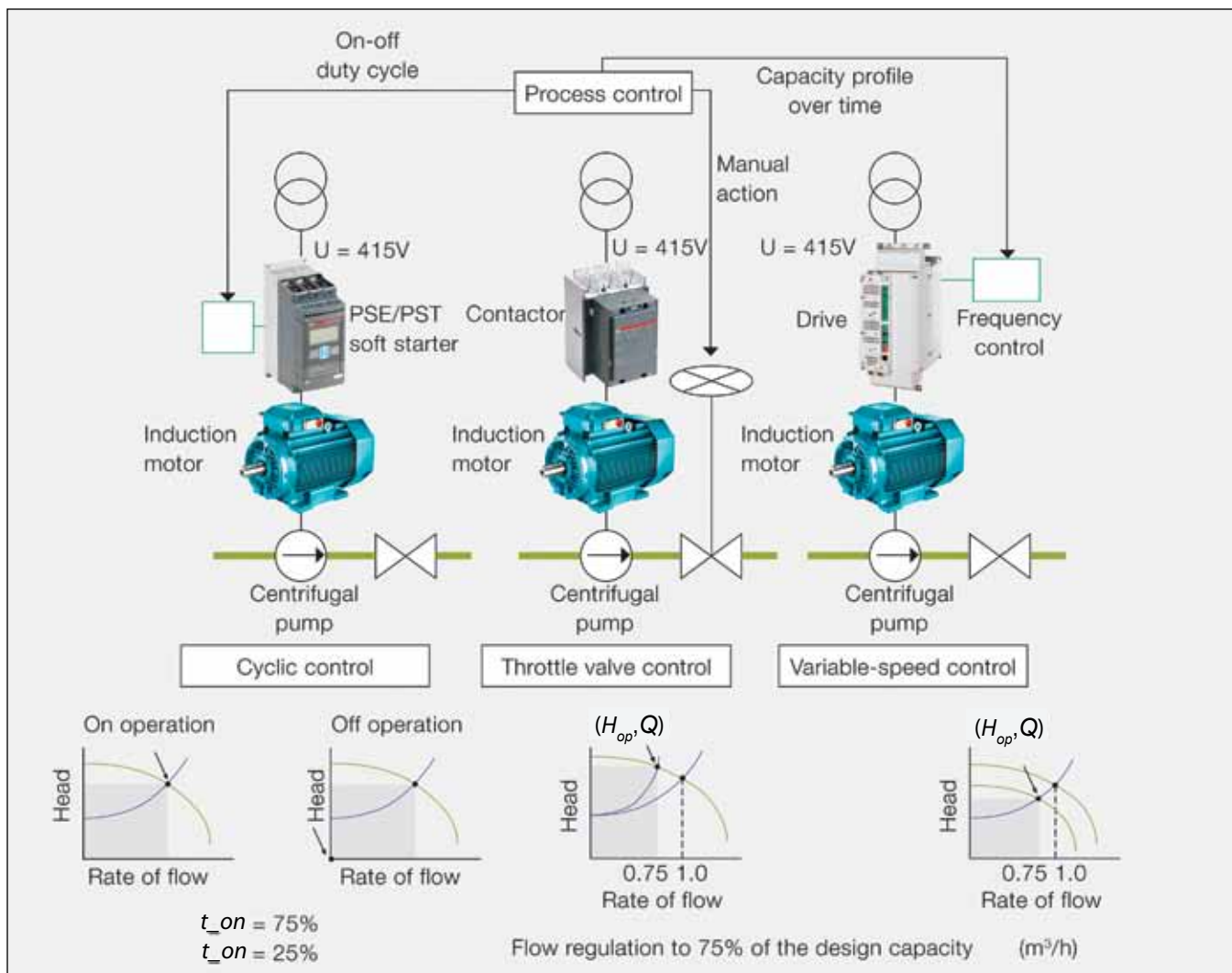


Figure 1—System illustration for cyclic, throttled and VFD (variable frequency drive) flow control methods.

Nomenclature

H_{bep} (m)	Hydraulic head at the best-efficiency point of the centrifugal pump.
Q_{bep} (m³/s)	Capacity at the best-efficiency point of the pump.
H_{st} (m)	Total static head—i.e., the vertical distance the pump must lift the water. If pumping from a well, for example, it is the distance from the pumping water level in the well to the ground surface—plus the vertical distance the water is to be lifted from the ground surface to the discharge point. If pumping from an open water surface, it would be the total vertical distance from the water surface to the discharge point.
Q_{op} (m³/s)	Capacity at the system design point. In practice, this is determined for the occasional peak flows arising—about 5% of the time—in water treatment plants.
H_{op} (m)	Hydraulic head at system design point.
H_{opid} (m)	Hydraulic head at the design point in an ideal system.
H_t (m)	Hydraulic head associated with a generic capacity Q (m³/s) in fixed speed and throttled flow regulation.
H_d (m)	Hydraulic head associated with a generic capacity Q (m³/s) in variable frequency flow regulation.
H_{max} (m)	Maximum height at which liquid can be lifted by a given pump.
Q_{max} (m³/s)	Maximum capacity for a given pump.



Figure 2—ABB's PSE compact soft starter range, used primarily for pumping applications.

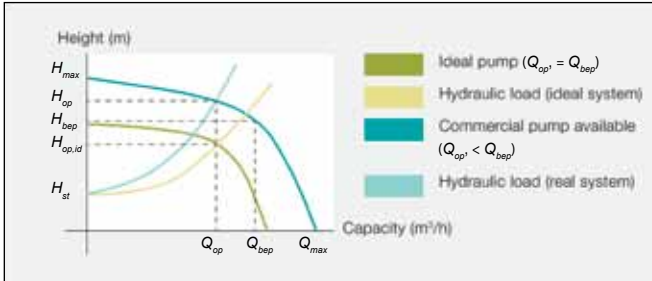


Figure 3a—Pump selection for an industrial installation.

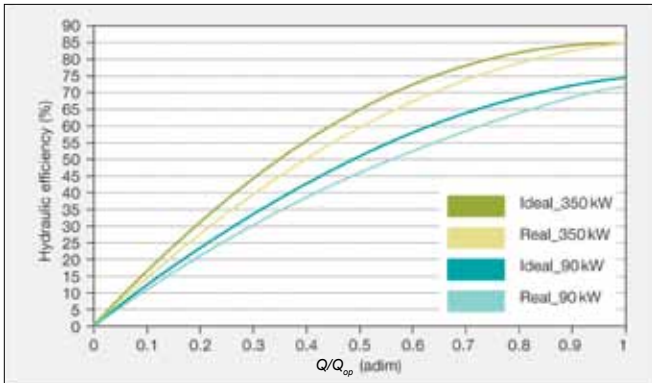


Figure 3b—Hydraulic efficiency loss in 90 kW and 350 kW pumps due to 15% over-sizing.

Manufacturer	Power (kW)	H_{max} (m)	H_{dep} (m)	Q_{dep} (m³/h)	η_{max} (%)
Aurora	90	13.0	57.0	575	74.9
Aurora	350	52.7	83.8	2500	84.5

Figure 4—Characteristic data of the two pumps studied.

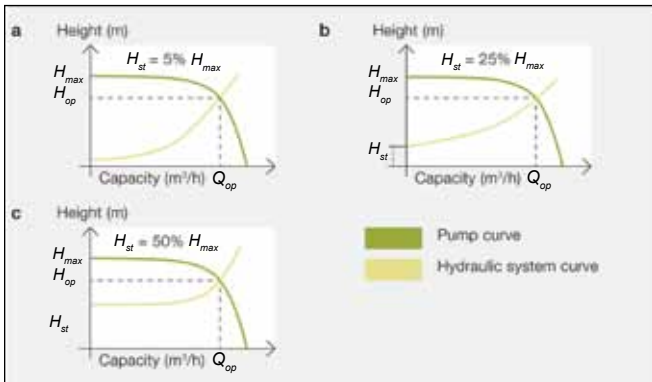


Figure 5—Hydraulic systems selected for energy-saving potential analysis. a: Friction head dominated, b: Mixed head dominated, c: Static head dominated.

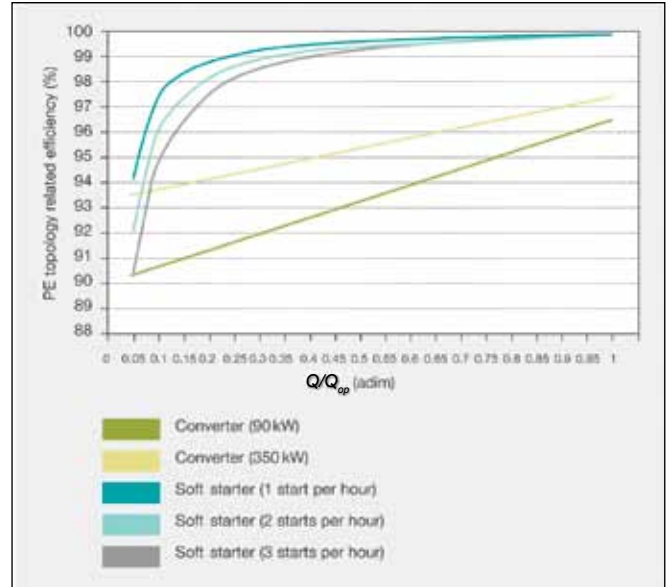


Figure 6—Variation of electrical efficiency (%) in the power electronics circuit (soft starter and converter) with hydraulic load.

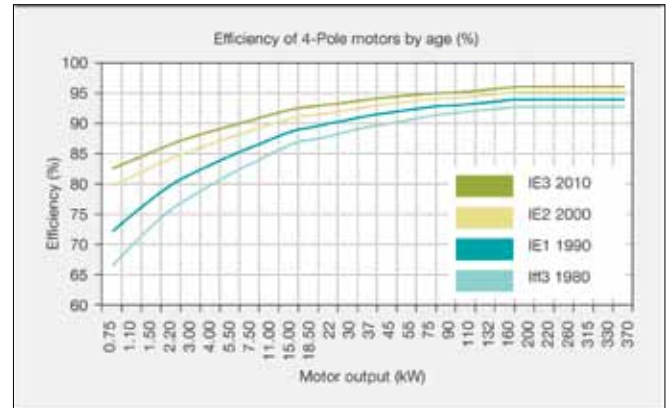


Figure 7a—Impact of class type on motor efficiency.

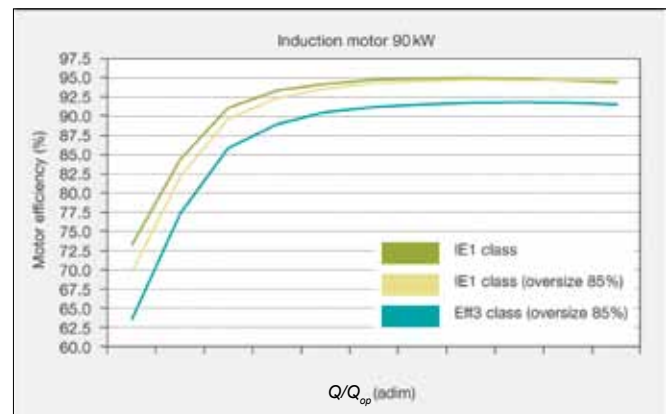


Figure 7b—Variation of motor efficiency with hydraulic load.

selecting one or the other control method.

In wastewater processing, for example, the on/off operation of the centrifugal pumps is, in general, process-control based. Residual water (effluent from residential or commercial buildings) is commonly collected in septic tanks or sewage basins until it is pumped to municipal treatment plants (Ref. 1). Owing to several start events, the use of soft starters significantly reduces the risk of pump clogging due to sludge in the water (Fig. 2). In general, cyclic control is an attractive alternative to the variable-frequency drive (VFD) strategy, despite losing flexibility in flow regulation. In other words, a soft starter is seen as a suitable and competitive technology that preserves the induction motor from electrical strain, mechanical shock and vibration during start-up, and prevents water hammering as the pump stops. Additionally, the motor is used at its best efficiency point and switched off when not needed.

In the following sections, energy savings and payback of variable-speed and cyclic-control solutions are analyzed for two centrifugal pump systems: 90 kW and 350 kW.

A Typical Pump System

When a pump system is assembled, a target flow Q_{op} (m^3/h) must be guaranteed. In an ideal system, the selected pump has a coincident Q_{bep} (m^3/h) with Q_{op} (m^3/h). In reality, however, a larger pump is chosen (Fig. 3). As a result, the pump works under reduced hydraulic efficiency for most of the capacity range. This point is illustrated in Figure 3b for two Aurora centrifugal pumps with power ratings of 90 kW and 350 kW, respectively (Fig. 4; Ref. 2).

To analyze the potential for energy savings in these pumps, three different hydraulic systems were taken into account (Fig. 5):

1. **Friction head-dominated**—the ratio (ν) of static head H_{st} (m) to maximum hydraulic height H_{max} (m): 5%
2. **Static head-dominated**: ν is 50%
3. **Mixed**: ν is 25 %

Converter, Soft Starter and Motor Performance

Frequency converters have a high efficiency (η_{conv}) that drops naturally when the output power decreases with respect to the rated value. The efficiency of soft starters is practically 100% when the motor bypass is activated. Their efficiency decreases noticeably with the number of starts-per-hour and shorter operating time intervals owing to additional joule losses during motor start-and-stop (Fig. 6).

Today's tighter IEC standards guarantee high motor efficiency—in general, greater than 90%—for loads (Refs.3–4; Figs. 7a–7b). This efficiency, which is strongly dependent on its graded class, is affected by the use of either a frequency converter or soft starter. It decreases when supplied by a fast-switching converter due to harmonic current and voltage distortion, but is not altered when the motor is bypassed after soft starting, due to a purely sinusoidal supply.

The impact of system-oversizing, motor class and harmonic losses (drive control) in a real system is shown in Figure 8.

Energy Savings

Energy savings made using VFD and cyclic control in a 90 kW and 350 kW pump system are illustrated in Figures 9a and 9b, respectively. In friction-head-dominated systems ($\nu = 5\%$), VFD control ensures higher energy savings across almost the entire operating range, or 7 to 98% in both pump systems. In a 90 kW pump and static-head-dominated system ($\nu = 50\%$), cyclic control is a better technical solution than VFD control for all working points, while for the 350 kW system, VFD control guarantees slightly higher energy savings but only between 75 and 92% pump capacity. When a combined hydraulic system ($\nu = 25\%$) is considered, VFD control only ensures a larger economic benefit for pump

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	Load (%)				
Efficiency drop (%) caused by	5%	25%	50%	75%	100%
1 – Oversized pump (by 15%)	-1.3	-3.8	-6.0	-4.5	-2.1
2 – Oversized motor (by 15%)	-3.2	-1.2	-0.4	-3.0	0.2
3 – Motor class (Eff 3)	-9.5	-3.4	-3.0	-3.0	-3.0
4 – Harmonic loss	-7.0	-2.1	-2.4	-1.9	-1.3
Increase in power consumption (%)	26.5	11.7	13.3	10.3	6.6

Figure 8—Effect of system over-sizing, motor class and harmonic losses on electric power consumption ($P_n = 90$ kW; switching frequency 4 kHz).

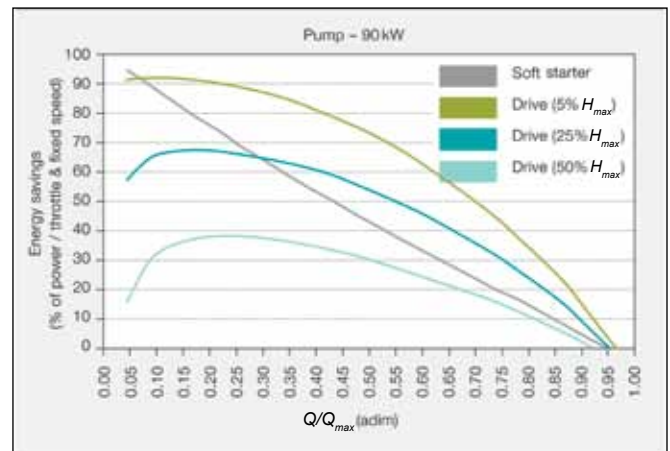


Figure 9a—Energy savings (%) of VFD and cyclic control in the 90 kW pump system.

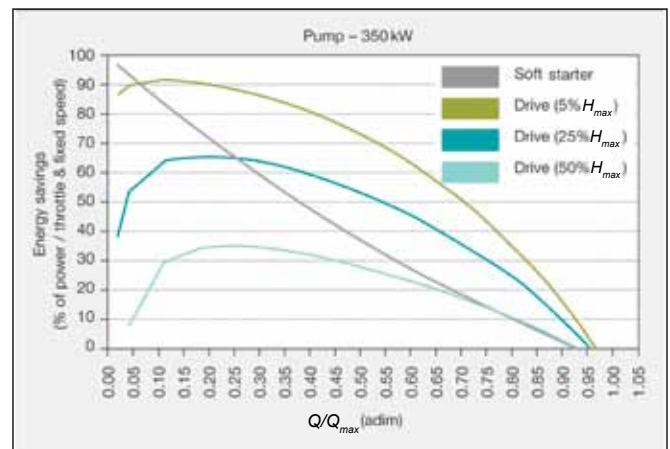


Figure 9b—Energy savings (%) of VFD and cyclic control in the 350 kW pump system.

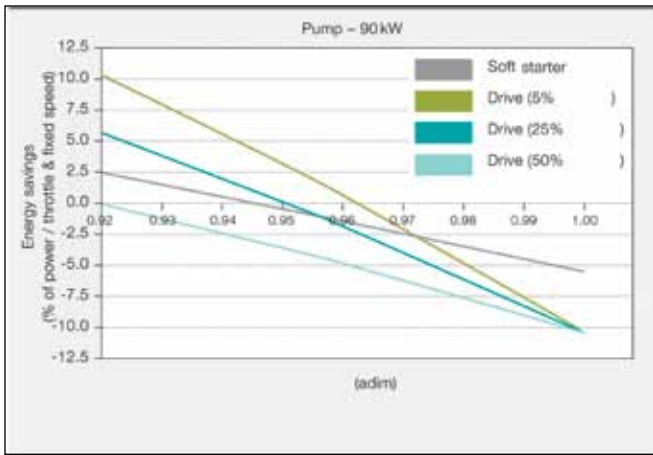


Figure 9c—Optimum efficiency in the 90 kW pump due to soft starter bypass capability at high loads—90–100% of design capacity.

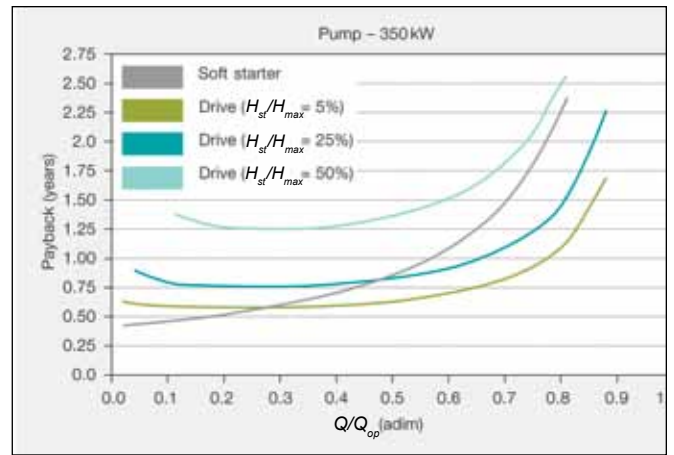


Figure 11b—Payback time of VFD and cyclic (soft starter) solutions for the 350 kW pump.

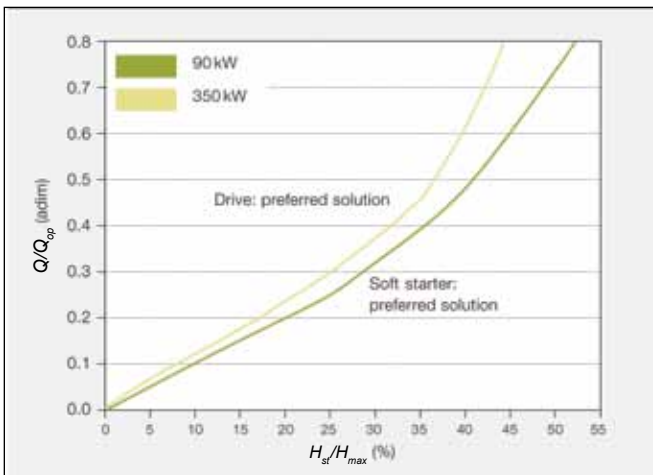


Figure 10—Breakpoint where economic savings with cyclic control (soft starter) exceed a VFD solution.

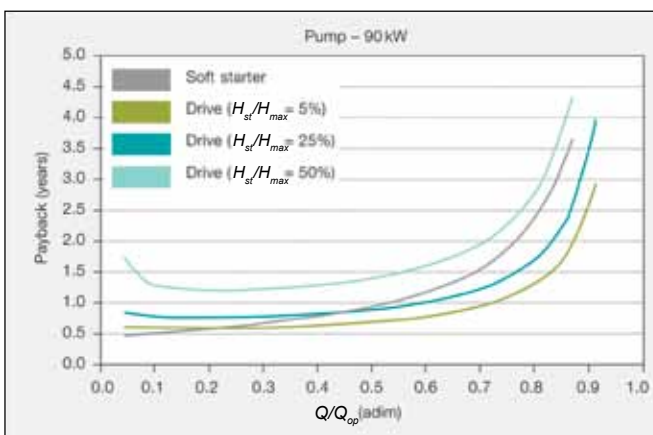


Figure 11a—Payback time of VFD and cyclic (soft starter) solutions for the 90 kW pump.

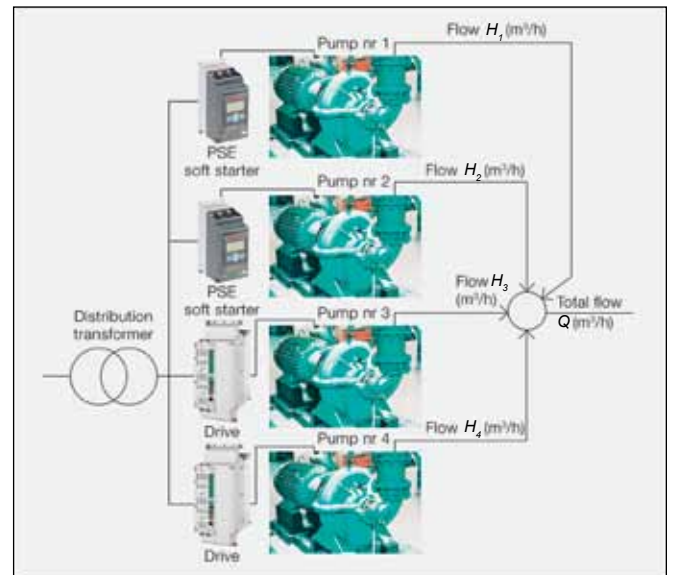


Figure 12—Recommended power electronics solution for a four-parallel pump system (friction-dominated hydraulic system).

	Pump 1	Pump 2	Pump 3	Pump 4
PE	Soft starter	Soft starter	Drive	Drive
Flow control	Cyclic	Cyclic	VFD	VFD
Flow Q ₀ (M³/h)	1–1,110	0–1,110 (0–22,220)	0–1,110 (0–22,220)	0–1,110 (0–22,220)
1,110–2,220	Oil	Oil	Oil	Oil
2,220–4,440	Oil (1,110–2,220)	Oil (2,220–4,440)	Oil (2,220–4,440)	Oil (2,220–4,440)
4,440–6,660	Oil (1,110–2,220)	Oil (2,220–4,440)	Oil (2,220–4,440)	Oil (2,220–4,440)
6,660–8,880	Oil (1,110–2,220)	Oil (2,220–4,440)	Oil (2,220–4,440)	Oil (2,220–4,440)
8,880–10,000	By pass	By pass	By pass	By pass
10,000	By pass	By pass	By pass	By pass

Figure 13—Flow control scheme in a four-parallel pump system (friction-loss-dominated).

capacities above 28% (for the 90 kW system) and 24% (for the 350 kW system). In fact, the highest gain with VFD control is found at between 15 and 20% capacity.

Unlike frequency converters (characterized by semiconductor losses at nominal load), soft starters operate in bypass state at nominal load (Fig. 9c). No additional losses in the thyristors are thus accounted for. The operating and system conditions—when either cyclic control or VFD is the preferred solution for pump flow regulation—are illustrated in Figure 10. (Authors' note: Converting percentage energy savings—with respect to fixed speed and throttle—into economic benefits assumes that the pump works for 8,760 hours per year (330 x 24) at a price of \$0.065 for 1 kWh of electricity; see also Ref. 5).

Return on Investment

Customers will inevitably want to know when they can reasonably expect a return on their investment—which, keep in mind, includes the additional costs incurred by production downtime while the drive or soft starter is being installed and commissioned.

For pumps with a power rating of around 25 kW, the price ratio of converter to soft starter is around three, and reaches an approximate value of five for 350 kW pumps (Ref. 6). The total initial investment associated with VFD and cyclic solutions is calculated as the sum of the cost of the drive or soft starter plus a percentage of the lifecycle costs to cover production downtime (Ref. 7). For both power electronic topologies, a value of 7.5% is used.

Too, cost of individual components may vary for a number of reasons. Primarily, low-voltage VFDs operate on a continuous—rather than stop-start basis—and enable more sophisticated control. However, they use insulated gate bipolar transistors (IGBTs) and so must be designed with sufficient cooling capability, making them more expensive when compared to soft starters with the same power rating. Soft starters, on the other hand, which operate during reduced time intervals of up to 15 seconds, incorporate robust and cost-competitive thyristors and benefit from natural cooling.

The payback times for VFD and cyclic flow control are shown in Figures 11a and 11b—for the 90 kW and 350 kW pumps, respectively—for the three hydraulic systems: $\nu = 5\%$, 25% and 50%.

Parallel Pump System Solutions

In many hydraulic systems, optimum energy savings and a good return on investment can be achieved using parallel pump solutions (Authors' note: For optimal flow regulation in parallel systems, one individual pump is operated until a breakpoint in the target flow is reached, at which time two pumps simultaneously share the hydraulic load—see Ref. 8. When a second breakpoint is attained, three pumps become active, and so on.) that combine both drives and soft starters.

For example, in a friction-dominated hydraulic system ($\nu = 5\%$), a recommended power electronics solution for a four-parallel pump system—each pump with a power rating of 350 kW (2,500 m³/h)—consists of two converters and two soft starters (Fig. 12). The scheme providing the optimum solution in terms of payback time and control functionality equips Pump 1 and Pump 2 with a soft starter, and Pump 3 and Pump 4 with a frequency converter (Fig. 13). Pumps equipped with a soft starter are directly connected to the net-

work at high capacity; by increasing the rotational speed in a pre-defined range—over 50 Hz—pumps driven by converters can deliver a peak flow if occasionally required.

In a mixed hydraulic system ($\nu = 5\%$), the scheme providing an optimum solution in terms of payback time and control functionality uses three pumps—the first two of which are equipped with soft starters, the third with a drive (Figs. 14–15).

For both systems the initial investment in power electronics solutions is translated into economic profit in less than 1.5 years, provided the regulated flow is below 80% of the total capacity (Fig. 16).

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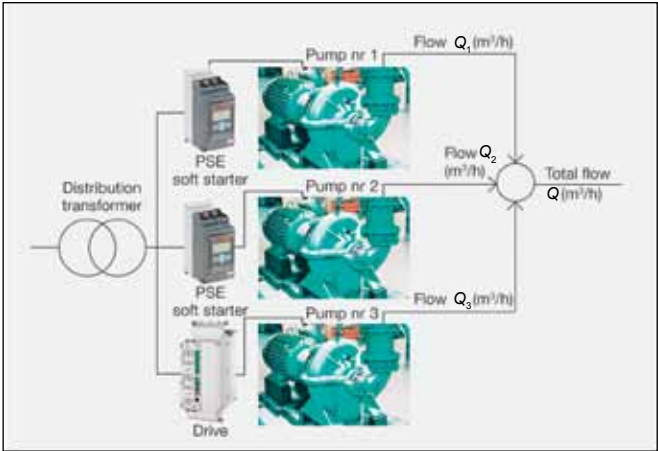


Figure 14—Recommended power electronics solution for a three-parallel pump system (static head-, friction-dominated hydraulic system).

	Pump 1	Pump 2	Pump 3
PF	Soft starter	Soft starter	Drive
Flow control	On/Off	On/Off	Variable frequency
Flow Q(m³/h)			
0 - 2 000	On/Off 50%	On/Off 50%	on
2 000 - 4 500	On/Off 50%	On/Off 50%	On/Off 50% - 4m
4 500 - 7 500	On/Off 50%	On/Off 50%	On/Off 50% - 5m
7 500 - 9 500	On/Off 50%	On/Off 50%	On/Off 50% - 6m
9 500 - 12 500	On/Off 50%	On/Off 50%	On/Off 50% - 7m
12 500 - 15 500	On/Off 50%	On/Off 50%	On/Off 50% - 8m
15 500 - 18 500	On/Off 50%	On/Off 50%	On/Off 50% - 9m
18 500 - 21 500	On/Off 50%	On/Off 50%	On/Off 50% - 10m
21 500 - 24 500	On/Off 50%	On/Off 50%	On/Off 50% - 11m
24 500 - 27 500	On/Off 50%	On/Off 50%	On/Off 50% - 12m
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30 500 - 33 500	On/Off 50%	On/Off 50%	On/Off 50% - 14m
33 500 - 36 500	On/Off 50%	On/Off 50%	On/Off 50% - 15m
36 500 - 39 500	On/Off 50%	On/Off 50%	On/Off 50% - 16m
39 500 - 42 500	On/Off 50%	On/Off 50%	On/Off 50% - 17m
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174 500 - 177 500	On/Off 50%	On/Off 50%	On/Off 50% - 62m
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195 500 - 198 500	On/Off 50%	On/Off 50%	On/Off 50% - 69m
198 500 - 201 500	On/Off 50%	On/Off 50%	On/Off 50% - 70m
201 500 - 204 500	On/Off 50%	On/Off 50%	On/Off 50% - 71m
204 500 - 207 500	On/Off 50%	On/Off 50%	On/Off 50% - 72m
207 500 - 210 500	On/Off 50%	On/Off 50%	On/Off 50% - 73m
210 500 - 213 500	On/Off 50%	On/Off 50%	On/Off 50% - 74m
213 500 - 216 500	On/Off 50%	On/Off 50%	On/Off 50% - 75m
216 500 - 219 500	On/Off 50%	On/Off 50%	On/Off 50% - 76m
219 500 - 222 500	On/Off 50%	On/Off 50%	On/Off 50% - 77m
222 500 - 225 500	On/Off 50%	On/Off 50%	On/Off 50% - 78m
225 500 - 228 500	On/Off 50%	On/Off 50%	On/Off 50% - 79m
228 500 - 231 500	On/Off 50%	On/Off 50%	On/Off 50% - 80m
231 500 - 234 500	On/Off 50%	On/Off 50%	On/Off 50% - 81m
234 500 - 237 500	On/Off 50%	On/Off 50%	On/Off 50% - 82m
237 500 - 240 500	On/Off 50%	On/Off 50%	On/Off 50% - 83m
240 500 - 243 500	On/Off 50%	On/Off 50%	On/Off 50% - 84m
243 500 - 246 500	On/Off 50%	On/Off 50%	On/Off 50% - 85m
246 500 - 249 500	On/Off 50%	On/Off 50%	On/Off 50% - 86m
249 500 - 252 500	On/Off 50%	On/Off 50%	On/Off 50% - 87m
252 500 - 255 500	On/Off 50%	On/Off 50%	On/Off 50% - 88m
255 500 - 258 500	On/Off 50%	On/Off 50%	On/Off 50% - 89m
258 500 - 261 500	On/Off 50%	On/Off 50%	On/Off 50% - 90m
261 500 - 264 500	On/Off 50%	On/Off 50%	On/Off 50% - 91m
264 500 - 267 500	On/Off 50%	On/Off 50%	On/Off 50% - 92m
267 500 - 270 500	On/Off 50%	On/Off 50%	On/Off 50% - 93m
270 500 - 273 500	On/Off 50%	On/Off 50%	On/Off 50% - 94m
273 500 - 276 500	On/Off 50%	On/Off 50%	On/Off 50% - 95m
276 500 - 279 500	On/Off 50%	On/Off 50%	On/Off 50% - 96m
279 500 - 282 500	On/Off 50%	On/Off 50%	On/Off 50% - 97m
282 500 - 285 500	On/Off 50%	On/Off 50%	On/Off 50% - 98m
285 500 - 288 500	On/Off 50%	On/Off 50%	On/Off 50% - 99m
288 500 - 291 500	On/Off 50%	On/Off 50%	On/Off 50% - 100m
291 500 - 294 500	On/Off 50%	On/Off 50%	On/Off 50% - 101m
294 500 - 297 500	On/Off 50%	On/Off 50%	On/Off 50% - 102m
297 500 - 300 500	On/Off 50%	On/Off 50%	On/Off 50% - 103m
300 500 - 303 500	On/Off 50%	On/Off 50%	On/Off 50% - 104m
303 500 - 306 500	On/Off 50%	On/Off 50%	On/Off 50% - 105m
306 500 - 309 500	On/Off 50%	On/Off 50%	On/Off 50% - 106m
309 500 - 312 500	On/Off 50%	On/Off 50%	On/Off 50% - 107m
312 500 - 315 500	On/Off 50%	On/Off 50%	On/Off 50% - 108m
315 500 - 318 500	On/Off 50%	On/Off 50%	On/Off 50% - 109m
318 500 - 321 500	On/Off 50%	On/Off 50%	On/Off 50% - 110m
321 500 - 324 500	On/Off 50%	On/Off 50%	On/Off 50% - 111m
324 500 - 327 500	On/Off 50%	On/Off 50%	On/Off 50% - 112m
327 500 - 330 500	On/Off 50%	On/Off 50%	On/Off 50% - 113m
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336 500 - 339 500	On/Off 50%	On/Off 50%	On/Off 50% - 116m
339 500 - 342 500	On/Off 50%	On/Off 50%	On/Off 50% - 117m
342 500 - 345 500	On/Off 50%	On/Off 50%	On/Off 50% - 118m
345 500 - 348 500	On/Off 50%	On/Off 50%	On/Off 50% - 119m
348 500 - 351 500	On/Off 50%	On/Off 50%	On/Off 50% - 120m
351 500 - 354 500	On/Off 50%	On/Off 50%	On/Off 50% - 121m
354 500 - 357 500	On/Off 50%	On/Off 50%	On/Off 50% - 122m
357 500 - 360 500	On/Off 50%	On/Off 50%	On/Off 50% - 123m
360 500 - 363 500	On/Off 50%	On/Off 50%	On/Off 50% - 124m
363 500 - 366 500	On/Off 50%	On/Off 50%	On/Off 50% - 125m
366 500 - 369 500	On/Off 50%	On/Off 50%	On/Off 50% - 126m
369 500 - 372 500	On/Off 50%	On/Off 50%	On/Off 50% - 127m
372 500 - 375 500	On/Off 50%	On/Off 50%	On/Off 50% - 128m
375 500 - 378 500	On/Off 50%	On/Off 50%	On/Off 50% - 129m
378 500 - 381 500	On/Off 50%	On/Off 50%	On/Off 50% - 130m
381 500 - 384 500	On/Off 50%	On/Off 50%	On/Off 50% - 131m
384 500 - 387 500	On/Off 50%	On/Off 50%	On/Off 50% - 132m
387 500 - 390 500	On/Off 50%	On/Off 50%	On/Off 50% - 133m
390 500 - 393 500	On/Off 50%	On/Off 50%	On/Off 50% - 134m
393 500 - 396 500	On/Off 50%	On/Off 50%	On/Off 50% - 135m
396 500 - 399 500	On/Off 50%	On/Off 50%	On/Off 50% - 136m
399 500 - 402 500	On/Off 50%	On/Off 50%	On/Off 50% - 137m
402 500 - 405 500	On/Off 50%	On/Off 50%	On/Off 50% - 138m
405 500 - 408 500	On/Off 50%	On/Off 50%	On/Off 50% - 139m
408 500 - 411 500	On/Off 50%	On/Off 50%	On/Off 50% - 140m
411 500 - 414 500	On/Off 50%	On/Off 50%	On/Off 50% - 141m
414 500 - 417 500	On/Off 50%	On/Off 50%	On/Off 50% - 142m
417 500 - 420 500	On/Off 50%	On/Off 50%	On/Off 50% - 143m
420 500 - 423 500	On/Off 50%	On/Off 50%	On/Off 50% - 144m
423 500 - 426 500	On/Off 50%	On/Off 50%	On/Off 50% - 145m
426 500 - 429 500	On/Off 50%	On/Off 50%	On/Off 50% - 146m
429 500 - 432 500	On/Off 50%	On/Off 50%	On/Off 50% - 147m
432 500 - 435 500	On/Off 50%	On/Off 50%	On/Off 50% - 148m
435 500 - 438 500	On/Off 50%	On/Off 50%	On/Off 50% - 149m
438 500 - 441 500	On/Off 50%	On/Off 50%	On/Off 50% - 150m
441 500 - 444 500	On/Off 50%	On/Off 50%	On/Off 50% - 151m
444 500 - 447 500	On/Off 50%	On/Off 50%	On/Off 50% - 152m
447 500 - 450 500	On/Off 50%	On/Off 50%	On/Off 50% - 153m
450 500 - 453 500	On/Off 50%	On/Off 50%	On/Off 50% - 154m
453 500 - 456 500	On/Off 50%	On/Off 50%	On/Off 50% - 155m
456 500 - 459 500	On/Off 50%	On/Off 50%	On/Off 50% - 156m
459 500 - 462 500	On/Off 50%	On/Off 50%	On/Off 50% - 157m
462 500 - 465 500	On/Off 50%	On/Off 50%	On/Off 50% - 158m
465 500 - 468 500	On/Off 50%	On/Off 50%	On/Off 50% - 159m
468 500 - 471 500	On/Off 50%	On/Off 50%	On/Off 50% - 160m
471 500 - 474 500	On/Off 50%	On/Off 50%	On/Off 50% - 161m
474 500 - 477 500	On/Off 50%	On/Off 50%	On/Off 50% - 162m
477 500 - 480 500	On/Off 50%	On/Off 50%	On/Off 50% - 163m
480 500 - 483 500	On/Off 50%	On/Off 50%	On/Off 50% - 164m
483 500 - 486 500	On/Off 50%	On/Off 50%	On/Off 50% - 165m
486 500 - 489 500	On/Off 50%	On/Off 50%	On/Off 50% - 166m
489 500 - 492 500	On/Off 50%	On/Off 50%	On/Off 50% - 167m
492 500 - 495 500	On/Off 50%	On/Off 50%	On/Off 50% - 168m
495 500 - 498 500	On/Off 50%	On/Off 50%	On/Off 50% - 169m
498 500 - 501 500	On/Off 50%	On/Off 50%	On/Off 50% - 170m
501 500 - 504 500	On/Off 50%	On/Off 50%	On/Off 50% - 171m
504 500 - 507 500	On/Off 50%	On/Off 50%	On/Off 50% - 172m
507 500 - 510 500	On/Off 50%	On/Off 50%	On/Off 50% - 173m
510 500 - 513 500	On/Off 50%	On/Off 50%	On/Off 50% - 174m
513 500 - 516 500	On/Off 50%	On/Off 50%	On/Off 50% - 175m
516 500 - 519 500	On/Off 50%	On/Off 50%	On/Off 50% - 176m
519 500 - 522 500	On/Off 50%	On/Off 50%	On/Off 50% - 177m
522 500 - 525 500	On/Off 50%	On/Off 50%	On/Off 50% - 178m
525 500 - 528 500	On/Off 50%	On/Off 50%	On/Off 50% - 179m
528 500 - 531 500	On/Off 50%	On/Off 50%	On/Off 50% - 180m
531 500 - 534 500	On/Off 50%	On/Off 50%	On/Off 50% - 181m
534 500 - 537 500	On/Off 50%	On/Off 50%	On/Off 50% - 182m
537 500 - 540 500	On/Off 50%	On/Off 50%	On/Off 50% - 183m
540 500 - 543 500	On/Off 50%	On/Off 50%	On/Off 50% - 184m
543 500 - 546 500	On/Off 50%	On/Off 50%	On/Off 50% - 185m
546 500 - 549 500	On/Off 50%	On/Off 50%	On/Off 50% - 186m
549 500 - 552 500	On/Off 50%	On/Off 50%	On/Off 50% - 187m
552 500 - 555 500	On/Off 50%	On/Off 50%	On/Off 50% - 188m
555 500 - 558 500	On/Off 50%	On/Off 50%	On/Off 50% - 189m
558 500 - 561 500	On/Off 50%	On/Off 50%	On/Off 50% - 190m
561 500 - 564 500	On/Off 50%	On/Off 50%	On/Off 50% - 191m
564 500 - 567 500	On/Off 50%	On/Off 50%	On/Off 50% - 192m
567 500 - 570 500	On/Off 50%	On/Off 50%	On/Off 50% - 193m
570 500 - 573 500	On/Off 50%	On/Off 5	

Would an Integrated Control System Benefit Your Business?

Switching your automation or motion control platform requires careful consideration. Ultimately, the decision may come down to risk management—whether the benefits of a PAC controller with integrated, high-performance motion control outweigh any potential risks. Some questions to ask in assessing the potential benefits of an integrated control system include:


- Are your customers getting the machine through put they desire with current motion controls? What is the bottleneck in your current machine?
- Does adding more axes to your system degrade system performance?
- Is the throughput of your machine limited by the slow servo update rates, the ability to respond to motion events quickly enough, or long program scan time resulting from sharing a single processor for motion and logic control?
- Does your motion control solution allow you to make changes to end position, velocity acceleration or jerk to active motion profiles at any point along the profile?
- Are you able to synchronize the position loop of all axes in the system to eliminate position phase errors?
- Are you able to instantly reconfigure your machine or line to handle different products? Can you programmatically change master/slave axis assignments and scaling, electronic gear ratios, cam profiles, and engineering units (e.g., English to metric) on the fly?
- Could your solution benefit from the reduced wiring, improved noise immunity and reliability provided by distributing servo amplifiers and motion-centric machine I/O via a fiber optic link?
- Does your solution include multiple programming software packages and/or different programs for logic, motion and operator interface control that require synchronization?
- Would an integrated programming environment reduce risk or improve engineering efficiency?
- Would your engineering resources benefit from an integrated environment?



Figure 17—Pump system in a water treatment installation.

Conclusion

The suitability of variable-speed and cyclic-flow regulation in centrifugal pump applications has been analyzed for two pumps (90 kW and 350 kW) in the low-voltage range. The data show that variable-frequency control is the best solution in friction-loss-dominated hydraulic systems (fluid transportation without height difference) while cyclic control is recommended for static-head-dominated systems. Speed control in systems with very flat pump and load characteristics should be avoided due to the risk of instability and pump damage (Ref. 9).

Soft starters are a very competitive technical solution, especially for water and waste applications in which the regular on/off operation for emptying a tank and pumping up fluid for further treatment are common practice. They are robust, have good bypass capability and dedicated control algorithms for start (kick boost) and stop (no water hammering) sequences. However, optimum energy savings and good payback times can be achieved in a wide range of hydraulic systems by employing parallel-pump schemes that use a combination of drives and soft starters (Fig. 17). 

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