Pumping Machinery, LLC

ARTICLE #44: HOW TO EVALUATE VFD SPEED EFFECT ON HYDRAULICS

By
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Few would dispute that VFD drives save energy, but how much exactly – depends on a system. Hydraulically speaking, the main difference between a *variable frequency* (speed) *drive* and a discharge valve is that a VFD changes a *pump curve only*, while a valve changes a *system curve only*. A pump operates at the intersection between its H-Q curve and a system curve, and a change in either moves operating point to a new intersection.

Consider an example of a centrifugal pump operating at 4,000 gpm and producing 300 feet of head at 1800 rpm. According to its curve (Fig. 1), pump efficiency is 82%. (Here, this happens to be a BEP point, but, in general, the same logic would apply to any operating point). Suppose we want to reduce the flow by 50%, to 2,000 gpm. By closing the discharge valve, we would change a system curve, which would intersect the *same pump curve* at 370 feet of head, 61% efficiency. Such control process is simple, quick and easy. But it has issues too, which we will review in a minute.

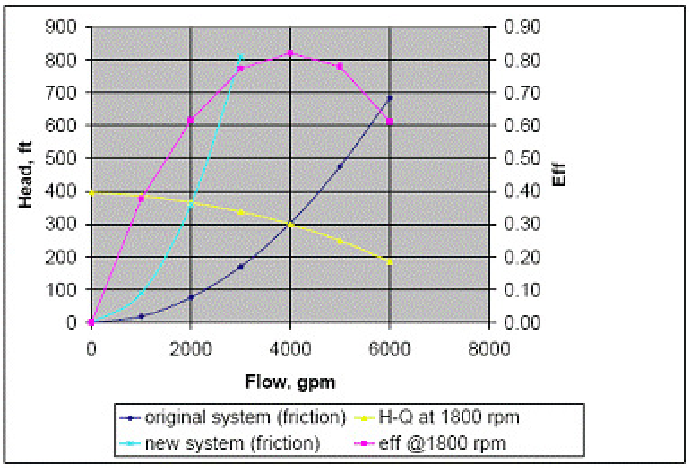
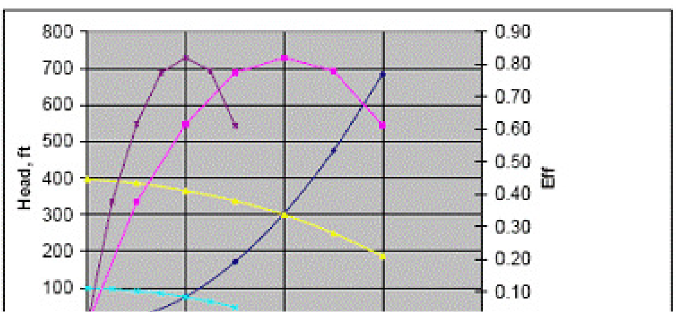


Fig. 1 Flow control by throttling discharge valve

Hydraulically, the system above is referred to as *predominantly friction* (no static head). Such system is ideal for application of the VFD for flow control. The main reason for that is at the heart of the nature of affinity laws, which state that pump flow changes directly with the speed ratio, head as a square, and power as cube. That implies the relationship between head and flow as $H=aQ^2$ – a parabola. Since a system curve is also a parabola ($H = bQ^2$), then a given point on a pump curves scales down with speed ratio, and at the same time slides down along the system friction curve, and coefficients a=b for a given system setting. Fig. 2 shows how pump flow is reduced by exactly 50% with RPM reduced in half, while pump head is reduced as a square of a speed ratio $(900/1800)^2$, i.e. 0.25 x 300 = 75 feet. Notice that efficiency does not change, as entire efficiency curves "slides" to the left, and remains at a peak of 82%.



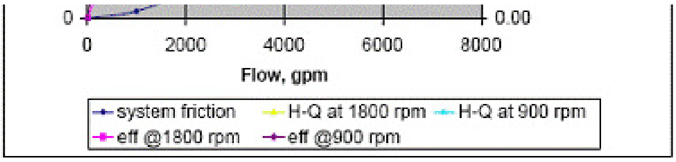


Fig. 2 Flow control by VFD speed reduction, friction system head example

But what would happen if a pump operates against constant (static, or mostly static) head, such as a lift station application? Consider Fig 3:

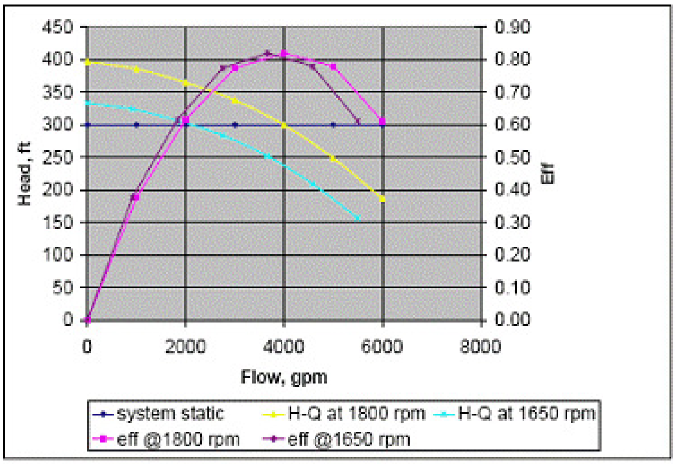


Fig. 3 Flow control by VFD, static system head example

In example above, 300 feet is a constant static head, with friction losses assumed to be negligible in comparison. A range of RPM variation is significantly reduced now, in order not to drop the entire pump H-Q curve below the contact H=300 feet. By applying affinity laws, we will find that at RPM=1650, a new pump curve (H-Q) intersects a constant 300 feet head line at desired 2,000 gpm, and efficiency at that point is 62%.

Table 1 is a comparison of these (3) cases:

	Throttling	**VFD (friction)**	**VFD (static)**
RPM	1800	900	1650
Flow, gpm	2000	2000	2000
Head, feet	370	75	300
Eff, %	*61%*	*82%*	*62%*
Power, hp	306	46	244
Energy cost, $/KW-hr	0.10	0.10	0.10
Energy used per year, $	$200,193	$30,187	$159,701
BEP Flow, gpm	4000	2000	3667
Operation %BEP	50%	100%	55%

Table 1 comparison of valve throttling, VFD (friction), and VFD (static head) examples

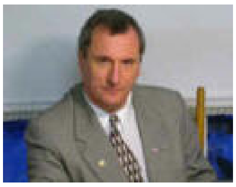
Observations:

For *friction-dominated* systems (long pipes, flow transfer cases) VFD saves a very substantial amount of energy, and operates pumps reliably due to close proximity to BEP flow (100% in example shown)
For *static-dominated* systems (injection against constant pressure, lifting against constant head) the energy savings are substantially less, and the pump operates, surprisingly, substantially *off-BEP* position, not significantly different from a valved flow control case
For cases where both systems are present, an in-between scenario would result

VFD drives are not inexpensive devices and require certain knowledge of controls, proper electrical and electronic maintenance and care. Flow control by VFD requires programming, training, and is more complex then a simple control by throttling a valve. These are some considerations against the VFD applications, but, on the other hand, they offer convenience of remote control (although so do some valves), energy savings when operated in friction-dominated systems, as well as more reliable pump operation (closer to the BEP means less loads, better seal life, lower vibrations, and improved suction recirculation conditions).

Each system requires specific and detailed understanding of its hydraulics, with unique H-Q curves and flow control requirements, to make sure the money to be invested are justified. Organization making a VFD implementation decision must be prepared to deal with the added complexity, with the realization that the anticipated benefits are supported by the efforts, training and commitment to operate, maintain and appreciate the usefulness such systems offer. For organizations that leave these issues to chance or a promise, the anticipated benefits can quickly turn into headaches, and that is not a good thing.

As always, a parting Quiz! – at what RPM will a pump completely stop delivering flow to the system in case shown on Fig. 3? The first three answers will get you a free pass to the Pump School session, per schedule posted at our web site: www.pumpingmachinery.com/pump_school/pump_school.htm



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