Pump ED 101

Volts per Hertz, Motor HP & Other Considerations

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Last year I received a question about matching VFDs and motors from a Pumps & Systems reader. Here is what he wanted to know. "I have a spare pump in my warehouse that requires 15 Hp at BEP flow when running at 1760 RPM. I also have a new application with a duty point that can be matched perfectly by this pump at about 1466 RPM. This speed is about 83% of full speed and equates to 50 Hz when operated by a VFD. The affinity laws indicate that the power required at 50 Hz is reduced to just 8.7 Hp. I have a limited budget and would like to keep my total cost for the motor and VFD as low as possible. Is it "OK" to use a 10 Hp motor as long as I make sure the VFD will never exceed 50 Hz?" I was on the road doing training at the time so I had to send him my short answer - - "No it is not OK, so you may want to consider running the pump via a belt drive instead". He never questioned the reason for my answer but he thought the belt drive alternative made good financial sense. I received an email about a month later letting me know that his new, belt drive system was up and running.

So, why was it not "OK" to use a 10 Hp motor? There are a number of ways to insure that a VFD will not exceed some maximum preset speed. Why wouldn't the motor be protected? It turns out that his plan was flawed from the very beginning and the problem had nothing to do with limiting the maximum speed. Centrifugal pumps follow the affinity laws when pump speed changes. When the speed of an electric motor changes due to a change in frequency there are some other rules that will dictate how that motor performs.

The HP produced by an induction motor is directly proportional to its torque and rotational speed (HP = (T x RPM) / 5250). Assuming the number of stator poles remains constant, the rotational speed of that motor is directly proportional to the frequency of the input power. When the frequency changes so does the speed but motor torque remains constant. In order for torque to remain constant, another value must change and that value is HP. Therefore if the incoming power frequency is reduced from 60 Hz to 50 Hz (5/6), motor HP will also be reduced to 5/6 of its original value. If we apply this to the 10 HP motor in the example above, its output at 50 Hz would be just 8.3 HP. Even though the power required by the pump was reduced to about 57% (8.7 HP) of its original 60 Hz value it is still more than the

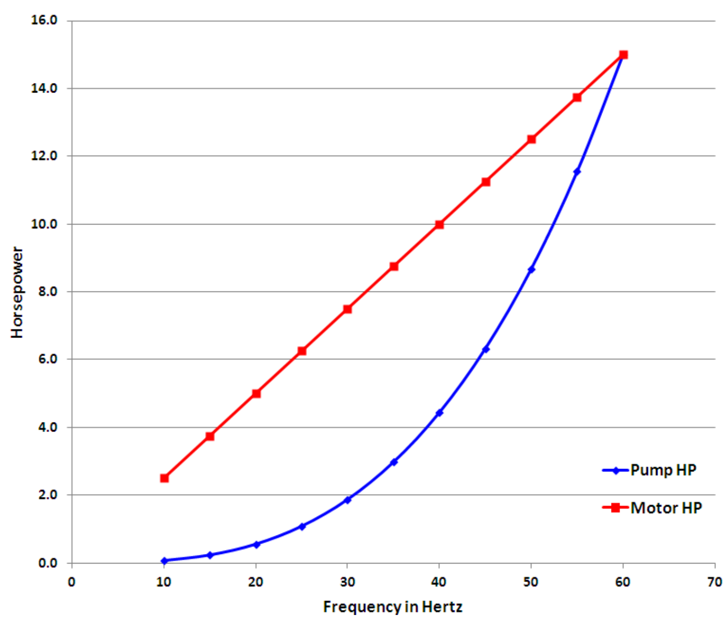
10 HP motor can supply at 50 Hz.

Motors manufactured in the US for 60 Hz operation must be de-rated for operation overseas on 50 Hz power. The standard de-rating factor for 230, 460 and 575V models is 5/6 (0.83) of the 60 Hz power but most manufacturers use a 0.85 for ODP and 0.80 for TEFC. These assume a service factor of 1.0 and line voltages of 190, 380 and 475V. If line voltages are higher than stated here, the de-rating factor is reduced proportionally.

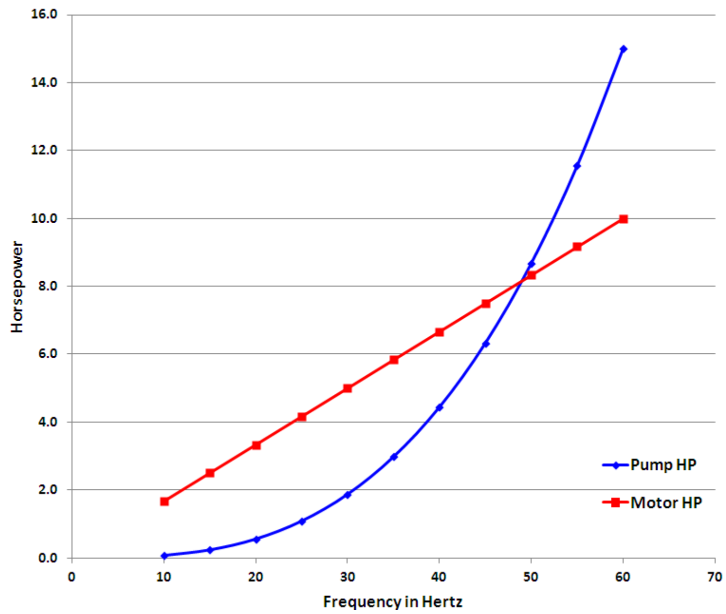
Application of the proper line voltage at reduced frequencies is extremely important. A motor designed for 460V, 60 Hz operation has a Volts / Hertz (V/Hz) ratio of 7.66. If the same voltage is used at 50 Hz, the ratio would increase to 9.2. In order to accommodate this increase in voltage per cycle, the size of the motor's magnetic circuit would have to be increased. Since this is impossible, the existing circuit will saturate causing an increase in current draw and a corresponding increase in winding temperature. And, of course, winding temperature plays a major role in insulation life. For 50 Hz operation, line voltage is reduced to 380V and thus keeps the V/Hz ratio at 7.66.

A constant V/Hz ratio is always maintained when a motor is operated under VFD control. Whenever frequency is changed, the line voltage is automatically compensated via pulse width modulation (PWM). If voltage is 460V at 60 Hz, it is reduced to 230V at 30 Hz.

One of the reasons VFD operation is so popular in the centrifugal pump industry is the third affinity law. It states that power varies as the cube of a change in speed. If speed is reduced to 75% of full speed, power is reduced to just 42% of full speed power. If a pump motor is properly sized for full speed operation, it will always have adequate power at reduced speeds. Motor power reduction is directly proportional to speed reduction while the pump power requirement drops as the cube of a speed reduction. Figure 1 shows this relationship for a 15 HP motor and a pump with a full



speed, power requirement of 15 HP. The ratio of available motor Hp to the required pump HP increases exponentially as speed is reduced. Figure 2 shows this relationship for the same pump and a 10 HP motor. In this example, available HP does not meet the required HP until speed drops below 50 Hz. If our reader's design point could have been met at 45 Hz, the 10 Hp motor would have been more than adequate.



The calculator used to produce these charts is available on the "Pump Evaluation, Selection & Testing Tools" page at www.PumpEd101.com. You can use it to evaluate the maximum operating speed of a pump when driven by a motor that does not match the full speed HP requirement.

Joe Evans is responsible for customer and employee education at PumpTech Inc, a pump & packaged systems manufacturer & distributor with branches throughout the Pacific Northwest. He can be reached via his website www.PumpEd101.com. If there are topics that you would like to see discussed in future columns, drop him an email.