YASKAWA

Clean Room Recirculating Fans

Over the past six years to save energy, IGBT based VFD s with quiet transistor switching rates above 8Khz have been extensively used in the clean room industry instead of inlet vane type systems. Recently, specially wound 30 Hz, 4 pole motors have been used to take advantage of their improved efficiency and power factor as compared to a 60Hz 6 pole 1200 RPM motor or 60Hz 8 pole 900 RPM motor.

In the past three years, four Fab expansions have successfully used 30 Hz 4 pole motors instead of 60 Hz 6 pole or 60 Hz 8 pole motors with VFDs. Located throughout the United States, these installations have a combined total of over 1000 Yaskawa AC Drives and motors.

On these large Fabs, they were able to take the time to closely examine the benefits of using a 4 pole motor over an 8 pole motor. The 4 pole motor was chosen for the following reasons:

Improved Efficiency - Four, six, and eight pole premium efficiency motors all have similar efficiency ratings at full load, but as load is reduced, a four pole E-plus¤ 3 designed motor retains its efficiency at a high level down to 25% load. Six and eight pole motors generally have an efficiency curve which begins to fall off more rapidly below 75% load, as shown in the following chart for a 20 Hp motor:

MOTOR	LOAD	EFFICIENCY	AMPS	HZ	RPM
4 pole	25%	86.7%	13.5	30	900
6 pole	25%	82.3%	12.8	60	1200
8 pole	25%	81.8%	21.1	60	900
4 pole	50%	90.9%	16.4	30	900
6 pole	50%	89.2%	16.1	60	1200
8 pole	50%	88.7%	23.4	60	900
4 pole	75%	91.1%	20.6	30	900
6 pole	75%	90.5%	20.4	60	1200
8 pole	75%	90.7%	27.0	60	900
4 pole	100%	90.9%	25.0	30	900
6 pole	100%	90.5%	26.5	60	1200
8 pole	100%	91.0%	31.5	60	900

In most clean room applications, the motors operate between 25% and 75% of full load torque with 100% torque required only when a neighboring unit is shut down. Also, if a 1200 RPM motor is used instead of a 900 RPM motor, a smaller fan wheel would be selected due to the higher operating speed; this would likely increase air noise and lower the fan s mechanical efficiency.

Higher Power Factor - At 100% load on motors between about 5 Hp and 40 Hp, a four pole motor has a power factor that is 10% to 20% higher than an eight pole motor. Also, as load is reduced a four pole motor maintains a much higher power factor than an eight pole motor. A higher power factor allows the motor to draw less current while doing the same amount of work. This can allow a smaller, less expensive VFD to be used, such as a 20 Hp 27 amp VFD for a 25.6 amp 4 pole 30 Hz motor as compared to a 25 Hp 34 amp VFD for a 31.5 amp 60 Hz motor. This extra capacity can also allow the fan to operate at a higher RPM (CFM) before overloading the VFD.***Quieter Operation*** - Stator slot combinations and magnetic flux densities used on 4 pole motors reduce the likelihood of hitting a mechanical resonance point with the motor and fan assembly. This increases the chances of having quiet operation at all speeds without last minute design changes to the recirc air handler or motor.

Less KVA required of the power distribution system with less harmonic distortion - If a 20 Hp 900 RPM motor is needed, a typical 60 Hz 8 pole motor would have a full load amp rating of between 28 and 32 amps. A 30 Hz 4 pole motor would have a full load amp rating of between 25 and 26 amps. A 20 Hp 460 V VFD sized based on the industry standard of National Electric Code current ratings would be rated 27 amps and would be undersized for the 60 Hz motor. If a 34 amp 25 Hp VFD is used with the 60 Hz motors the designed KVA usage of the electrical system would increase along with the cost of the wiring distribution to the VFDs. A 25 Hp VFD would have a larger DC bus capacitance than a 20 Hp VFD, which would increase the peak currents on the input, thus causing greater harmonic distortion of the power line. If a six pole 1200 RPM motor was used on a 900 RPM fan, it would have to be rated for 25 Hp to be able to develop close to 20 Hp at 900 RPM.

Note. If a line bypass is desired, because only one or two recirc air handlers feed a critical plenum, a 30Hz motor cannot be used. Typically, four or more recirc air handlers feed a common plenum allowing the speed of units to be increased to compensate for the fourth unit being shut down.

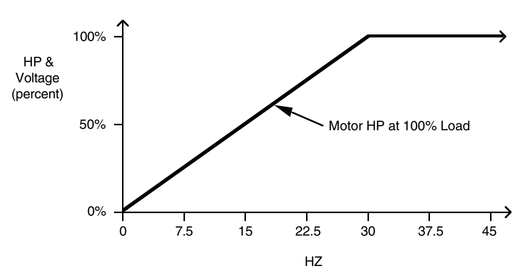
What is a 30Hz Motor? A.C. motors are electrically wound and connected for many different frequencies. Europe is 50 Hz and high speed router and drill motors are wound for 300 Hz to 2000 Hz. Motors can also be connected for different voltages at the nameplate frequency. This determines the volts per hertz required by the motor to operate at 100% torque, and is programmed into the VFD.

The operating speed of an A.C. motor is basically determined by the number of magnetic poles wound into the motor and the frequency applied to the motor as shown by the formula below:

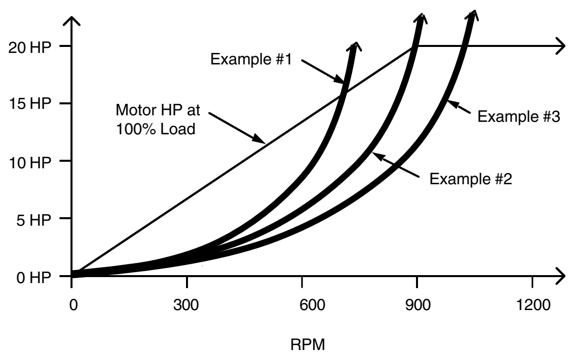
SPEED (RPM) = FREQUENCY (HZ) x 120 / # OF POLES

Based on this formula, a 900 RPM motor could either be wound for 8 poles and operated at 60 Hz or it could be wound for 4 poles and operated at 30 Hz. The 8 pole motor would be wound for a volts per hertz of 460 V / 60 HZ or 7.67 V/HZ. The 4 pole motor would be wound for 460 V / 30 HZ or 15.3 V/HZ.

60 Hz 4 pole motors have been used on many fan applications with VFDs operating between 15 Hz and 90 Hz for many years without problems. Therefore, it is possible to operate a 30 Hz 4 pole motor between 7.5 Hz and 45 Hz with a maximum continuous HP developed at the motor s full load amp rating, as shown in the graph below:



A 20 Hp 460 V 30 Hz 900 RPM 4 pole motor or a 20 Hp 460 V 60 Hz 900 RPM 8 pole motor could be used on a direct drive plug fan that requires 15 Brake HP or less at 675 RPM (example #1), as well as 20 Brake HP or less at 900 RPM (example #2). Also, if the VFD and motor were operated above 30 Hz, the plug fan could have a BHP requirement of up to 20 Hp from 901 RPM to 1200 RPM or higher (example #3). This is shown on the graph below with each curve showing the three different fans brake HP increasing as the cube of speed based on the Affinity Laws.



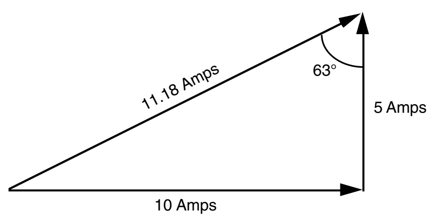
For each fan application there is a particular fan size and operating speed that best suits the low sound levels and maximum mechanical efficiency that is required for large Fabs. With the increased use of air handlers which are larger in size, going from 20,000 CFM to 30,000 CFM plus, wheel sizes are increasing and maximum mechanical efficiency is occurring at lower speeds. Often these speeds are between 600 RPM and 800 RPM and a VFD allows the motor to operate quietly and efficiently around the maximum efficiency point and below in cases where too much capacity is designed into the system.

A 30 Hz motor is a motor wound for a volts per hertz that is twice that of a 60 Hz motor by putting twice as many windings in series similar to going from a 230 V winding to a 460 V winding. It allows a recirc fan to operate from a VFD using a 4 pole motor which has a higher power factor and a better low load efficiency than an 8 pole motor.

How Does The High Power Factor of a 30Hz Motor Affect the VFD s input Power Factor and Efficiency? The lower current at the output of the VFD due to the higher power factor of the 30 Hz motor can be further improved by using a VFD which automatically adjusts the volts per hertz to the motor based on the motor load or a preset variable torque volts per hertz curve. This will also help reduce the current to an 8 pole motor when operating below the RPM where the fan loads the motor to 100%.

As motor current is reduced by an improved power factor of 10% to 20%, the VFD and motor losses are reduced slightly thus increasing system efficiency by 1% to 3%. This will lower the input current to the VFD by 1% to 3% and reduce the harmonic voltage distortion by 1% to 3%. The true power factor at the input to the VFD would remain about the same because both the fundamental current and harmonic current would be 1% to 3% less. The displacement angle and displacement power factor on the input to a PWM type inverter with a full wave diode bridge rectifier is about 0.95 at all loads and speeds. The true power factor on the input of the VFD is largely determined by the current harmonic, which varies depending on the rectifier design and filtering used. Interestingly, the input current to the VFD on a fan load follows the brake HP of the load and not the VFD output current, which allows the VFD to initially start a fan with a VFD input current which is less than a tenth of the VFD output (motor) current. This can be important after a long power outage compared to the large inrush when starting a motor without using a VFD. The power factor on the inverter s output is determined by the motor design and volts per hertz applied (which determines the motor s magnetizing current) along with the brake HP of the load (which determines a motor s torque producing current). The vector sum of the motor s magnetizing current and torque producing current determines the total current that would be measured with a current meter.

For example, if a motor had 5 amps of magnetizing current and 10 amps of torque producing current, the total current measured with a clamp on amp probe would be 11.18 amps ($5^2 + 10^2 = 125$, and ˆ125 = 11.18). The power factor would be the TAN 10A/ 5A, or 63 degrees.



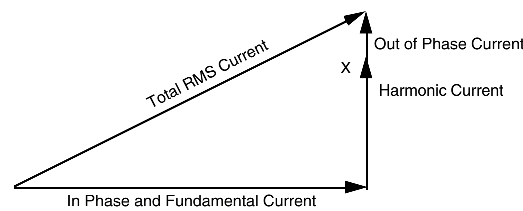
There is not a direct relationship between the input power factor to the VFD and the output power factor because they are electrically separated by the VFD s DC bus and there is no power factor with DC current. The formulas to relate KW and KVA into the VFD and KW and KVA drawn by the motor are as follows:

KW(in) = KW(out) + VFD Losses

KW(in) = ˆ3 x Volts(in) x Amps(in) x Power Factor(in) / 1000

KW(out) = ˆ 3 x Volts(out) x Amps(out) x Power Factor(out) / 1000

The VFD s input power factor and total RMS input current is the vector sum of the in phase and fundamental current, the harmonic current and the out of phase input current, as shown below:



Conclusion

30 Hz motors are an excellent alternative when a VFD will be used and a bypass is not required. The lower amp draw of a 4 pole motor either provides additional CFM capacity or allows a smaller, less expensive VFD to be used. When multiple air handlers are feeding the same plenum, this extra capacity can allow one unit to be shut down and the other units ramped up so a bypass is not required, saving money. The lower amp draw also reduces losses in the inverter, improving efficiency and reliability. Finally, a 4 pole motor will generally have a higher efficiency below 50% load which occurs on fans operating at 70% of the speed where 100% load occurs.

Using a 30 Hz motor instead of a 60 Hz motor on a recirculation fan in a clean room makes good economical sense!