Monthly Informative Application Guidelines, with respect to *Motors & Drives* to keep you better INFORMED.

APPLICATION GUIDELINE #23

(Application Considerations When Applying VFD's – Part 1)

Brought to you by your Motor & Drive Specialists……

When the speed of a motor is to be controlled by a Variable Frequency Drive (VFD), there are a number of factors that must be considered. These factors are plentiful and include such things as: voltage, horsepower, line and load side harmonics, load torque, speed range, speed regulation and accuracy, acceleration/deceleration times, overspeed capability, braking requirements, power loss ride-through time, audible noise, length of cable from the VFD to the motor, enclosure requirements, area classification, power factor correction, altitude, efficiency, motor insulation life, and many other factors.

One of the first things that should be made clear when looking at a new application is the reason why it is being applied (goal) - i.e. Why is the VFD being installed? The objective is to help provide a solution to a problem or need. On complex applications, make a strong effort to talk to all people involved including maintenance personnel, operators, engineering and even management. There may be several expected benefits that may not all come to light by talking to only one group.

- Product quality improvement
- Increased throughput/production
- Increased system reliability
- Repetitive start capability
- Less impact on mechanical system
- Less impact on electrical system – Soft start
- Reduced operating cost / Energy saving
- Integration or future integration with mill wide information system

Once a clear understanding of the goal has been made, information gather as much as possible by answering some of the following application questions:

- **Driven Equipment (Type of load / load description)**
- **Load Requirements (Special Considerations)**
- **What is the load?** (Variable torque, Constant torque, Constant HP, Other)
- **Is the drive used to retrofit an existing controller such as DC drive, WRIM, Eddy Current Coupling, mechanical variable speed control etc?** If so, what is existing and what are its characteristics/ratings? This will often provide insight as to motor/drive sizing requirements if the load details are not available.
- **What are motor characteristics?**
  HP, Enclosure, Voltage, FL Current, FL RPM, BDT, Stator Temp Rise, Bearing Temp Rise, Other Info..
- **What is the average Load Torque in lb/ft?** (if Constant torque)
- **What is the torque profile?** (For example, if the load is an ID or FD fan, torque might change considerably from startup with cold air to normal running with hot air. "Constant torque" loads may be cyclical with peak torque demands. Applications such as lathes may be constant HP. Loads such as slurry pumps may require high breakaway torques, variable torque while running and impact loading when cavitating. A firm understanding of how much torque is required at the motor shaft is essential. Loads such as pump jacks may cycle from motoring to generating.)
- **What are the limitations for upper and/or lower speeds?** Some applications such as submersible pumps may require a minimum operating speed. Many loads have a maximum allowable upper speed.
- **What is the required speed regulation?**
- **Is torque regulation required?**
- **What is the required Breakaway Torque? How long is this required for?**
- **What are the maximum expected peak torque transients (if any)?**

- **What is the speed range at which peak torque transients can occur?** (For example, the drive that turns a kiln will be highest at starting until the product starts to tumble then reduces and is quite consistent. A screw feeder may be subject to plugging at any speed.)
- **What is the starting and stopping duty cycle?** (This is important for motor heating considerations, especially when the drive is sized larger than the motor for performance reasons.)
  - Time of each "start-run-stop" cycle (if known):
  - How many "start-run-stop" cycles per hour:
- **What is the required acceleration time and/or accelerating distance?**
- **What is the required deceleration time or stopping distance?**
- **If rapid stopping is needed is regenerative or dynamic braking required?**
- **What is the load inertia as reflected to the motor shaft <u>or</u> load inertia plus gear or sheave reduction ratio?** (Reduction ratio is expressed as motor speed ÷ load speed)
- **Is zero speed stationary holding required?** Please note that in many applications it may be better to supply a very slow (virtually zero speed) requirement. For example, operating at 1 Hz on an 1800RPM motor through a 10:1 gear reduction equals 3 revolutions per minute. This may be close enough to being stopped to handle the application. There are advantages pertaining to the bearings to actually have the motor creep rather than sit at a dead stop.
- **Does the application require a holding brake?** Although maintenance is higher with an electric brake, motor heating is reduced, motor bearing concerns are eliminated and in the event of a power failure, an electrically operated brake is failsafe. If a brake is required, how will it be powered? Note that the drive can directly control release of the holding brake including torque proving prior to release.
- **Does the application require load sharing?** If so, can one drive be used to power both motors?
- **How will the drive be controlled?** (e.g. 4-20mA, 0-10V, -10V +10V, speed pot, joystick, preset speeds, preset speeds with trim, PLC communication such as Device Net, Profibus, Modbus, Modbus +, Remote I/O etc.)
- **How is the drive required to stop during an emergency stop?** (The drive's default is to shut the drive down and cut power to the motor for a "coast to stop". The drive can be set up to decelerate the motor, which will normally result in a faster stop.)
- **What is the altitude?**
- **What is the maximum ambient temperature that the drive will be subjected to?**
- **What enclosure type is required?** (e.g. NEMA 1, NEMA 3 or 3R, NEMA 12, NEMA 4, floor or wall mount, bottom or top cable entry, bottom or top cable exit etc.)
- **What accessories are required?** (e.g. Input breaker, output contactor, bypass, input reactor, output filter, thermal overload(s), communication cards, isolated analogue input / output, window kit, surge arrestor etc.)
- **Are any special controls required?** (e.g. PID, positioning, master – follower, PLC interface etc.)
- **Is power ride through a requirement?** Note that the drive can be set to speed search then restart into a rotating load upon restoration of normal power. The customer's speed reference must be maintained during the power dip. This may require the addition of a UPS. Regenerative ride through can also be used but again, the speed reference must be maintained.
- **Are any other special drive parameters required?** (e.g. Soft stall, stall protection, accel/decel patterns, dual accel/decel patterns, drooping control, low current detection, overtorque trip, jump frequencies, DC injection braking, changed carrier frequency, customized input and output terminal operation, overvoltage stall protection, modified V/Hz "curve", cummulative run timer alarm, pattern run, disable keypad parameters etc.)

<u>Electrical System Considerations</u>

- **Harmonics on the electrical system.** Is this an issue? (A rule of thumb is that if >20% of the connected load is non-linear [i.e. equipment that converts AC to DC such as VFDs, computers, electronic ballasts, etc., then harmonics are probably an issue.)
- **Common mode RFI / EMI noise in the system. Is this an issue?** (In most industrial applications, if proper wiring and grounding practices are followed, common mode noise is not a problem. This issue, however, should be considered especially if sensitive equipment will be connected to the same system.)
- **What is the main transformer size and impedance?**
- **Define the point of common coupling – a one line diagram with all pertinent information is ideal.**

Motor Issues

- **What is the operating speed range and time duration at various speeds?** (A constant torque application may run as low as 10% speed but for very short periods of time then operate for extended periods of time at, for example, 80 – 100% speed. Further, the load may be cyclical. The average I^2t heating needs to be considered to determine if the motor needs to be oversized or if a separately powered blower is required for proper cooling.)
- **What is the maximum desired operating temperature of the motor?** (Note that a standard T-frame motor can operate at a class F temperature rise – 105^0C + 40^0C ambient + 10^0C hot spot. This will not provide maximum motor life but is often used by manufacturers when they rate their motors for a turndown ratio. If, for example, a 90^0C maximum temperature rise is desired, this can be factored into the design of the motor / drive system.)
- **Motor insulation considerations**. (Are motors new or existing, are there multiple motors on one drive, are lead lengths excessively long) i.e. are filters required? See Application Guideline #24 next month for a more detailed review.
- **Does the application require bypass? If so, is the motor capable of starting the load across the line?** (This may become an issue on ID or FD fans which has higher loading during start and the air is cold. It may be an issue with high inertia, or repetitive start applications. Applications that require high breakaway or starting torque may be an issue as some "inverter duty" motors may have very low locked rotor torque .)
- **What is the maximum required motor speed?** Often limiting speed is a function of load torque requirements, maximum bearing speeds and motor balance. In larger motors it may also include centrifugal force on the rotor bars and/or critical motor frequency concerns.
- **Is a lower speed motor that is oversped more suitable for the application?** If, for example, a load requires a large amount of breakaway torque, it may be more cost effective to use, for example, a 1200RPM motor on an 1800RPM application. This provides 50% additional torque breakaway for the same sized VFD. Note that re-sheaving or re-gearing the load and over-speeding an 1800RPM motor can provide the same benefits.
- **What is the motor's critical speed?** Large HP motors require knowledge of the motor's critical speed. Large 2P motors are often designed as flexible shaft motors. This means that the critical resonant frequency is below rated speed (often approx. 25% below rated RPM). If the application requires running at or close to this speed, either the motor needs a design change or the drive needs to avoid the corresponding output frequency. Large HP 4P and slower speed motors are typically stiff shaft with critical speed approx. 25% above rated RPM.
- **If a new motor is required what enclosure type and options are required?**
  - Enclosure type
  - Electrically powered fan (blower motor)
  - Tachometer or resolver
  - Inverter duty wire
  - Insulated bearings or ceramic hybrid
  - Grounding brush
  - Holding brake
  - Thermistor (including type)
  - Klixons
  - Stator RTDs
  - Bearing RTDs
  - Space heaters
  - Vibration probes (and type)
  - Air filters (for WPII)
  - Differential pressure switch (for filters)
  - Other options