Application Note - Setting up Speed Search

Overview

A motor is not always at rest when the operator is ready to start it up. It may be rotating at an unknown speed and even in an unknown direction before it receives a run command. There are a number of reasons this could occur. Maybe the motor is coasting because someone pressed stop. Maybe the system just faulted and the motor is coasting at some speed. Maybe another part of the system started up first and is causing this motor to rotate. Maybe there was a power failure and the system is switching from the commercial power supply to a back-up generator. Regardless of the reason, the drive will always attempt to start the motor from zero speed, unless Speed Search is enabled. Speed Search allows the drive to find the motor speed and ramp it to the frequency reference from THAT speed, rather than from zero speed.

Application Highlights

The drive can be set to perform a Speed Search on every start. It can also be programmed to only perform a Speed Search when a digital input on the drive is closed. Keep in mind that in closed loop control methods (CLV, V/f w/PG, CLV/PM) Speed Search is automatically enabled, and the drive will perform a Speed Search at every start. It is also automatically enabled when Auto-Restart is enabled (L5-01 $\neq$ 0) or if Momentary Power-loss Ride-thru is enabled (L2-01 $\neq$ 0), but will only perform a Speed Search if one of these functions is active. The drive will not perform a Speed Search during a normal start in these cases.

There are three different Speed Search methods available; Current Detection, Speed Estimation and Current Detection 2, though not all are available in every drive. The Speed Search method used is determined by b3-24.

Current Detection is unidirectional and thus, can detect the motor speed in the forward direction only. The drive sweeps output frequency from high to low while monitoring motor current. Synchronization is considered complete when motor current drops below the level programmed in b3-02.

Speed Estimation is bi-directional and can detect the motor speed in forward and reverse by setting b3-14=1. In this method the drive will use the motor's Back EMF to determine motor speed and direction. If the measured Back EMF is below 5%, the drive will inject voltage into the motor windings and measure the current feedback to determine motor speed.

Current Detection 2 is also bi-directional, and it also uses Back EMF to determine motor speed if available. If not, it uses a sweeping method similar to the Current Detection method. The difference between this and Current Detection is that output current is limited in this method. Current Detection 2 is currently only available in all versions of U1000. It will also be available in the next generation of Yaskawa drives.

Application Challenges

Waiting for a coasting motor to come to a rest can be inconvenient. For high inertia loads, this coast down process can take 15 minutes or more. If given an option, most end users would rather not wait for the motor to come to rest before issuing a run command. Programming the drive to decelerate to stop may be an option, but to gain a clear advantage over coast to stop you need a way to dissipate the regenerative energy, i.e. dynamic braking, regenerative converter, line regeneration unit, etc. External forces may be the cause of motor rotation in some installations, so it may never stop on its own. Speed Search can eliminate these concerns.

Most of the time, setting up Speed Search is as simple as enabling it and choosing the method. However, some installations may require some additional tuning. Programming good motor data into the drive will increase the accuracy of Speed Search, and thus increase the likelihood of properly detecting motor speed. Performing an Auto-Tune is a great way to ensure the proper motor data is set in the drive. Each Speed Search method presents its own challenges when it doesn't work immediately. These are explained later in this document.

Products Used

All 1000 series Yaskawa drives (except J1000) have the Speed Search function.

Application Solution and Benefits

Enable Speed Search either by parameter (b3-01=1) or closing a digital input (H1-0x=61 or 62). Next, choose the Speed Search method in parameter b3-24. The proper Speed Search solution depends on the type of installation, so recommended uses for each Speed Search method are listed below. Also outlined below are the basic setup procedure and troubleshooting techniques for each Speed Search method. When it comes to troubleshooting, the trending feature in DriveWizard is a great tool to monitor multiple signals from the drive. If this is not an option, the keypad works as well.

Current Detection Method

Current Detection is the preferred method for the following situations

- High inertia loads such as fans/blowers, centrifuges, etc.
- Installations where Auto-Tuning can't be performed
- When the motor speed remains relatively constant during free-run
- When multiple motors are run from a single drive

Basic Setup for Current Detection Speed Search

1) Enable Speed Search by parameter or digital input
2) Set b3-24=0 (Current Detection Method)
3) Perform an Auto-Tune for best results
4) Run the drive throughout its entire speed range
5) Monitor output frequency and output current using the DriveWizard trending feature or the keypad

Troubleshooting Current Detection Speed Search

- OL1/OL2 or OC when frequency sweep completes before reaching actual motor speed

If the output frequency stops sweeping down before it matches motor speed and triggers a high current fault such as OL1, OL2 or OC, check the V/f Pattern settings in the E1 group. Current Detection works best with a linear V/f Pattern. This means the volts per Hz ratio is constant across the entire speed range. This ratio is 7.66V/Hz for 460V/60Hz motors and 3.83V/Hz for 230V/60Hz motors. While all other Yaskawa drives default to a linear pattern, the Z1000 and Z1000U default to a variable torque pattern which has a reduced volts per Hz ratio below base speed. When using a variable torque pattern, the current can drop to the synchronization level (b3-02) prematurely. If Speed Search completes above actual motor speed, the drive will attempt to accelerate the motor while in a pulled out condition. This leads to higher than normal current and can cause drive faults. Set the frequency and voltage midpoints to keep the same volts per Hz ratio across the entire speed range. So for a 460V/60Hz motor, set E1-07=30Hz and E1-08=230V. Keep in mind there are preset V/f Pattern settings available in the drive such as high starting torque that can cause faults during Speed Search as well.

- OL1/OL2 or OC while frequency is still sweeping down

If the drive faults while it is still sweeping the frequency down, it is not synchronizing with the motor quickly enough. Output frequency is sweeping down too slowly, causing the drive to spend too much time in a high current condition. The two parameters to target in this situation are Speed Search Decel Time (b3-03) and Voltage Recovery Ramp Time (L2-04). Decreasing one or both of these parameters will allow the drive output to synchronize with the motor speed more quickly. Start by setting either b3-03 or L2-04 to 2/3 of its default value. If the same problem persists, decrease the other one to 2/3 of its default value. Continue to decrease both parameters if necessary.

- OL1/OL2 or OC immediately upon Speed Search completion when drive output frequency appears to be synchronized with motor speed

In most cases, completing Speed Search when output frequency is slightly above actual motor speed is preferable. This ensures the drive is in a motoring condition so that a regenerative solution is not necessary. This is why the default Speed Search Detection Level (b3-02) is 120% of drive rated current in V/f control mode. Some extremely high inertia applications however, require the drive output frequency to more closely match motor speed. Decreasing b3-02 to 110%, 105% or even lower can help eliminate high current faults in these types of applications.

- OV In either of the two cases above

If the drive trips on OV in these cases, use the same parameters (b3-02, b3-03, L2-04) but adjust them opposite from the solutions above. For example, increase b3-03 and/or L2-04 if a high current fault occurs during the sweep. Increase b3-02 if a high current fault occurs immediately upon Speed Search completion.

- OC or OV occur immediately

This can happen is residual voltage is still present in the motor. Increase the Speed Search Delay Time (b3-05) to allow this voltage to decay.

- OL2 near minimum frequency

The default Minimum Voltage setting (E1-10) in most drives yields a higher volts per Hz ratio near Minimum Frequency (E1-09) than the rest of the speed range. This often leads to increased current. Couple that with the accelerated OL2 counter at low speeds and you can end up faulting the drive. Decreasing Minimum Voltage to 2/3 of its default setting can help eliminate these faults.

- Motor immediately accelerates from zero to full speed at start

Motors that start out unloaded or lightly loaded can be abruptly accelerated at start because the initial output frequency is either maximum frequency or frequency reference. If this is undesirable, use Current Detection 2 (if available) or Speed Estimation.

Speed Estimation Method

Speed Estimation Method is the preferred method for the following situations

- When the motor direction is backward or unknown when given a run command
- When the possibility of overspeeding is unacceptable
- When a truly "bumpless" solution is required
- When lower current is desired

Basic setup for Speed Estimation Speed Search

1) Perform an Auto-Tune (rotational if possible) or enter proper motor data
2) Enable Speed Search by parameter or digital input
3) Set b3-24=1 (Speed Estimation Method)
4) Enable bi-directional Speed Search (b3-14=1) if the motor may rotate in reverse
   Note: Some form of braking (dynamic braking, regenerative converter, line regeneration unit, etc.) may be required to bring a reverse rotating load back into the forward direction. This may not apply to the U1000 family since they are fully regenerative.
5) Run the drive throughout its entire speed range
6) Monitor output frequency and output current using the DriveWizard trending feature or the keypad
7) Pay particular attention to the initial output frequency and motor speed, make sure they match

Troubleshooting Speed Estimation Speed Search

- Incorrect initial output frequency or inconsistent results

The drive uses its Automatic Current Regulator (ACR) to determine the motor speed. Sometimes the default values of the ACR PI loop are not aggressive enough and cause misdetection of motor speed. Try increasing the ACR P Gain (b3-08) to 0.80 and/or decreasing the ACR I Time (b3-09) to 1ms. This technique is particularly effective when misdetection occurs at higher speeds.

- OL1/OL2 or OC immediately upon Speed Search completion when drive output frequency appears to be synchronized with motor speed

Similar to Current Detection, forcing a motoring condition is preferable when using Speed Estimation. Rather than using a detection level though, Speed Estimation applies a gain to the detected speed to make this happen. This gain is called the Speed Search Detection Compensation Gain (b3-10) and it defaults to 1.05. This means that a 5% adder is applied to the detected speed, and that becomes the initial output frequency. For example, if the drive detects motor speed of 30Hz with b3-10=1.05, the initial output frequency will be 31.5Hz. You can run into the same issues with extremely high inertia loads in Speed Estimation too, so decreasing b3-10 is sometimes necessary. A setting of 1.02 or 1.03 has proven effective in these cases

- OC or OV occur immediately

This can happen if residual voltage is still present in the motor (same as with Current Detection). Increase the Speed Search Delay Time (b3-05) to allow this voltage to decay.

Current Detection 2 Method

Current Detection 2 is the preferred method for the following situation

- If Current Detection 2 is available on your drive, use it!

- Current Detection 2 is available on the following drives

    a) GA800 (and future drives)
    b) U1000 Industrial
    c) Z1000U
    d) Z1000U Bypass

- The original Current Detection method is not available on drives that have Current Detection 2

Basic setup Current Detection 2 Speed Search

1) Enable Speed Search by parameter or digital input
2) Set b3-24=2 (Current Detection 2 Method), this is the default setting for drives that have Current Detection 2 available
3) Enable bi-directional Speed Search (b3-14=1) if the motor may rotate in reverse, this is the default setting
   Note: Some form of braking (dynamic braking, regenerative converter, line regeneration unit, etc.) may be required to bring a reverse rotating load back into the forward direction. This may not apply to the U1000 family since they are fully regenerative.
4) Perform an Auto-Tune for best results
5) Run the drive throughout its entire speed range

Troubleshooting Current Detection 2 Speed Search

- OC Faults during Current Detection 2 Speed Search

Although rare, Overcurrent faults can occur with this method. Sometimes the default setting of the Voltage Recovery Ramp Time (L2-04) is too aggressive. In these cases, voltage ramps up too quickly and can cause OC faults. Increase L2-04 in 1 second increments to avoid this. Setting L2-04 too high can cause OL2 faults though. If this happens, set L2-04=2sec (or the highest setting that doesn't cause OL2) and start increasing b3-31 in 0.1 increments.

- The backspin function isn't working as anticipated (U1000 only)

The backspin function (b3-50 – b3-53) should only be used when the following two conditions are true. 1) Current Detection 2 and Power-loss Ride-thru are both enabled. 2) While coasting after a power-loss, the load will cause the motor to rotate opposite its normal run direction. Knowledge of the motor direction in this condition is necessary to properly setup the backspin parameters. Set b3-50 for the minimum amount of time the motor will remain rotating forward after power is lost. Set b3-51 for the maximum amount of time it takes for the motor rotation to change direction while coasting.

- OPE08 when setting backspin parameters (U1000 only)

When setting up the backspin function, enabling bi-directional Speed Search will counter intuitively trigger an OPE08 fault. Make sure to set b3-14=0 when setting the backspin parameters. An OPE08 will also be triggered when b3-50 is set greater than b3-51.