White Paper

High Slip Braking Software

Applicable Product: V1000, A1000, E7, F7, G7, and P7
(V/f Motor Control Method)

Mike Rucinski,
Manager, Applications Engineering, Yaskawa Electric America, Inc.
Paul Avery,
Sr. Product Training Engineer, Yaskawa Electric America, Inc.

HIGH-SLIP BRAKING SOFTWARE PUTS THE BRAKES ON TRADITIONAL LOAD-BRAKING METHODS WITHOUT EXTERNAL EQUIPMENT

The techniques for braking of high inertial loads to a stop traditionally involved either Dynamic Braking or DC Injection Braking technology.
This article examines a new load-braking alternative called High-Slip Braking (HSB). We identify the different aspects of HSB, look at what it does, how it works, and how it is different from other braking methods. We also provide examples of "real world" successes, and discuss the new technology's cost effectiveness.

WHAT DOES HSB DO?

High-slip braking allows the stopping of larger inertial loads without the need for expensive and bulky braking options such as Dynamic Braking packages. Inertial loads involve only inertia and friction and given enough time, will tend to stop on their own when power is removed. HSB is most effective in applications involving infrequent stopping of inertial rotating loads where speed control during stopping is not required. Typical applications of this sort include; laundry equipment, centrifuges, large commercial fans, punch presses, blowers and mixers. Do not use HSB on overhauling static loads like; hoists, winches, elevators, product lifters, and similar applications. HSB is applicable only for complete stopping of the load and not as a means of braking for speed changes.

The HSB feature has proven to cut braking times in half without requiring extra equipment. The overall stopping time, however, does depend on the inertia of the load being stopped and the characteristics of the motor. HSB can achieve braking torque of more than 100 % of the full motor torque.

HOW DOES HSB WORK?

When any motor acts as a brake, it becomes a generator. HSB controls the motor in a way that makes it a "very poor" generator. In fact, HSB functions by controlling motor slip so that all the load-generated energy is absorbed in the motor itself. Since none of the generated energy is fed back to the drive, no dynamic braking or line-regeneration unit is needed to dispose of it.

An induction motor needs current and slip to produce torque. Positive slip produces motoring torque and negative slip produces braking torque. HSB regulates negative motor slip to an amount much greater than what typically is used for braking with a standard motor-control algorithm. This process creates the required braking torque while keeping the regenerative energy flowing back into the drive at or near zero. In essence, the motor operates as an inefficient generator.

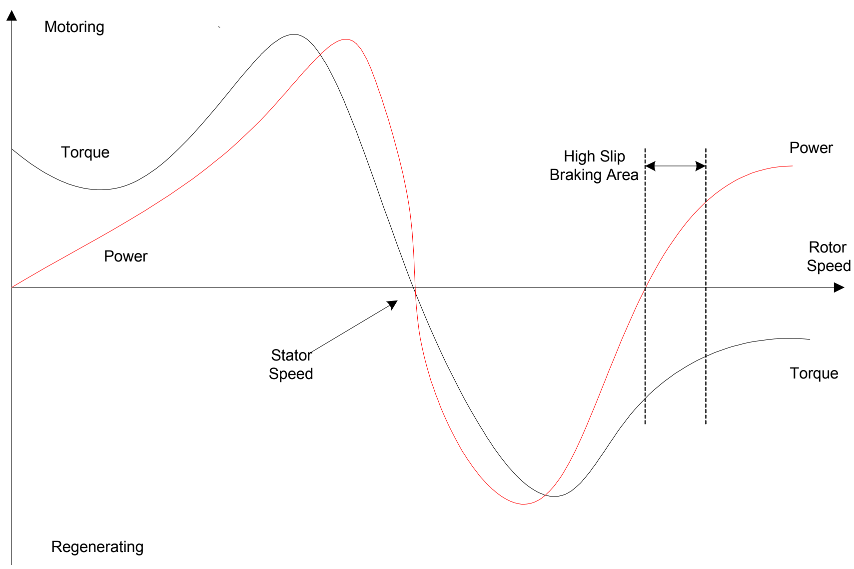

Figure 1. Positive and Negative Slip

When HSB is invoked, the control creates a large negative slip by stepping the stator frequency considerable lower than the actual rotor speed (hence, negative slip). The large step change in applied stator frequency operates the motor with a slip frequency larger than the slip to produce normal motor breakdown torque. A braking force is generated due to the negative slip. However, regenerative energy reflected back to the drive is minimal as the losses in the motor are large while operating at the large slip. Therefore, the drive's DC bus does not rise as it normally would when decelerating a high inertia load. However, as the rotor speed slows and approaches the applied stator frequency, the drive's DC bus begins to rise as the motor losses reduce and power begins to regenerate back to the drive. The drive monitors the DC bus voltage and upon reaching a pre-configured level the HSB function again will step the stator frequency down to create the proper negative slip condition to restrict regeneration.

HSB does have limitations. Most of the mechanical energy transferred from the load gets dissipated in the motor as heat during HSB. Even though this increased motor heating only occurs during braking, it does limit the number of stops per hour. The upper limit on the amount of energy absorbed by the motor during high-slip braking can be calculated from the inertia (J) and the radian speed (ω) by the formula:

$$\text{Energy} = \frac{1}{2} J\omega^2$$

Energy is in Joules (Watt·seconds), inertia (J) is in kg·m2, and radian speed (ω) is in radians per second.

$$\omega = \frac{\pi}{30} \bullet \text{Speed in RPM}$$

Also, HSB, by its nature, only regulates motor slip not motor speed. It does not enforce any particular deceleration pattern during the braking process. Actual stopping time depends on total inertia, the motor speed when the command is given, and the torque / slip characteristics of the individual motor. Furthermore, the motor characteristics are temperature dependent. This makes precise stopping times hard to predict.

APPLICATION SUGGESTIONS

Due to HSBs reliance on motor characteristics, auto-tuning the drive to the motor is strongly recommended. Auto-tuning enables the drive to determine critical motor parameters so that optimum motor performance is achieved.

As mentioned above, HSB stopping times are dependant on the load inertia and speed. As the inertia increases or speed increases, the resulting stopping time also will increase.

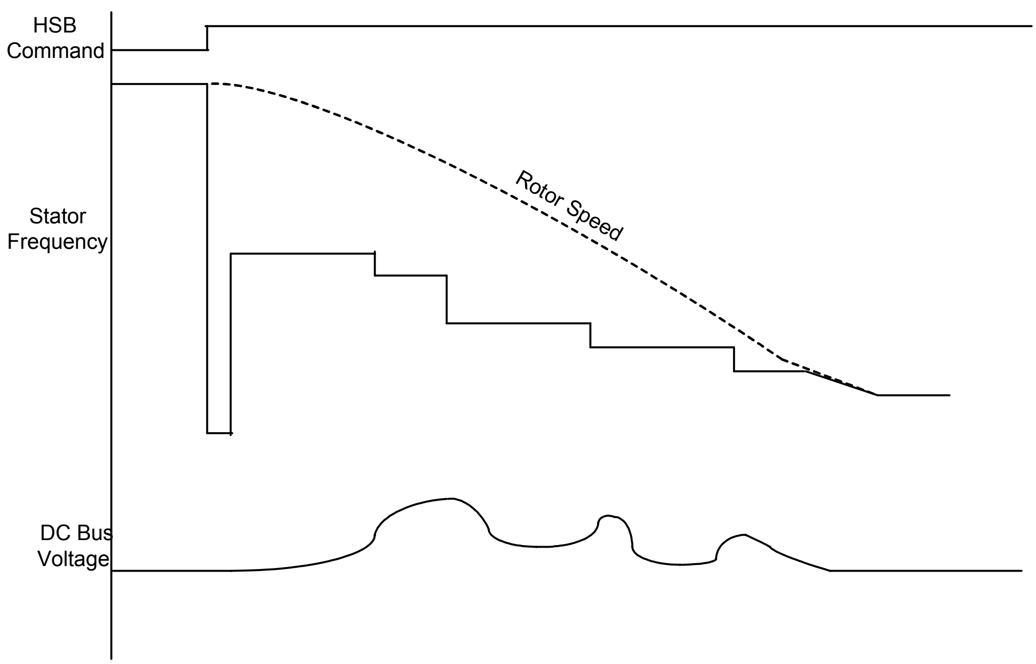

Figure 2. Load Inertia and Speed

Some large inertial loads that have little friction sometimes will continue to creep after the high-slip braking process ends. If this occurs, enable DC injection braking at stop. This will stop any tendency to creep. Never use HSB on overhauling static loads like hoists, elevators, product lifters, and the like. For these applications consider dynamic braking (chopper and resistor) or line regenerative braking.

WHAT DIFFERENTIATES HSB FROM THE OTHER BRAKING TECHNIQUES?

HSB is not the only technique for stopping large inertial loads quickly. Dynamic Braking and DC Injection Braking are both common. Each method has its own advantages and disadvantages.

Dynamic Braking (DB) is a very effective method of stopping because the braking torque can be up to 150 % of the full-load motor torque and the deceleration profile is controlled. Dynamic Braking operates the motor under normal slip conditions inherent with standard drive control. Required braking times and load inertia determine the sizing of the extra equipment necessary for DB. Part of what makes DB a desirable choice is that the drive follows the programmed deceleration time regardless of the load inertia, providing predictable deceleration. In addition, DB is effective even for load decelerations that do not lead to stopping (speed reductions). The main drawback though is that a brake chopper and resistor are required for control, which means a 20-30 % increase in the cost of the drive.

DC Injection Braking applies DC voltage to the motor's stator winding to create a magnetic field whose stationary polarity will place a drag on the rotating polarity of the rotor's magnetic field. A VFD with DC Injection capability is all that's needed for DC Injection Braking, so the cost is zero. DC injection is most effective at low speed for preventing creep during stopping. Braking torque drops off markedly as speed increases. Only limited braking torque is possible with DC injection, which is generally about 67 % of the full motor torque. In addition, DC Injection Braking subjects the drive to increased stress as the current is not shared evenly among output phases and increased heating occurs in the drive's output transistors.

In between Dynamic Braking and DC Injection Braking is where HSB's capabilities lie. HSB allows greater braking torque and greatly shortened stopping times than possible with DC Injection Braking. It is far less expensive and offers the advantage of no extra maintenance and wiring when compared to Dynamic Braking.

REAL WORLD SUCCESS!

To further under stand the impact that HSB can have on a application, we can review the results of some interesting tests that have been done within actual applications.

The first application is an industrial washing machine that has the capacity to wash an impressive load of 600 pounds of linen. The normal coast-to-stop time of the fully loaded machine from the extract speed is 25-30 minutes. After auto-tuning the drive and configuring the HSB function, the ramp time of the same load from the same extract speed is reduced to a mere two minutes, a stopping time nearly 15 times faster.

To really qualify the HSB function's abilities, we need to compare it to the other two braking techniques. Dynamic Braking actually was able to stop the load faster, but it came with a price tag. The DB method stopped the load in one minute and 20 seconds, but the cost of the extra equipment necessary for this ability was 30 % of the cost of the drive. The other free braking method, DC injection braking, takes 10-15 minutes to perform the same stopping sequence as DB and HSB.

A second application involves a centrifuge used in the Dairy industry. Here, it took the centrifuge about 20-25 minutes to coast to a stop. With the help of HSB, this stopping time was reduced significantly to 3.5 minutes. Just like in the laundry applications, DB performed a faster stop than HSB but at a prohibitive cost addition. DC Injection Braking couldn't even achieve a stopping time acceptable to the customer.

WHAT MAKES HSB COST EFFECTIVE?

HSB saves both cycle time and money by not requiring dynamic braking equipment while still giving vastly improved stopping times. The lack of extra equipment also leads to less maintenance and smaller enclosure sizes.

A YASKAWA INNOVATION

There are distinct and unique advantages to using the HSB feature. It saves money, cycle time, and maintenance costs. When used properly and under the right circumstances, HSB is an ideal choice for applications that involve high inertia loads.

The engineers at Yaskawa Electric developed this method of stopping large inertial loads without the added costs of existing braking methods in an effort to innovate new ways to save their customers money while still delivering them a world class product.

Yaskawa Electric is a world leader in the manufacturing of AC drives, servomotors, motion controllers and robotics. Its breakthrough HSB technique was introduced with the release of its industrial workhorse F7 drive. The concept behind this break-through function is simple, but impact can be impressive.

Yaskawa now makes the HSB function a standard feature on newer drives and as a software upgrade on some older drives for the industrial market. Comparing HSB to other stopping methods is a good way of discovering the benefits of yet another Yaskawa innovation.