Regeneration Vs Dynamic Braking in DC Drives

RELIANCE ELECTRIC

Application Solution

Introduction

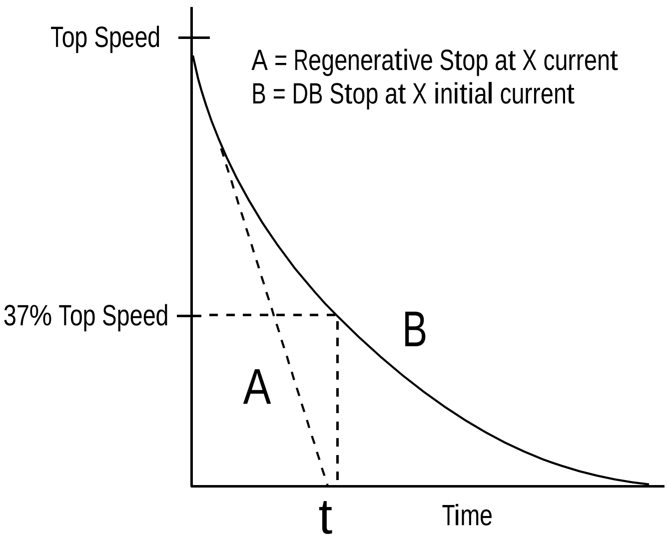
Both regeneration and dynamic braking (DB) slow down a rotating DC motor and its load, but when should one method be chosen over another, or when possibly should both be used? There are significant differences in stopping time, controllability during stopping, and safety issues depending how one defines what should happen under emergency conditions. Many application requirements may dictate that a regenerative drive be selected for an application. This comparison however deals only with regeneration with respect to stopping performance. First let's review exactly what regeneration and DB are in a DC phase controlled drive.

Discussion

REGENERATION in a phase controlled DC drive involves a second (antiparellel connected) rectifier bridge. During regeneration, mechanical energy from the rotating load and armature (now acting as a generator), is inverted from DC directly back onto the AC power line. The reversal of current in the DC motor causes a braking action to slow the rotating load. It is a controlled process. The drive is operating and in control of the load during regeneration. Regeneration does not occur when the drive is in a coast/DB stop mode or when a drive fault shutdown occurs.

DYNAMIC BRAKING on a phase controlled DC drive is an “uncontrolled” process. During DB, the motor armature is disconnected from the drive. A resistor is placed across the motor's rotating armature (now acting as a generator) and the resulting current causes braking torque in the motor that decays exponentially (assuming no overhauling load and fixed motor field) with the motor's Counter Electro Magnetic Force (CEMF). The motor will decelerate, even with a drive failure, as long as motor field excitation is maintained.

Figure 1. Relative Stopping Times



The following is a list of characteristics to consider:

1) STOP TIME

<u>Regen</u>: The deceleration torque is constant down to zero speed in fixed field applications. It is a function of the decel rate setting of the drive, or current limit setting if the decel rate causes limit to be reached. Minimum stop time occurs in a current limit stop with limit set as high as possible. Neglecting frictional losses, the stopping time is easily calculated with the following equation:

t = RPM * inertia / 308 * T

t = time in seconds

RPM = motor speed when stopping begins in revolutions/minute

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Inertia = total motor and reflected load inertia in lb-ft^2
T = motor torque during regeneration in foot pounds

DB: In fixed field applications, the deceleration torque decreases exponentially with speed (armature volts) and is a function of the total armature and DB grid resistance. The grid is often sized to allow 150% of rated armature current to flow at top speed (voltage). As the motor slows down, the armature voltage decreases and hence the current and decelerating torque continually decrease. In the time a regenerative 150% current limit stop would occur, this DB stop would reduce the speed to 37% of top speed (this again assumes negligible friction losses). In twice that time, the speed would be down to .37 x .37 = 14% of the original speed etc. Eventually the motor will reach zero speed. Of course observed stopping time will be somewhat quicker than calculated given the actual frictional losses.

General: In both cases the decel time is proportional to the speed and total rotating inertia. Those two entities define the amount of kinetic energy that needs to be “disposed of” in either case. Consider the example where a 150% current limit stop from top speed is compared to a DB stop from top speed (where the DB grid was selected to allow 150% initial DB current). At the first instant of stopping both methods allow the same current and hence the same decel torque. The regenerative drive maintains that current and torque through the stopping cycle. The decel current in the DB case immediately begins to reduce because the motor speed and voltage are decreasing. See figure 1.

2) DRIVE STATUS
Regen: The drive must be energized and running for regeneration to occur. Regenerative stopping occurs when a “Normal” stop command is given. This is also known as a “Ramp” stop where the drive regenerates and decelerates as necessary to follow the decel ramp. If there is not enough torque to follow the ramp at current limit then the drive decelerates in current limit. Some drives also have a "Current Limit Stop" mode. This is a regenerative stop where the decel ramp is bypassed causing a current limit deceleration. During a regenerative stop the contactor is not opened until zero speed is detected. One other consideration is that a regenerative drive can be decelerated by lowering the speed reference without the need to put the drive into a stop mode.

DB: The drive must have the DC contactor open for DB stopping to occur. This typically occurs with a Coast/DB Stop command or a drive fault where the drive is in a standby mode.

3) FAULT CONDITIONS
Regen: Under drive fault conditions the drive is put into standby and the contactor is opened. There is no regeneration. The load coasts unless DB or a mechanical brake is applied.

DB: Under drive fault conditions, the DC contactor opens applying the DB grid across the motor for a DB stop.

General: What happens under drive fault conditions is a major consideration because this could happen at any time during any operating conditions (eg. tach loss of field loss). The application and or user preference will dictate if is OK to coast or if DB is required. The drive will not regenerate since a fault immediately puts the drive into standby and opens the contactor. Some applications that require regeneration for other reasons may require DB as well for braking under fault conditions.

4) "EMERGENCY" CONDITIONS
General: "Emergency" conditions are not for us to define. Different applications and different user preferences dictate what the drive should do under conditions that the user defines as an emergency. The fastest and surest way to disconnect the motor from the power source is with a Coast/DB stop. The contactor is opened, by a “hard-wired” mechanism immediately. The drive will DB if the proper contactor and grids are present, otherwise it will coast. Regeneration will not occur.

Typically, the fastest way to bring the load to a stop is with a current limit regenerative stop with current limits set to the maximum. Constant regenerative torque is provided for the entire stopping process provided the drive remains energized and that no drive faults occur. Some applications that require the fastest stopping time may employ a current limit stop with a time delayed Coast/DB stop as a backup. All stopping sequences should have the ability to employ the Coast/DB stop at some point since it will open the contactor even in the event of regulator malfunction.

5) REPETITION

Regen: In regeneration, the energy from the rotating load is converted and returned to the AC power lines for consumption elsewhere. The energy is not dissipated and no heating occurs other than the normal thyristor losses in the power unit. Regeneration can occur for as long as necessary and as repetitively as necessary within the thermal limitations of the drive and motor itself. This typically would be 150% regenerative current for one minute or equivalent. In a cyclical application, the RMS of the total current waveform (motor and regen) must not exceed the 100% rating of the drive.

DB: During DB, the energy from the rotating load is lost as heat in the DB grid. Because dynamic braking is not a continuous occurrence, the grids are usually sized for intermittent operation. Several successive DB cycles without sufficient time for cooling can damage or destroy the grids. Typically grids may be sized for three successive operations from top speed before a cooling period is required. Motor and connected load inertia must be used (or estimated) in these calculations. Consideration must also be given to equipment near or in the same enclosure with the grids so that the air temperature does not exceed acceptable limits during DB occurrences.

6) COST COMPARISONS

General: A regenerative phase controlled drive has twice the power components and driver circuitry of a non-regen drive and is correspondingly more expensive. Adding DB to a drive requires adding the grids and associated housing. If the drive contains a DC contactor it must have the normally closed pole to connect the grid across the motor. If the drive does not have a DC contactor then one must be added. These factors must all be considered in evaluating the price difference between adding DB or going to a regenerative drive.

NOTE: Assumes Fixed Field and Negligible Friction Losses.

Conclusion

Some applications require regenerative stopping, some require dynamic braking, while still others require both. Making the proper selection involves four main considerations:

1. What is the required stop time under normal stopping conditions for the application? Regen can be the fastest and deceleration doesn't necessarily require the drive be put in a stop mode.
2. What is the required stop time under drive and/or system fault conditions? Regen does not occur under these conditions. DB may be required whether or not the drive is regenerative.
3. How does the user define "emergency" stopping? Is the only concern to get the motor disconnected from the power source (coast or DB) or is the fastest deceleration necessary (Regen with a coast or DB backup)?
4. How repetitive is the stopping cycle? The more often, the more heat, and the more likely regen will be advantageous.

Exploring these aspects of the application will lead to the right decision regarding the need for regen, DB, both, or possibly neither if coasting is always acceptable.

NOTE: This material is not intended to provide operational instructions. Appropriate Reliance Electric Drives instruction manuals precautions should be studied prior to installation, operation, or maintenance of equipment.

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