Allen-Bradley

Regeneration Overview

What is Regeneration?

Rockwell Automation

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What is Regeneration?

When the rotor of an induction motor turns slower than the speed set by the applied frequency, the motor is transforming electrical energy into mechanical energy at the motor shaft. This process is referred to as ‘motoring’. When the rotor turns faster than the synchronous speed set by a drive output, the motor is transforming mechanical energy from the motor shaft into electrical energy. It may be a ramp to stop, a reduction in commanded speed or an overhauling load that causes the shaft speed to be greater than the synchronous speed. In any case this condition is referred to as ‘regeneration’. Essentially, mechanical energy is converted to electrical energy. The case is much the same for a DC drive and motor. The increase in DC voltage for the DC drive occurs at the armature connection. Some DC drives have not only a forward but also a reverse bridge. The reverse bridge allows the DC energy from the armature to be transferred to the utility line. If the DC drive has only the forward bridge, a shunt regulator can be used in parallel with the armature to dissipate this energy. On most AC drives, utility power is first converted into DC by a diode or SCR rectifier bridge. These bridges are very cost effective, but only handle power in the “motoring” direction. Since the laws of physics state that energy is never lost or gained, this energy needs a place to go.

Motoring
When the rotor of an induction motor turns slower than the speed set by the applied frequency, the motor is transforming electrical energy into mechanical energy at the motor shaft.

Regeneration
When the rotor turns faster than the synchronous speed set by a drive output, the motor is transforming mechanical energy from the motor shaft into electrical energy – referred to regeneration.

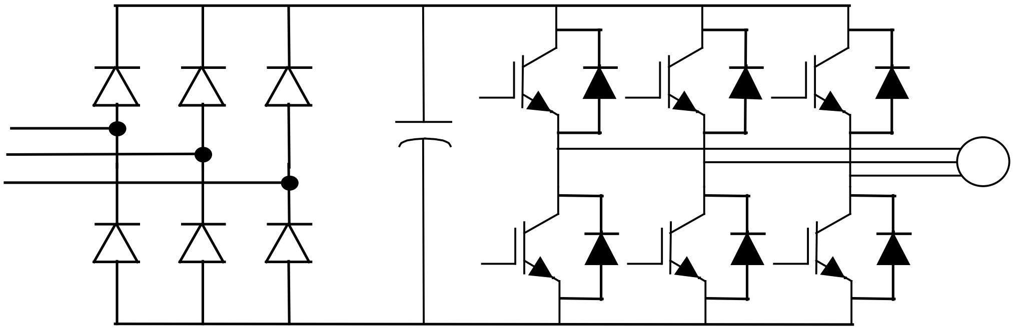


Figure 1

If the motor is regenerating, the DC bus voltage will increase. Unless a method of dealing with the regenerative energy is provided, the drive will protect itself with a Bus Overvoltage trip, thus stopping the regenerative condition. There are three ways to handle this energy.

1. Release this energy in the form of heat through a voltage regulated switching transistor and resistor. This series circuit is placed across the DC bus and is often called "chopper" or "Dynamic Brake". Other names for these units are "Shunt Regulator" or "Snubber".

2. Provide either a "regenerative bridge converter" or a "regenerative brake" that has the ability to change the DC bus energy into fixed frequency utility power.

3. Take several drives and tie the DC bus connections together such that "regenerative" energy from one motor / drive can be absorbed and used by another "motoring drive on the same DC bus line.

Dynamic braking is one of the simplest and most common methods of dealing with regenerative energy.

Since "Dynamic braking" is one of the simplest and most common methods of dealing with regenerative energy, let's cover this first. The figure 2 below is a schematic diagram of a dynamic brake circuit. The three major components are the transistor (switching device), the resistor and the control circuit.

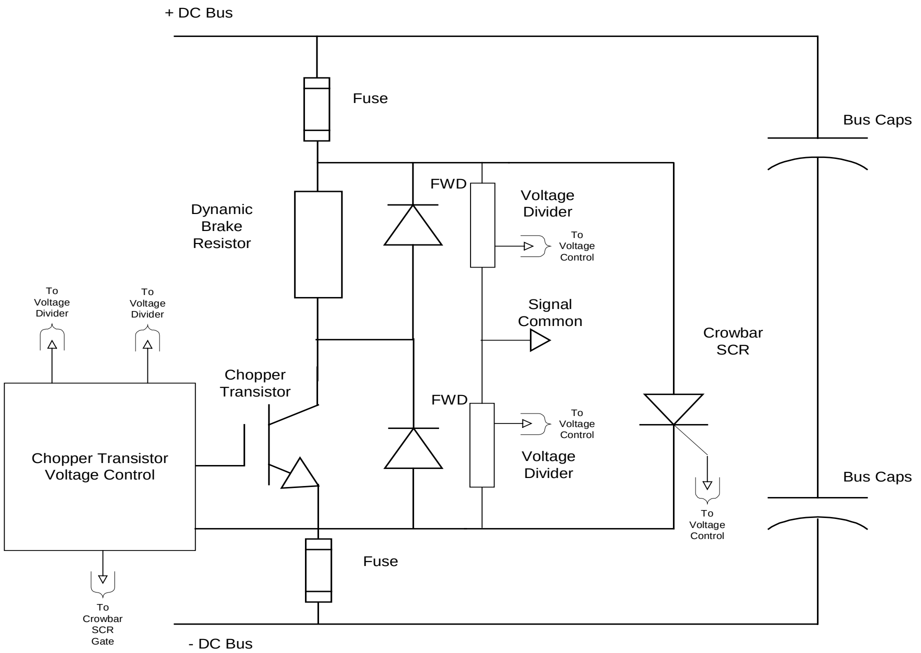


Figure 2

The whole circuit acts as a voltage regulator. The control circuit monitors the DC bus voltage level and turns the switching device on and off at the appropriate level. In the case of a 460 volt drive, the nominal DC bus voltage is about 650 volts. If the DC voltage reaches about 810, the drive will protect itself with an over-voltage trip. A 460 volt dynamic brake will regulate the DC bus voltage to about 750 volts. This provides enough voltage margin to prevent the over-voltage trip but does not interfere with the 650 volt nominal level observed during a "motoring" condition. When regeneration pushes the DC bus up to 750 volts DC, the switching device turns on allowing current to flow in the resistor. Regenerative energy is then released into heat. This causes the DC voltage to drop. The switching device will stay on until the bus voltage reaches about 735 volts DC and then turn off. This difference between turn on and turn off voltage is called hysteresis. For this reason one can observe DC voltage bouncing between 735 and 750 while the dynamic brake is active. The dynamic brake function is the same for drives rated at 575 and 230 volts. The turn on and turn off voltage levels are adjusted to accommodate the respective nominal DC bus levels.

Now that we understand that dynamic braking is converting mechanical energy in to heat energy, let's look at the different types of mechanical (kinetic) energy we need to deal with.

Rotational

In the case of a large rotating mass such as a Centrifuge. The stored energy is:

$$\frac{1}{2} \bullet Jw^2$$

Where *J* is the moment of inertia in Kg Meters squared and *w* is the angular velocity (rotational speed) in radians/second. From this equation we can see that the energy is proportional to the square of the speed. This means that if we cut the speed in half we will have only ¼ the kinetic energy. For this reason, a uniform "linear" ramp to stop from a given speed results in a linear reduction in the transfer of energy.

Linear

This type of load can generally be characterized by a large mass such as a conveyor belt or transfer car being driven by a motor through a gearbox. Though the dominant component or stored energy may be in the large mass traveling in a linear motion, calculating the stored energy is much the same. Kinetic energy for this case is:

$$\frac{1}{2} \bullet MV^2$$

Where *M* is the mass in Kg and *V* is the velocity in meters per second. In the case of the linear rotational load, ramping to a stop from a given speed will result in a linear decline in power being absorbed by the brake over the given deceleration time. See figure 3.

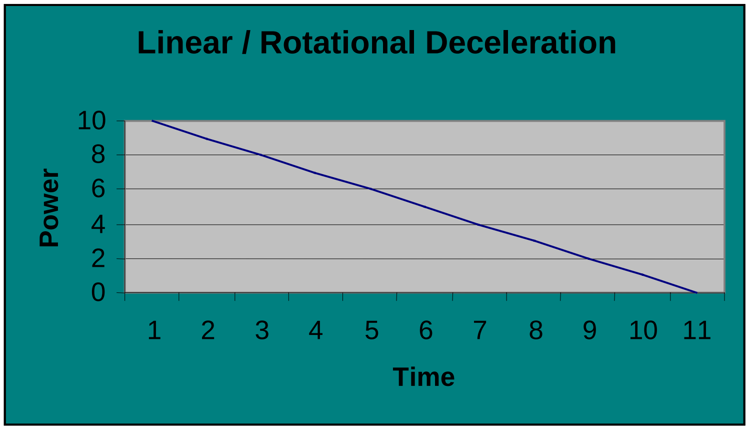


Figure 3

Overhauling Load

An overhauling load, on the other hand, usually acts a bit different. The big difference here is that the condition that causes the overhauling can be sustained for extended periods of time. An example would be an incline conveyor where material is being moved from the top to the bottom of the conveyor. The weight of the material constantly being loaded on the belt provides a continuous regenerative energy source. In this case the power into a dynamic brake will most likely be constant as seen in figure 4 below.

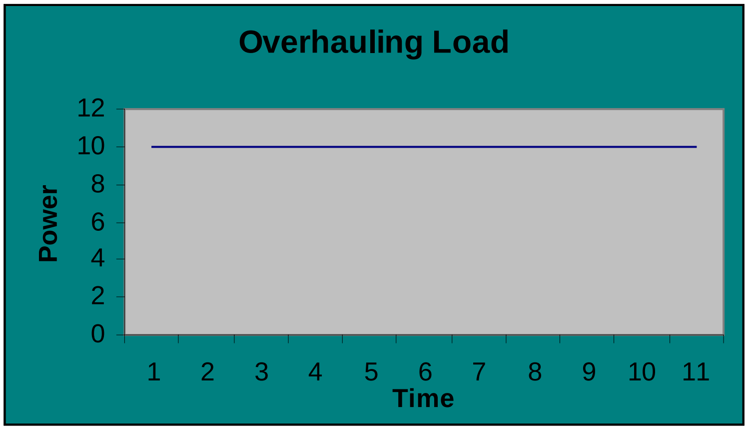


Figure 4

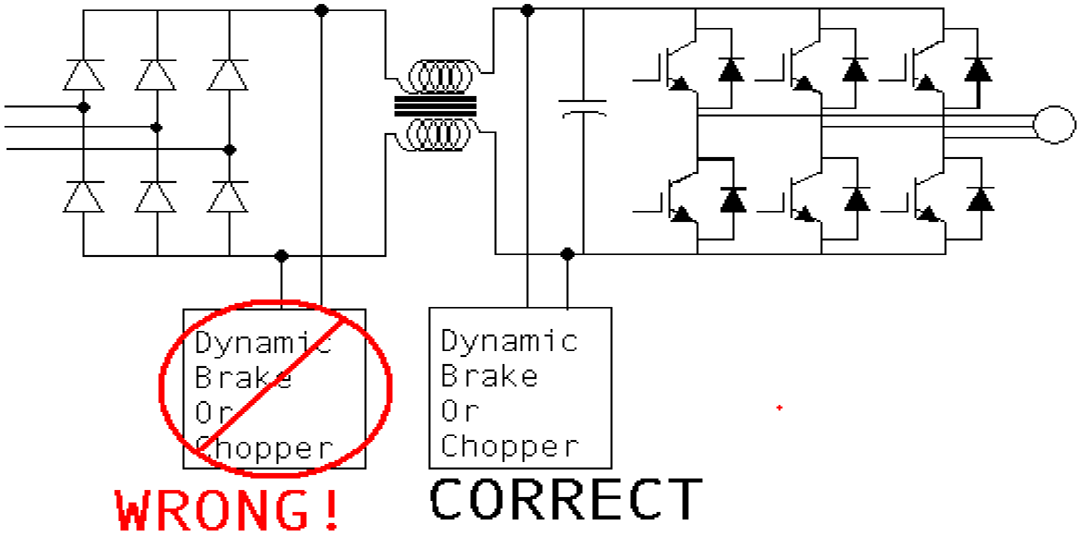
Dynamic Brake
Dynamic brakes have the controller, switching device and resistor housed in one self-contained unit. It is rated in horsepower and has only a 20% duty cycle rating.

Chopper
A chopper contains only the regulator circuit and switching device and is rated in amps. The resistors are treated as a separate component.

Dynamic Brake or Chopper – What's the difference?

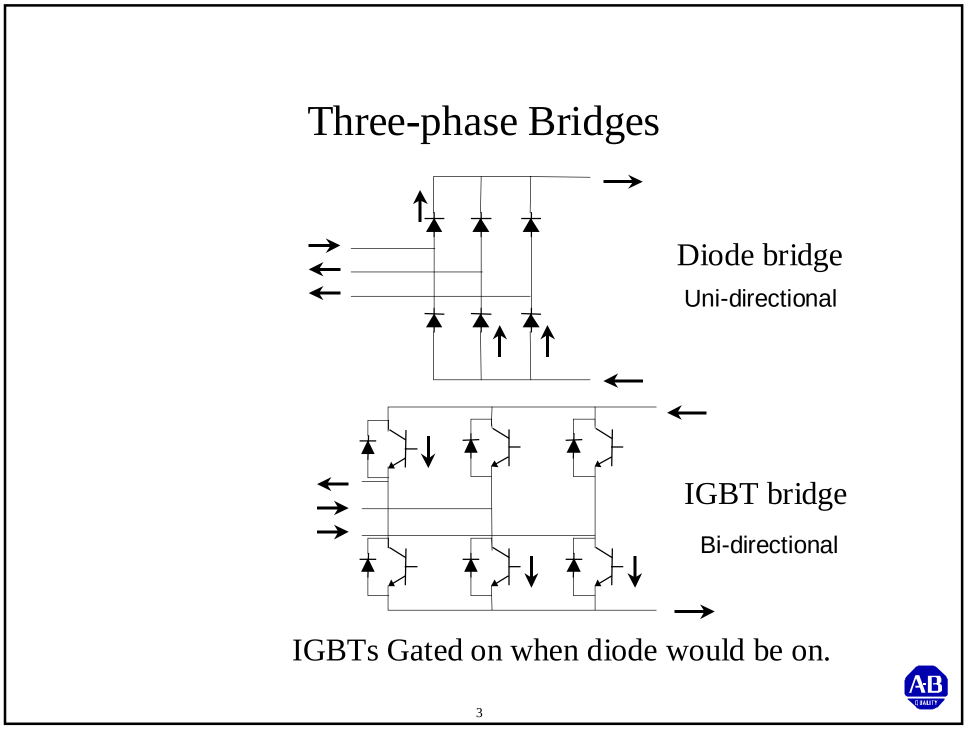
From an electrical standpoint they both do the same thing. The major difference is in the construction. Dynamic brakes have the controller, switching device and resistor housed in one self contained unit. It is rated in horsepower and has only a 20% duty cycle rating. A chopper contains only the regulator circuit and switching device and is rated in amps. The resistors are treated as a separate component. This gives the user several advantages. First, the resistors can be accurately sized for a given application. Also, the chopper module can be mounted in an enclosure while the resistor, with the large amount of heat energy to dissipate, can be remotely mounted up to 100 feet away. A close look at the application is needed before a decision to use a brake or chopper is made. Some rotational and linear loads with a low regenerative duty cycle can be handled with a brake while overhauling loads, and loads with a duty cycle greater than 20% are more suited to a chopper. In general, the chopper is a more "heavy duty" solution. When the 20% duty cycle is exceeded, it may be difficult to determine the cause of the brake failure.

Another cause of failure for dynamic brakes and choppers that warrants mention is misconnection. These devices need to be connected at the capacitor bank nodes of the DC bus. Many drives also provide a DC bus connection point at the input bridge rectifier nodes. **DO NOT USE THIS CONNECTION POINT!** If the connection is made here the current in the chopper or dynamic brake may pass through the DC link choke. This choke will produce a voltage spike when the power switch (IGBT) turns off. In most cases this spike will far exceed the rating of the IGBT switching device resulting in a failure of the Device. **Pay attention to the connection points!**



Line Regen Brake

Like dynamic brake or chopper, a line regenerative brake connects to the DC bus and prevents an over-voltage condition by providing a place for motor and load energy to go when a motor is acting as a generator. This however is where the similarity ends. Unlike the dynamic brake and chopper, the regen brake has no voltage regulator or power resistor. It does not attempt to regulate the drive bus voltage. Rather, it uses a set of IGBT switches synchronized to the AC line to provide a path for current flow should the DC bus voltage become higher than the line. See figure 5 below.



Three-phase Bridges

Diode bridge

Uni-directional

IGBT bridge

Bi-directional

IGBTs Gated on when diode would be on.

Figure 5

Other supporting hardware required but not shown are a 3% reactor and a precharge circuit.

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