What is dynamic braking?

Dynamic braking is the use of the electric motors as generators when slowing the machine speed. It is termed rheostatic if the generated electrical power is dissipated as heat in brake grid resistors, and regenerative if the power is returned to the supply line. Dynamic braking lowers the wear of friction based braking components, and additionally regeneration can also lower energy consumption.

How to change the motor speed?

By applying a torque (work in a period of time):

$\Delta n \approx (T * \Delta t) / J$

Where:

Δn:	change in speed
$T = Tm + Tc$:	total system torque: motor torque + load torque
Δt:	duration of speed change
J:	moment of inertia for motor and load-motor shaft

When the signs of torque and speed are opposite the motor transforms into a generator and the energy is returned to the drive

"Braking" or "Dynamic braking"?

We say "braking" to the natural decrease of motor speed due to natural dissipation of energy in the losses of the motor (it happens when we cut the power). The internal friction naturally and progressively slows the motor and it takes several minutes.

We say "dynamic braking" to the forced decrease of motor speed. The motor acts as a generator and the energy tries to store itself in the DC bus. This energy must be dissipated; otherwise the drive will go into overvoltage alarm of the DC bus. The braking time is directly related to the resistor value.

What does Overhauling mean?

A condition which exists when a motor is coupled to a load requiring a speed which is faster than required by the drive. The drive then tries to slow speed of motor. This condition causes the

motor to act as a generator and return energy back to the drive. The condition is different than a deceleration braking because the energy is constant during this period. This means the resistor has to absorb 2X (twice) the energy during the overdrive situation than during a deceleration braking.

Types of dynamic braking

- Deceleration braking (as found on ventilation systems - figure 1)
- Overhauling load braking (as found on conveyors, cranes - figure

Figure 1

Regeneration type: Deceleration
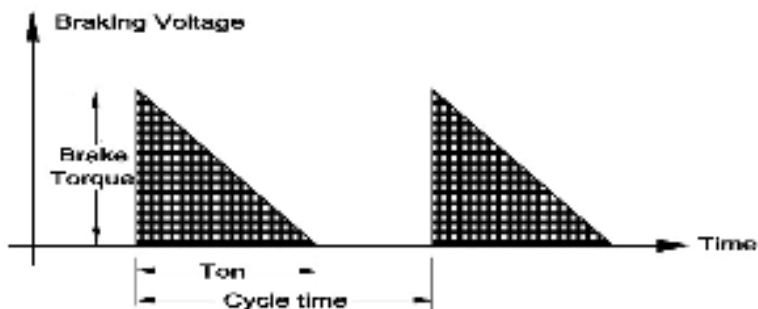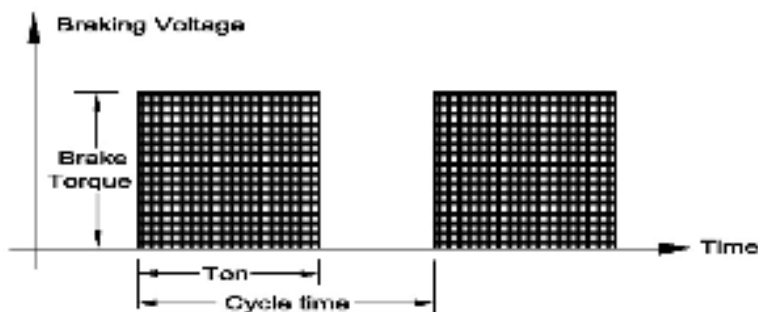
DC = Ton / Cycle Time   ▓ Braking Energy

Braking Voltage

Brake Torque

Ton

Cycle time

Time

Figure 2

Regeneration type: Overhauling

Energy = 2 x Deceleration energy approx.

Braking Voltage

Brake Torque

Ton

Cycle time

Time

2)

Which information do we need to specify the dynamic braking resistor?

- Drive horsepower
- DC bus voltage, drive input voltage

- Maximum braking power
- Continuous power
- Minimum value of dc resistance accepted by the drive
- Maximum value of I (braking current) accepted by the braking circuit
- Braking torque 100% or 150%
- Duty cycle 10/20/50%. Maximum braking time: 60 sec.
- Type of dynamic braking: deceleration or overhauling
- Maximum temperature rise
- Desired enclosure (affects the cooling) inside / NEMA
- Thermal switch installed on (alarm contact, NC)

What does DC bus voltage mean?

The continuous voltage of the DC bus which is the result of the drive rectification of the input AC voltage. The DC bus voltage appears prior to the drive inverter circuit on the DC bus capacitors. The output section of the drive chops the DC bus voltage to create the 3 phase output voltage and supply the power to the motor. The maximum DC bus voltages for the associated AC input voltages are:

- 230Vac = 350-400Vdc
- 460Vac = 750-800Vdc
- 575Vac = 925-975Vdc

If the DC bus voltage exceeds the level permitted by the drive, a transistor in the drive braking circuit is activated and the energy in redirected in the braking resistor.

Let us take a look to an example

Basic formulae:

	Deceleration (figure 1)	Overhauling (figure 2)
Vdcbus max	Vac x 1.35 x 1.2 *	Vac x 1.35 x 1.2 *
Vac	Input AC (drive input voltage)	Input AC (drive input voltage)
P_cont	P_peak x 0.5 x DC	P_peak x DC
P_peak	HP x 746 x BT	HP x 746 x BT
BT	1.0 = 100% / 1.5 = 150%	1.0 = 100% / 1.5 = 150%
DC	T_braking / t_cycle	T_braking / t_cycle
HP	HP_motor	HP_motor

- Figure 1 and figure 2: refer to "types of dynamic braking" question
- * according to manufacturer

Where:

$R\_BRAKING = (Vdcbus\ max)^2 / P\_continuous$ Important tip = Braking time < 60sec.

P_cont =   Continuous Power
P_peak =   Peak Power
BT =   Braking Torque
DC =   % Duty Cycle
HP =   HP of motor

EXAMPLE:

- **Drive:**
  - Rmin = 5 ohms
  - Max current for braking circuit = 130 amps
- **Motor (75 HP):**
  - Drive input voltage = 460 VAC
  - Braking Torque = 150%
  -

Operation cycle: ON = 3 sec
                 OFF = 15 sec

Regeneration type	Deceleration braking
Wattage motor average	75HP x 746W/HP = 55950W
Wattage motor peak	55950W x 150% = 83925W
Value of DC bus Voltage	460 VAC x 1.2 x 1.35 = 745.2 VDC approx 750 VDC
Value of braking resistor	(750 VDC^2) / 83925W = **6.7 ohms > 5 ohms OK**
Duty Cycle	3sec / (3sec + 15sec) = 0.167
Wattage continuous of DBr	83925W * 0.167 / 2 = 7008W
Braking Current (Bi)	(83925W / 6.7 ohms)^0.5 = **112A < 130A OK**
DBr Current (DBri)	(7008W / 6.7 ohms)^0.5 = 32.4 Amps

Regeneration type	Overhauling load
Wattage motor average	75HP x 746W/HP = 55950W
Wattage motor peak	55950W x 150% = 83925W
Value of DC bus Voltage	460 VAC x 1.2 x 1.35 = 745.2 VDC approx 750 VDC

Value of braking resistor	(750 VDC^2) / 83925W = **6.7 ohms > 5 ohms OK**
Duty Cycle	3sec / (3sec + 15sec) = 0.167
Wattage continuous of DBr	83925W * 0.167 = 14016W
Braking Current (Bi)	(83925W / 6.7 ohms)^0.5 = **112A < 130A OK**
DBr Current (DBri)	(14016W / 6.7 ohms)^0.5 = 45.8 Amps

We must not forget

- Verify if the drive and chopper circuit are compatible with the value calculated of the resistor (Rmin and Rmax).
- Important to verify the resistor value which each drive manufacturer (VFD).
- If not available the manufacturer's will state the maximum braking current of the drive which will be the maximum current in the braking circuit transistor for the duration of the cycle.

DBr current = DBri = $(P\_peak/R\_Braking)^{0.5}$

- Braking time must be < 60 seconds.
- If the operation time is greater than 50% therefore the calculation method will be the overhauling method.
- Value of "R_Braking" and "C_DCbus" create a time constant "τ".

What if the duty cycle is higher than 50%?

If a deceleration braking load is specified with a duty cycle higher than 50%, we must use the overhauling calculation method. This is because the braking waveform no longer looks like a right triangle but begins to look more like the rectangular pattern of the overhauling load.

Which are the mechanical considerations to keep in mind?

- Place to be installed: braking resistors physical dimensions must be considered when we are planning a new installation, specially when we are talking about a running system (reduced spaces).
- Thermal dissipation due to electrical needs and place to be installed. Forced ventilation may be needed.
- Optional wall or roof mounting types.

Which are the basic applications of braking resistors?

• Dynamic braking AC/DC drives
• Neutral grounding resistors

- Linear and non-linear load banks
- Harmonic filters
- Alternate and DC motor acceleration
- Speed regulation
- Conveyors
- Cranes