Shunt Regulation

When the motor is used to slow the moving load, this is called regenerative deceleration. Under this operation, the motor is acting as a generator consuming energy from the load while passing the energy into the DC Bus storage capacitors. Left unchecked, the DC Bus voltage can raise high enough to damage the drive. For this reason there are protection mechanisms built into the Geo Drive product such as shunt regulation and over-voltage protection.

The shunt regulator monitors the DC Bus voltage. If this voltage rises above a present threshold (Regen Turn On Voltage), the Geo Drive will turn on a power device intended to place the externally mounted regen resistor across the bus to dump the excessive energy. The power device keeps the regen resistor connected across the bus until the bus voltage is sensed to be below the Regen Turn Off voltage at which time the power device removes the resistor connection.

Minimum Resistance Value

The regen resistor selection requires that the resistance value of the selected resistor will not allow more current to flow through the Geo Drive's power device than specified.

Maximum Resistance Value

The maximum resistor value that will be acceptable in an application is one that will not let the bus voltage reach the drive's stated over voltage specification during the deceleration ramp time. The following equations defining energy transfer can be used to determine the maximum resistance value.

Energy Transfer Equations

Regen, or shunt, regulation analysis requires study of the energy transferred during the deceleration profile. The basic philosophy can be described as follows:

- The load has stored energy in its rotating mass.
- The drive removes this energy by transferring it to the DC Bus.
- There are significant energy losses in the transfer, both electrical and mechanical.
- The DC Bus capacitors can store some energy.
- The remaining energy, if any, is transferred to the regen resistor.

Understanding this process in all its individual parts, it is possible to analyze the shunt regulator circuitry in more detail.

Energy Stored in the Load

Energy stored in the moving mass is a function of inertia and velocity according to the equation:

$$e_L = 0.678\, j \varpi^2$$

Where:

J is the total system inertia (including motor) in $lbftsec^2$

ω is the velocity of the motor in Radians per Second

e_L is the stored energy, in Joules (watt-seconds), of the load

Energy Loss in Transmission

The energy loss in the transmission of the energy occurs in two distinctive areas. First, the motor's resistance burns energy in simple watts. Second the mechanical gearing, bearings, and linkages present a frictional loss. The motor's resistive losses can be calculated for a linear deceleration profile as follows:

$$e_{xr} = \frac{3}{2} i * r_{phase} * t_d$$

Where:

i is the current used during deceleration in amperes

r_{phase} is the motor's resistance phase-to-phase in ohms

t_d is the time duration of the deceleration profile in seconds

e_{xr} is the lost energy in Joules (watt-seconds)

The mechanical transmission energy losses can be calculated as follows:

$$e_{xm} = 0.678i * T_{friction} * \omega t_d$$

Where:

$T_{friction}$ is the total friction in $lbftsec^2$

ω is the velocity of the motor in Radians per Second

e_{xm} is the mechanical energy loss in Joules (watt-seconds)

t_d is the time duration of the deceleration profile in seconds

Energy Stored in the Drive

Not all regenerative energy is spent in the resistive dump process. The drive has bus capacitors capable of storing some of the returned energy. This energy storage is calculated using the following equation:

$$e_c = \frac{1}{2} c\left(v_1{}^2 - v_2{}^2\right)$$

Where:

C is the total bus capacitance in the drive in Farads

V_1 is the Bus Voltage at which Regen turns on

V_2 is the nominal bus voltage

e_c is the energy stored in Joules (Watt-Seconds)

Need for Regen Resistor

Any energy that is not lost in the transmission of the energy and cannot be stored by the bus capacitors must be dumped by the Regen circuits into the regen resistor. The following equation summarizes the energy flow:

$$e_{excess} = e_1 - e_{xr} - e_{xm} - e_c$$

Phrase this slightly differently and it can be stated that if e_{excess} is less than or equal to 0 there is no need to use an external Regen Resistor.

Regen Resistor Wattage

Converting this energy into wattage can allow the rating of the regen resistor to be analyzed. The unit of Joule is converted to wattage by dividing by the duty cycle of the overall motion profile.

$$Watts_{rms} = \frac{e_{excess}}{t_d}$$

Where:

T_d is the motion profile duty cycle, in seconds.

The peak wattage rating of the regen resistor is determined simply by dividing the square of the DC bus overage specification by the resistors ohm value:

$$Watts_{Peak} = \frac{V_{ov}^{\;2}}{R}$$