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Monthly Informative Application Guidelines, with respect to *Motors & Drives* to keep you better INFORMED.

APPLICATION GUIDELINE #39

(Dynamic Braking)

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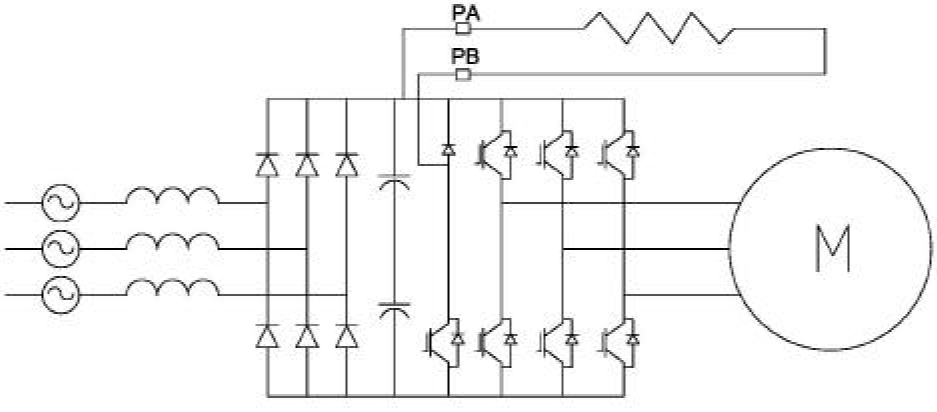
When a motor is connected to a 60Hz sinewave power and is turning faster than its synchronous speed, it will generate power back to its power source. An example of this would be if a conveyor is moving product down a hill. This same principle allows motors to be used as an induction generator. Power generation is directly proportional to slip much the same way as motor torque is directly proportional to slip. Essentially, if the rotor is turning faster than the rotating magnetic field, the motor becomes a generator. If the rotor is turning slower than rotating magnetic field, the motor acts as a motor.

With the preceding principle in mind, a motor connected to a drive can be used to rapidly slow down or stop a load. If, for example the inverter output frequency is 55Hz (1800RPM motor is turning at 1630 RPM) the motor can be slowed by smoothly reducing the output frequency. When the frequency is reduced, the motor's rotor is now rotating faster than the rotating magnetic field and therefore becomes a generator. When a motor is braking (decelerating), the energy from the motor flows back to the drive and causes the DC bus voltage to rise. If there is nowhere for the energy to go, the DC bus voltage rises to the trip level and the drive is taken off line and the load coasts to a stop. In a high inertia application that could mean a very long time before the load comes to a complete stop. If, however, a "7th" IGBT is added to the DC bus and an external Dynamic Braking (DB) resistor is connected to that transistor, the motor's braking energy can be very effectively dissipated.

Dynamic Braking resistors can be purchased with different duty ratings. A 100% duty rated resistor (by Toshiba's definition) is capable of dissipating 100% braking torque for 50% of the time that it is connected to a drive, if the motor is operating at full rated speed (typically 60Hz). 'Percentage torque' hence 'HP' hence 'Watts Dissipated' is a function of the rate of deceleration (deceleration torque or negative acceleration torque). An example of this would be a continuously overhauling load such as a downhill conveyor, if the overhauling load was 100% of rated torque at 30Hz, a 100% duty rated resistor would be large enough. The logic is that 1 HP = 746W. A 1 HP motor outputting full rated torque at 1/2 speed is developing 1/2 HP because HP = T x RPM / 5252. If speed is half, HP is half therefore wattage is 1/2. The same 100% duty rated resistor is capable of dissipating 200% braking torque while linearly ramping a motor from 60Hz to 0Hz for 50% of the time that it is connected to a drive. The average speed of the braking cycle is 30Hz. This means that the average HP during braking would be 100%. Again, HP = T x RPM / 5252, if T = 200% and average RPM = 50%, average HP = 100%. Please note that a linear deceleration rate will not provide a



constant current to low from the motor to the drive, ror will the drive regulate the current to a consistent number such as 100% or 150% etc. If braking from 70Hz to 0Hz or 80Hz to 20Hz the calculations get more complex and inertia, load, rate of decel etc. all play a role in the total integration of heating. In general, the G7 drive will try to decel the load at the rate that it is programmed to and the current required to perform the decel rate will be what it is. This makes calculation very difficult since heating is a function of I^2 x R.

Toshiba has created an acceleration/deceleration calculator spreadsheet which calculates a trip time based on resistor size, decel speed range, inertia and cycle times to better estimate accel/decel times. The calculator considers that current will be continuous at 150% resulting in the calculated decel time. If the decel time is increased in value, the current will no longer be 150% and the heating will be reduced. Further, if decel time is very large due to a very high inertia or overhauling load the drive's protection algorithm may cause a trip to protect the resistor. In other words, 50% duty cycle cannot brake a downhill conveyor motor at 60Hz for an hour. There is a definite trip time associated with 100% braking at 60Hz for a 100% duty rated resistor.

Voltage Level Considerations

From a drive design point of view, it is important to know at what level the drive activates dynamic braking and at what level the drive will trip. If the DC bus trip voltage is set too low, the drive is subject to nuisance tripping on overvoltage. In order to provide a reliable, **600V** industrial duty drive, the DC bus trip voltage needs to be above the 933V level for the following reasons.

- The DC bus voltage is approximately equal to the square root of 2 times the RMS AC input voltage. If the input voltage is 600V, the DC bus voltage becomes 848V. If the input voltage rises to 10% above nominal, i.e. 660V the DC bus voltage becomes 933V.
- If there are any transients on the line, the input voltage increases accordingly.
- When the drive slows the load down, the motor acts like a generator and transfers energy back to the drive further increasing the DC bus voltage.

To provide nuisance free, high performance braking, there has to be some headroom above the firing voltage of the dynamic braking transistor and the DC bus trip voltage. If the dynamic braking transistor firing voltage is set below 933V, the drive will try to regulate the system voltage every time the voltage exceeds 600V + 10% = 660V. This will cause nuisance trips or damage to either the dynamic braking transistor or the dynamic braking resistor.

Toshiba Dynamic Braking

Toshiba G3 & G7 series drives have dynamic braking as a standard, built in feature. The Toshiba drive’s IGBT7, (the dynamic braking transistor), is directly controlled by the microprocessor. Typically, dynamic braking circuits are provided on drives as an add-on module that is basically a DC voltage regulator. This means that when the DC bus voltage increases above a predetermined level, the transistor fires and dissipates energy into the externally connected dynamic braking transistor. Conventional dynamic braking circuits require an overload relay to protect the dynamic braking resistor plus they require an input contactor to shut power off to the drive in the event that a continued high input voltage level causes the dynamic braking circuit to continuously fire. (High input voltages can occur, for example, during a mill shutdown when the mill is essentially unloaded and the main incoming transformer does not have an automatic tap changer – or if the automatic tap changer is inoperative.) The Toshiba drive (when not running) will not fire IGBT7, even if the input voltage rises high enough to cause the DC bus voltage to rise above the IGBT7 firing voltage level. Further, the microprocessor directly protects the externally connected dynamic braking resistor. This eliminates the need to install an input contactor on drives with dynamic braking, which increases system reliability because there is no associated problems with input contactors disconnecting the drive from power during power dips.

Basic Formula's for estimating Acceleration and Deceleration times on motor/drive systems include the following, however for more accurate calculations, please contact you're local representative.

ACCELERATION FORMULA:

$$t = \frac{(Wk^2 * \Delta n)}{(308 * T_A)}$$

$where$: t = time in seconds

$\text{Wk}^2 = total$ inertia in $\text{lb}_f * \text{ft}^2$

Δn = change of speed in RPM

$$\text{T}_\text{A} = \text{available acceleration/deceleration torque in } \text{lb}_\text{f} * \text{ft} = 1.5 * \left(\frac{FLA_{INV}}{FLA_{MTR}} \right) * FLT_{MTR}$$

DECELERATION FORMULA (NO DYNAMIC BRAKING)

$$t = \frac{(Wk^2 * \Delta n)}{(37 * T_A)}$$

DECELERATION FORMULA (with DYNAMIC BRAKING or REGENERATION UNIT)

$$t = \frac{(Wk^2 * \Delta n)}{(308 * RB * T_A)}$$

$where$: RB = 0.2 if using a 20% Dynamic Braking Resistor "Light Duty"
= 0.6 if using a 60% Dynamic Braking Resistor "Heavy Duty"
= 1.0 if using a 100% line regeneration unit

Suggested Ohm and "Heavy Duty" Watts Ratings for the Toshiba G3 & G7 Series VFD's are shown below.

			Heavy Duty Resistor		Light Duty Resistor		
INV			100%DBR		20%DBR		
TYPE FORM	MOTOR HP	100% KW	Minimum Rated Watt	Aprox Ohm	Minimum Rated Watt	Aprox Ohm	***Minimum DBR ohm***
G7-6015	1	0.8	309	953	62	2,858	**408**
G7-6025	2	1.5	618	476	124	1,429	**386**
G7-6035	3	2.3	928	318	186	953	**214**
G7-6060	5.0	3.8	1,546	191	309	572	**141**
G7-6080	7.5	5.6	2,319	127	464	381	**99**
G7-6120	10.0	7.5	3,092	95	618	286	**71**
G7-6160	15.0	11.3	4,638	64	928	191	**47**
G7-6220	20.0	15.0	6,184	62	1,237	187	**37**
G7-6270	25.0	18.8	7,730	50	1,546	150	**29**
G7-6330	30.0	22.5	9,276	42	1,855	125	**27**
G7-6400	40.0	30.0	12,368	31	2,474	94	**22**
G7-6500	50.0	37.5	15,459	25	3,092	75	**16**
G7-6600	60.0	45.0	18,551	21	3,710	62	**14**
G7-6750	75.0	56.3	23,189	17	4,638	50	**12**
G7-610K	100.0	75.0	30,919	12	6,184	37	**7.5**
G7-612K	125.0	93.8	38,648	10	7,730	30	**7.0**
G7-615K	150.0	112.5	46,378	8	9,276	25	**5.9**
G7-620K	200.0	150.0	61,838	6	12,368	19	**3.8**
G7-625K	250.0	187.5	77,297	5	15,459	15	**3.5**

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