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

APPLICATION GUIDELINE #9

(Speed Torque Curves)

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TORQUE

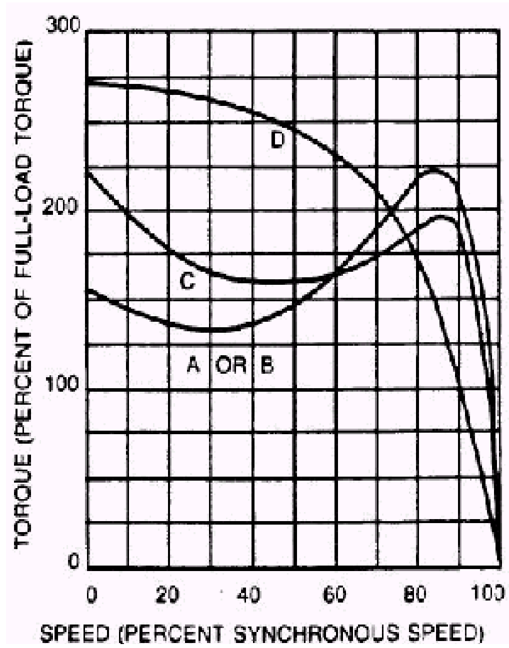
Torque refers to the turning effort exerted by the motor shaft. NEMA defines various torque characteristics for motors, which are designated as Designs A,B,C, and D. with Design B being by far the most common design used in industry. For each design classification, NEMA specifies performance parameters such as locked rotor torque, pull-up torque, breakdown torque (except for Design D), inrush current, and slip. The NEMA required minimum values are dependent upon the motor size and speed. Three values of torque are generally of particular interest, and are as follows:

(i) Locked Rotor Torque (LRT) - the torque developed by the motor at stand still, also know as starting torque.

(ii) Pull-up Torque (PUT) - the minimum torque developed by the motor as it accelerates from zero speed to the speed at which breakdown torque occurs.

(iii) Breakdown Torque (BDT) - the maximum torque that the motor is capable of developing.

The following chart indicates typical torque vs speed curves for typical NEMA Design A, B, C, & D motors.



Motor torque at any given speed is proportional to the square of the applied voltage. Thus, a 10% voltage dip during starting would result in $(0.9)^2$ =0.81% available torque. "Accelerating torque" is the difference between the motor torque and the load torque. Load torque is the torque required to drive the load, and includes the friction, windage, etc. of the load.

In order to determine the acceleration time of a motor driving a particular load, the torque vs. speed curves of both the motor and load must be provided, in addition to the load inertia and the power system information. The torque-speed curve for a given load is a function of the specific nature of the load. For instance, centrifugal loads such as centrifugal pumps and fans follow a square law relationship of torque vs. speed. That is, at zero speed, virtually zero torque is required, but the torque requirement increases as the square of the speed (to 100% torque at rated speed) as the load accelerates. Loads of this nature are generally referred to as "Variable Torque" (V.T.). Loads such as conveyors, screw pumps, etc. are generally referred to as "Constant Torque" (C.T.) loads, as they can require 100% torque (current) at any or all speeds. V.T. loads are therefore less demanding on motor starting performance, from the standpoints of torque and motor heating at less than full load speed. LRT and BDT are interdependent - each can be increased, but at the expense of the other. It is relatively easy to design a motor for a particularly high LRT, or a high BDT, but this would be at the sacrifice of the other. A thorough design should attempt to optimize both the LRT and BDT, and both should be considered when comparing torque.

Extra Torque capability for momentary overloads, and faster acceleration.

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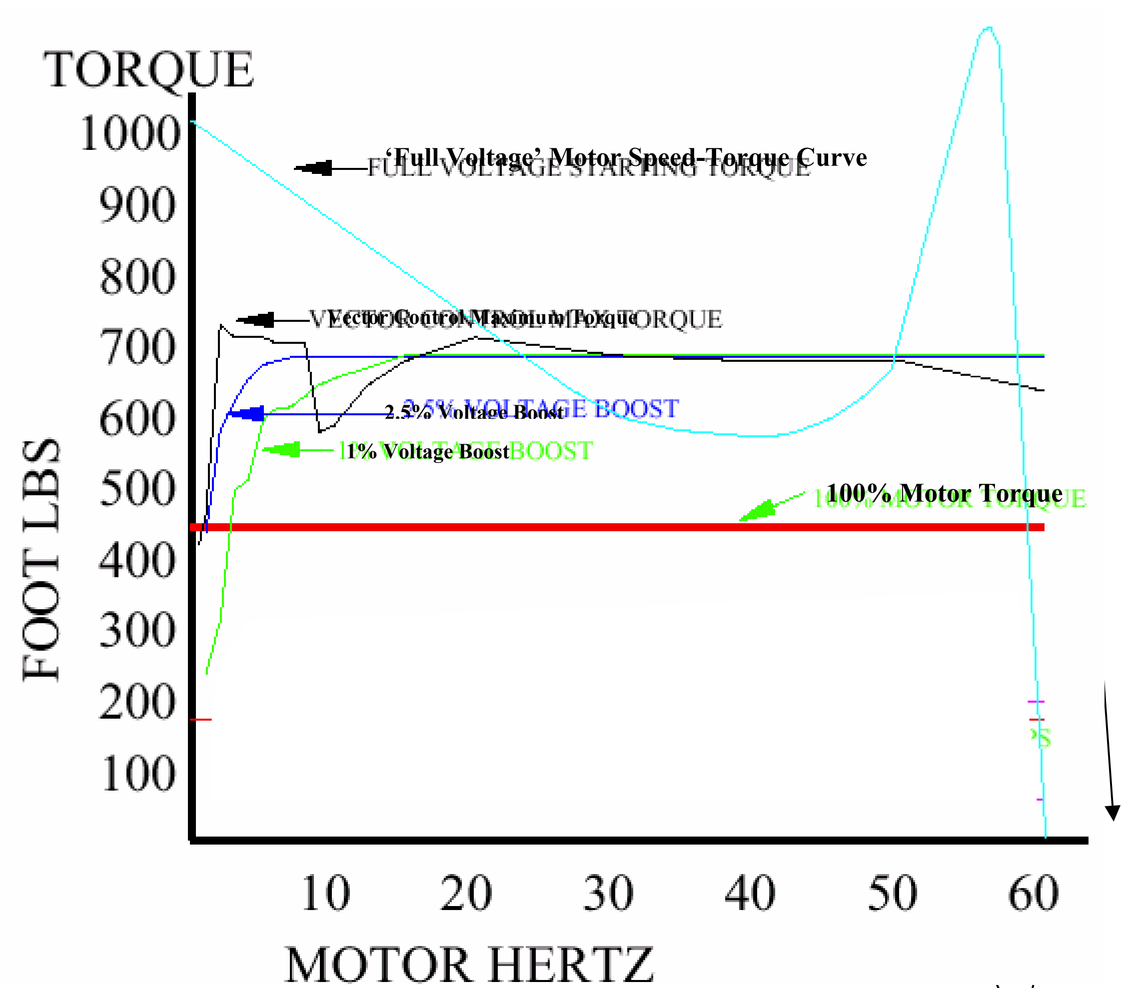
To take things a step further, factory tests on a 460v,150Hp Toshiba G3 VFD and 1800RPM Toshiba EQPIII TEFC motor was performed. This test will help explain some observations and will help in applying Toshiba G3 drive's for high starting torque applications. For the above system, these were our observations.

- Full Load Torque=$\frac{\text{hp x 5250}}{\text{RPM}}=\frac{\text{150 x 5250}}{\text{1782}}$=442 ft-lbs
- Full voltage start (across the line without the use of a VFD) has:
  1014 ft-lbs.(230%) start, 573 ft-lbs. (130%) pull up, 1146 ft-lbs. (260%) breakdown.
- Using factory parameters (no programming, standard PWM mode) in the G3, 318 ft-lbs. starting torque or 72% was observed.
- 2.5% voltage boost gives 433 ft-lbs. starting torque or 98%.
- Open loop vector control gives 616 ft-lbs. starting torque or 140%.
- Speed regulation was +/- 3 RPM from 1 Hz to 60 Hz.



Because a motor and VFD system operates in the linear region of a motor speed-torque curve, the pull-up torque is higher than that of a typical 'full voltage' motor speed-torque curve. This being the case, a motor and VFD system can have improved starting capability in demanding applications, even when compared against an across the line start.