Application Note: The electronic control of ALXION ST STK torque motors for direct drive of automated axis

ALXION ST STK Torque motors are three-phase permanent PM multipolar synchronous motors with high energy rare earth iron- neodymium permanent magnets.Therefore, they can be controlled by electronic servo drives and motion control systems available on the market. We give the following informations for correctly interfacing our torque motors with the drive or motion controller:

Mains voltage

Standard torque motors characteristics and related torque-speed curves correspond to operation with drives supplied by 400 V ac mains voltage.

According to the prescriptions of standard IEC EN 60034-1 : 2010 regarding motors supplied by mains up to 500 V ac, all standard ST and STK torque motors are controlled in insulation in plant at 2000 V ac rms, 50 Hz, between phases and earth and between phases in "surge test." , at various stages of manufacturing. In addition, regarding electronic drives supplying ST and STK ALXION torque motors, the standard motors are compatible with drives supplied by grids up to 500 V ac maximum provided that the output voltage of the drive at motor terminals would comply with standard IEC EN 60034-25 : 2007, level A.

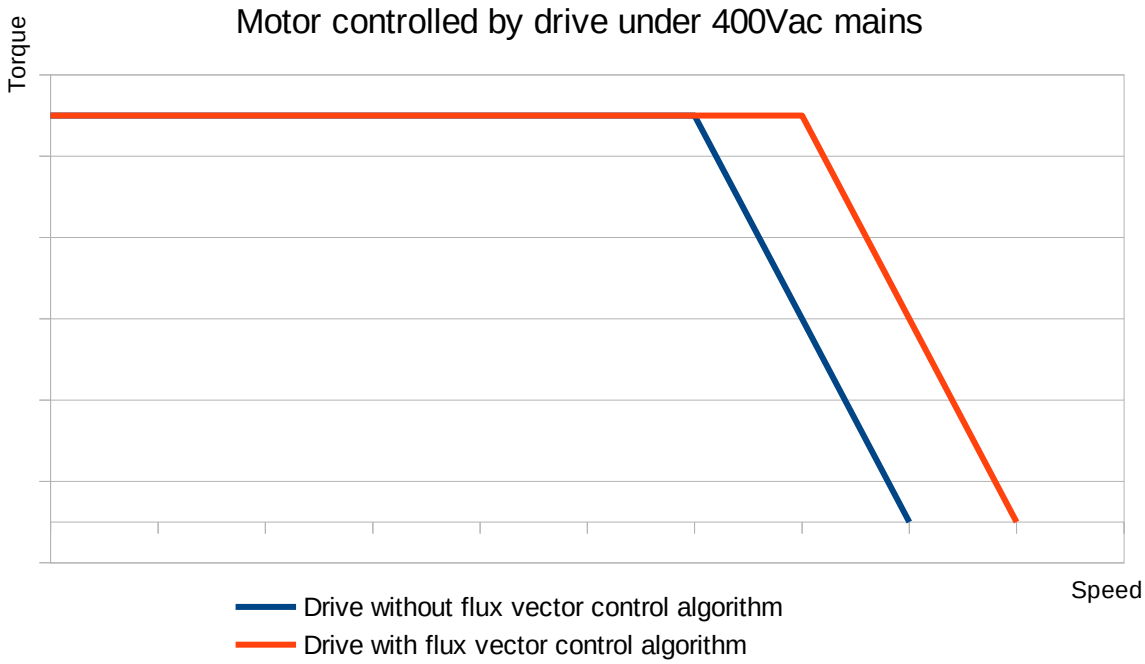
It should be noted that the use of grids below 400 V ac leads to maximum torque-speed characteristics derating. The use of grids above 400 V ac leads to potential higher maximum instantaneous power but can cause in high power motors a slight derating of rated characteristics. For further information, we recommended to contact our technical department.

Torque vs speed characteristics depending on the voltage level available at the output of the drive at motor terminals:

Two kinds of drive or motion controllers can be individuated in that respect:

- electronic drives of older design whose maximum fundamental line to line voltage at the drive output is equal to 330 V AC for 400 V ac mains
- electronic drives of modern design, equipped with flux vector control algorithm, in which the maximum fundamental line to line voltage is equal to 380 V /390 V ac for mains voltage of 400 V ac.

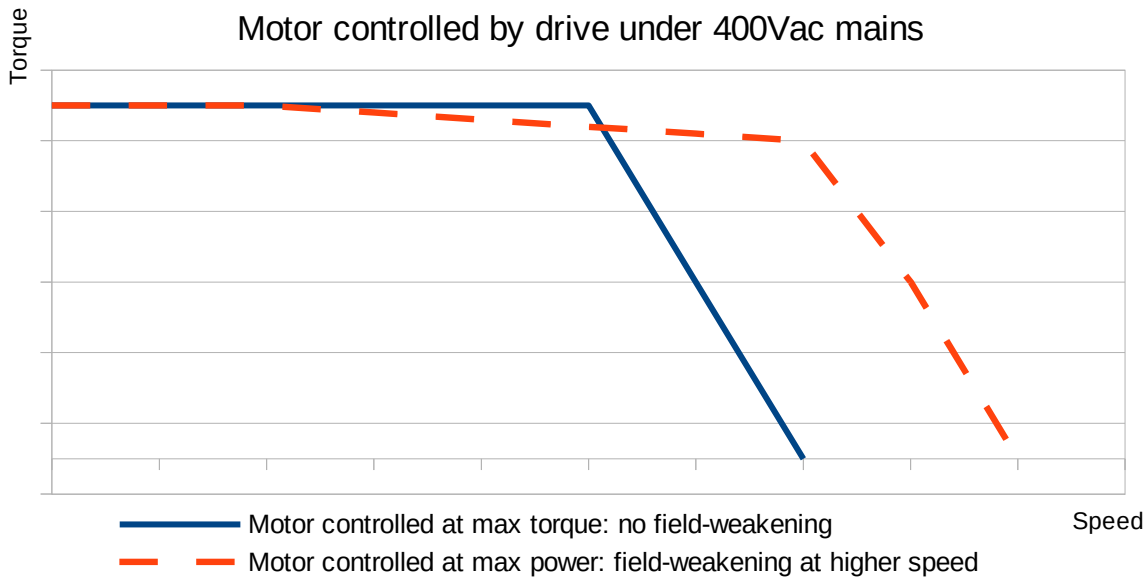
The standard torque-speed characteristics of ST and STKtorque motors are plotted by considering a fundamental voltage of 330 V ac at motor terminals, thus corresponding to drives under 400V ac mains not equipped with flux vector control algorithm . In the case of a torque motor suplied by a drive with flux vector control algorithm, the maximum speed at maximum torque, ie the maximum power will be greater. Another consequence is that for a given power output (ie for given torque and speed), we can consider a winding optimization leading to a higher torque constant or a lower current if the torque motor is controlled by a drive with flux vector control algorithm.



Field-weakening algorithms

Traditionnally, the motor was operated with drives in maximum torque position that is to say with magnets fllux and current axis at 90 arcdgrees. Hovever, most modern drives are equipped with field-weakening or « defluxing » algorithms. The weakening field consists in having a projection of the current with a negative value on the axis of magnets flux which results in decreasing the flux hence the voltage at motor terminals. Therefore, for a given current, the torque in a first approach is reduced by a factor equal to the sine of the angle between current and magnets flux, but as the power factor is increased when defluxing and can even reach unity, mechanical power can thus be increased. Clearly, for given values of current and maximum voltage, the output power is greater when operating with field weakening in an appropriate way as shown in the figure below.

The electromechanical characteristics and torque-speed curves are given in our catalogs regardless of field-weakening deed, that is to say by considering a 90 arcdgrees angle between current and magnets flux axis.



Encoders and position transducers

In ST complete torque motors , we propose the following position transducers which are generally compatible with most current drives and motion controllers (the # number represents the T digit in the ST motors part number):

- resolver with accuracy + / -10 arcminutes for solid shaft motors: # 6
- resolver with accuracy + / -1 arcminute for hollow shaft motors: # 1
- Incremental encoder sin cos ERN1381, 2048 and 4096 sinusoids optional, 1 v pp, solid shaft motor: # 5
- Incremental encoder sin cos ERN180, 2048 and 5000 sinusoids optional, 1 v pp, hollow shaft motors: # 2
- Incremental encoder sin cos ERN1387, 2048 sinusoids with commutation tracks, 1 v pp, solid shaft motors: # 4
- single-turn absolute encoder HIPERFACE Kit SCK 101, 1024 sinusoids , hollow shaft motors: # 3
- Single-turn absolute encoder EnDat ECN1313, 2048 sinusoids, solid shaft motors: # 8
- Single-turn absolute encoder EnDat ECN113, 2048 sinusoids, hollow shaft motor: # 7
- multi-turn absolute encoder EQN 1325 EnDaT, 2048 sinusoids per turn, 4096 turns , solid shaft motors: # 9

STK Kits of rotor-stator torque motors are supplied without encoder or position sensor. We distinguish two cases according to the user's needs.

In pure variable speed applications without position control and low bandwidth, it is possible not to use an encoder or encoder provided that the drive is equipped with a real-time algorithm estimating the rotor position (and thus the magnets one) to the stator (and therefore currents). This is particularly the case for most applications of continuous processes. Some drives and motion controllers among those cited further include optionally the algorithm for estimating the position thus avoiding the use of a position sensor.

In servo applications of position control and velocity control with high bandwidth, it is necessary to use a position sensor. A wide range of encoders or position transducers are available for the user during his study of mechanical integration depending on the resolution, the accuracy and the need of a hollow shaft or not:

- applications requiring a hollow shaft and a high precision : HEIDENHAIN ERA 4000 to 7000, ERP encoders 4000 to 8000, Renishaw RGH scales with hollow diameters up to 500 mm, resolution up to 360,000 sinusoids,accuracy up to 1 arcsecond ; Heidenhain encoders with bearings RCN and RON 700/800
- applications requiring a hollow shaft and a medium accuracy : Heidenhain encoder ERM 200, up to 7000 sinusoids and 300 mm internal diameter; instrumented bearings INA YRTM; resolvers ALXION + / -1 arcminute, inner diameter 90 mm; Hiperface encoders SCK kit 101, precision 3 arcminutes, up to 53 mm internal diameter; incremental encoder ERN180; EnDat absolute encoder ECN113
- high precision applications not requiring a hollow shaft: incremental encoder Heidenhain RON 285, 18,000 sinusoids, accuracy 5 arseconds ; RCN 2310, absolute encoder EnDat single-turn, 16384 sinusoids, 5 arcseconds.
- medium accuracy applications not requiring a hollow shaft:: absolute encoder EnDat Heidenhain ECN1313; ERN 1381 incremental encoders; SICK Hiperface SRS50

The informations relating to encoders and position transducers mentioned above for applications with STK torque motors are only indicative and may not be considered as exhaustive.

Switching frequency of the inverter driving the torque motor

Electronic drives for brushless permanent magnets motors electronically chop the rectified voltage (also possibly regulated) in order to create waves of phase currents and voltages at the motor terminals with variable frequency and amplitude. This operation is called PWM or Pulse Width Modulation.

The drives for permanent magnet brushless motors available on the market generally have a switching PWM frequency between 4 kHz and 20 kHz maximum. The switching frequency is set to a default value in factory and is configurable but needs a current derating (and power derating) if the frequency is increased. The standard switching frequency is generally lower on high power drives than on low power drives. Indeed, the dynamic losses (or switching losses) of power inverters are proportional to the PWM switching frequency. At high current, switching losses become predominant compared to static losses (or conduction losses) for high frequencies. In contrast, the torque motors have an interest in working with high switching frequencies for current shape approximating a pure sine wave with low harmonic distortion with the consequence of magnetic losses reduction. The PWM switching frequency is therefore a compromise between the inverter and the motor. The highest possible PWM frequency must be chosen in order to minimize motor magnetic losses without causing substantial derating of the drive. In some cases of high speed, low impedance applications, it can be necessary to use sine wave filters for damping PWM amplitude between drive and motor, depending on the kind of drive. It is recommended to consult ALXION in case of doubt. Practically, the PWM switching frequency of the drives controlling ST and STK torque motors is generally undertaken between 5 kHz and 10KHz.

Models of drives and motion controllers used with ST and STK torque motors

ST and STK Torque motors for direct drive have a total population of 12,000 units installed worldwide at the end of 2019 ; they are used in a wide variety of applications such as:

Machine tools and rotary tables
Extruders of plastics and rubber
Plastic injection machines
Bending machines, forming machines for tubes and wires
Handling machines and Robots
Machines for woven textile, dobby machines
Machines for nonwoven textile, lappers
Stage machines and amusement parks machines
Tire processing machines
Glass forming and decoration machines
Packaging machines
Instrumentation Machines
Printing machines, rotogravure
Machines for motion simulation
Radars
Terrestrial and submarine traction

Equipments of drives and motion controllers are often specialized for different kinds of applications.

This is particularly the case for machine tools which are the domain of the SIEMENS SIMODRIVE 611 or more recently SINAMICS S120, GE FANUC with drives SVM80, HEIDENHAIN EU ER drive systems.

Regarding general automation, our torque motors are driven successfully by drives and motion controllers mentioned hereafter for citing the most famous and frequent :

SIEMENS MASTERDRIVE AND SINAMICS S120
B & R ACOPOS and ACOPOS Multi
ROCKWELL KINETIX
CONTROL TECHNIQUES UNIDRIVE
SCHNEIDER ATV
DANAHER KOLLMORGEN SERVOSTAR 600
ABB ACS
REXROTH INDRADRIVE
KEB F5 COMBIVERT
PARKER COMPAX 3
DANFOSS VLT Automation Drive
MOOG DS 2000

Motor parameters needed for programming drives or motion controllers:

The parameters of the torque motors usually needed for programming the drives and motion control systems are provided in our online documentation and are listed below:

Continuous torque
Current at continuous torque (or torque constant around the nominal point obtained by taking the ratio of continuous torque to current at continuous torque)
Back -electro-motive force line to line (expressed in V / rd.S)
Phase resistance
Phase inductance
Number of poles
Rotor inertia