THE BRUSHLESS MOTOR REVOLUTION: CUSTOM AC "TORQUE" SERVOMOTORS INSTEAD OF GEARBOXES

The Ultract II series motors can be supplied on request with special windings, suitable for low speed applications without gearing.

In general, the elimination of a reduction stage mandates high torque, high stiffness, good motion uniformity at low speed. The "torque" custom winding allows to couple large, low speed motors with small drives, which are of the same or sometimes smaller size than what would be needed with a reduction stage.

THE TORQUE WINDING DESIGN

The "Torque" motors are motors with a special winding with unusually high K_e and K_t motor constants.

In order to fully appreciate the potential of these windings, consider an "ideal" motor with a $\cos\phi=1$ and efficiency=1; the motor is PM type, hence the motor field is constant, and consequently the motor voltage is proportionate to motor speed:

1 $$V = K_e \bullet \omega$$

while the motor torque is proportional to the motor current:

2 $$T = K_t \bullet I$$

Since the motor efficiency is 1, the electric power entering the motor must equal the shaft power:

3 $$\omega \bullet T = V \bullet I \bullet \sqrt{3}$$

Replacing 1,2 in 3:

$$\omega \bullet K_t \bullet I = K_e \bullet \omega \bullet I \bullet \sqrt{3}$$

and suppressing the common terms

$$K_t = K_e \bullet \sqrt{3}$$

This expression shows that the voltage and torque constant of the motor are intrinsically proportional to each other by the root of 3 factor.

Any standard motor is designed so that, at the maximum speed

$$K_e \bullet \omega < V \text{ maximum drive voltage}$$

Consequently, if the maximum used speed is limited, say, to 30 rad/sec ($\sim$ 300 rpm) instead of the standard 314 rad/sec (3000 rpm), it is possible to create a winding with K_e about 10 times higher than the standard: the same applies to K_t, so that this specially wound motor can provide high torque with low current.

As an example a ULII 1070XX motor, limited to 300 rpm, has $K_t \sim$ 17 Nm/A and outputs 100Nm with just 6A.

In conclusion, the use of special "torque" motors allows coupling large, high torque motors with small drives in low speed applications; the elimination of the gearbox carries the penalty of a larger motor (which is often less expensive than a precision gearbox, and is more dependable too) but does not require a larger drive.

The successful suppression of a mechanical transmission depends, for a start, on whether a larger motor, needed to provide all of the torque required by the slow shaft, is economically feasible when compared with the motor and reducer set.

This is typically the case when the gearing ratio is less than 10:1.

If this condition is verified, two further checks are necessary:

A - ROTATIONAL UNIFORMITY AT MINIMUM SPEED

All brushless servo motors perform well at very low speed. The minimum attainable speed is only limited by the resolution of the feedback sensor; with a standard 4096 p/rev encoder, a resolution of 16000 points/rev is achieved and the shaft rotation is uniform well below 1 rpm; a much higher resolution, up to 4 M points/rev, is achieved with sinusoidal encoders. In general, the rotation is perfect down to the speed at which the sensor frequency is still higher than the system control bandwidth, typically 30-50Hz.

B - LOAD INERTIA AND STIFFNESS

A speed reduction stage transfers on the load side the motor inertia multiplied by the square of the transmission ratio.

Consequently, the elimination of the gearbox generally reduces the system inertia considerably. In applications where the dynamic response is important, this allows higher performance and/or lower power requirements.

Conversely, if the motor inertia was used, in the original application, as a ballast to resist impact loads or quick load disturbances on the slow side, this ballast would be suppressed along with the gearbox. The stiffness must be achieved electronically by the drive feedback, until the (lower) load inertia takes over from the (necessarily higher) system control bandwidth. For this reason, where control bandwidth is a requirement, a stiff coupling between motor and load, without backlash or keyway, is mandatory.