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Introduction

Introduction

This month, we are pleased to welcome Dr. Luciano Bonometti to our select group of collaborators at Mavilor News.

Dr. Bonometti received his PhD. in Engineering from the Politechnic in Milan. He began his professional career as a designer of power electronics equipment in 1975. Currently, he is an automation manager and a Registered Professional Engineer. His areas of expertise are motor drives and mechatronics. He has written several technical papers and a book on brushless servo motors and drives (Convertitori di potenza e servomotori brushless, Utet, 2001).

We would also like to take this opportunity to remind our readers that Mavilor News is an instrument for internal communication where we share a wide range of collaborations regarding Mavilor products. We would like to encourage the active participation of our friends and clients, and hope to include their ideas, opinions and experiences.

Best Regards,

The Mavilor Team

PRECISION

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AVOIDING BRUSHLESS SERVO MOTOR INSULATION PROBLEMS

Dr. L.Bonometti

"Engineering from the Politechnic in Milan"

The winding of a brushless servomotor can lose its insulation because of the speed of the drive output voltage and/or because of the over voltage created by the L-C parasitic elements of the motor power cable.

This paper analyses the phenomenon and suggests the necessary installation solution.

The output voltage Vcp of a servo drive is a series of pulses with magnitude either Vb or -Vb, where Vb is the drive d.c. bus voltage, and with pulse width modulation (Figure 1).
Its spectrum exhibits frequencies up to $1/(\pi\ .tR)$, that is up to some mega Hertz: the motor power cable acts as a high frequency transmission line.

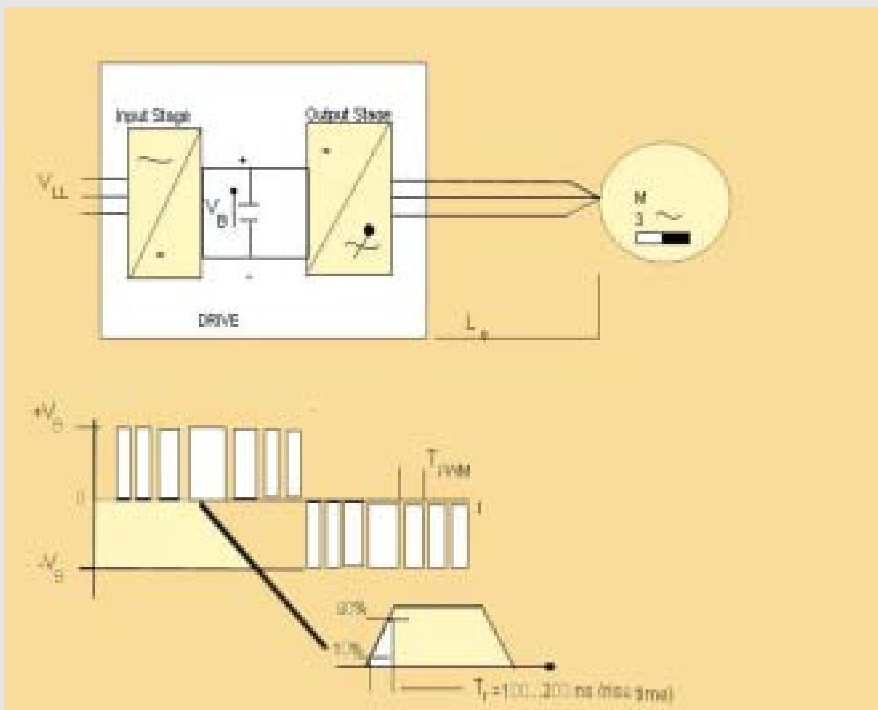


Figure 1 Output voltage of a servo drive.

Drive with--------------D.C lin,e voltage Vb for VLL =400V(:)
Resistive braking (*)--1.35Vll=1.35x400=540V+/-10%
regenerative Braking--1.55 Vll=1.55x400=620v+/-0%
(*) during the braking Vb increases (from 20% to 40%)
(:) Typically Vll<480v+/-10%

Tpwm [ms]	Fpwm =1/tpwm [leHz]
250	4
125	8
62.5	16

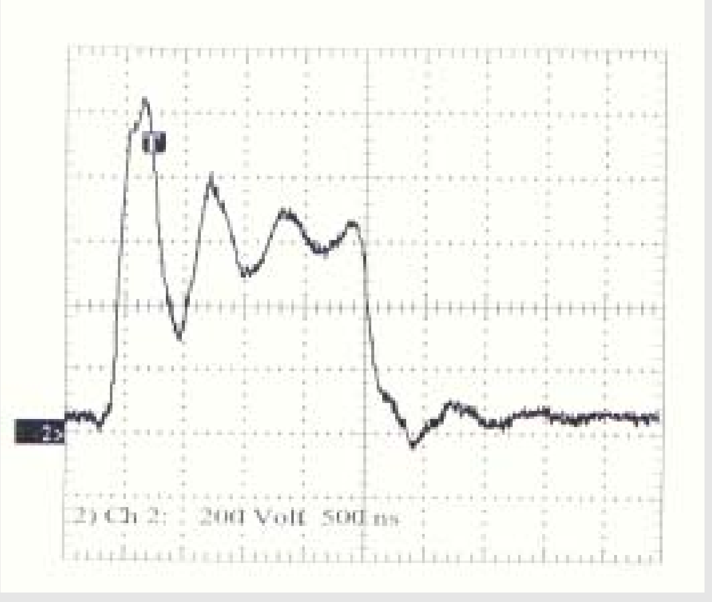


Figure 5 Servomotor voltage.

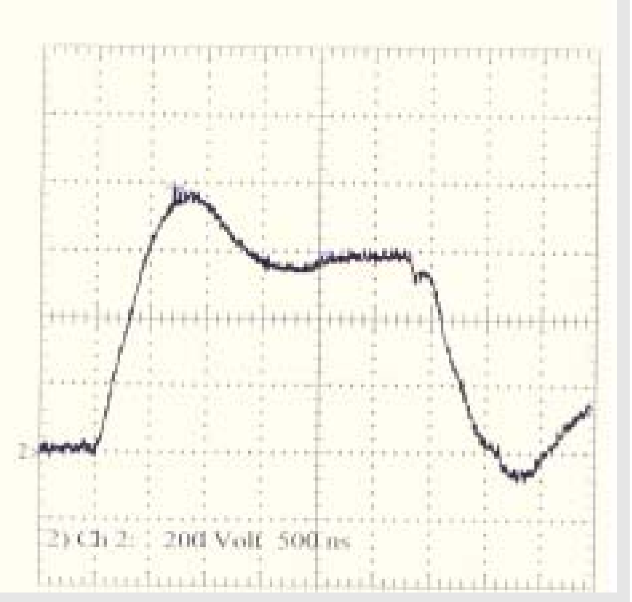


Figure 6 Servomotor voltage with inductor.

In conclusion, we point out that this problem is automatically solved if the drive/power cable/servo motor supplier is the same and the cable length of the specific application is not greater than the maximum value tested by the same supplier.

Note

The maximum value reached by the d.c. bus voltage of a drive with resistive braking is from 1.2 to 1.4 times the nominal value (it depends on the specific manufacturer). The d.c. bus voltage of a drive with regenerative braking increases, during the servo motor deceleration and a blackout of the a.c. supply, only if the machine manufacturer has designed the motor to stop by means of a braking resistance connected to the d.c. bus.
In this case the maximum value of the d.c. bus voltage is from 1.1 to 1.2 times the nominal value.

References

[1] J.Bonal , G.Sèguier .Entraînements électriques à vitesse variable-Vol.3, Ed.Tec&Doc , 2000.

[2] L.Bonometti . Convertitori di potenza e servo motori brushless , UTET Ed.Delfino , 2001.

[3] B.Drury.The Control Techniques drives and controls handbook ,IEE , 2001.

[4] A. von Jouanne, P.N, Enjeti.Design considerations for an inverter output filter to mitigate the effects of long motor leads in ASD applications, IEEE Trans. on Industry Application, Sep/Oct 1997, pp.1138-1145.

If the $\Delta V/\Delta T$ or the peak voltage is greater than the guaranteed value, it is necessary to connect an inductor LF between the drive output and the power motor cable. This inductance, which shouldn´t saturate with the servo motor overload current, forms a low pass filter with the cable parasitic capacitance, thus increasing the voltage pulse rise time tR, and reducing the $\Delta V/\Delta T$ and Vm values (Figure 4).

A conventional three-phase or individual phase iron-cored inductor is suitable; allowance should be made for additional core loss because of the high frequency fPWM.

The use of an inductor with 0.3-0.6% of voltage drop is sufficient to limit the $\Delta V/\Delta T$ to a safe value:

where

is the maximum value of the drive d.c.bus voltage (see the Note at the end of the paper);

is the motor power cable length;

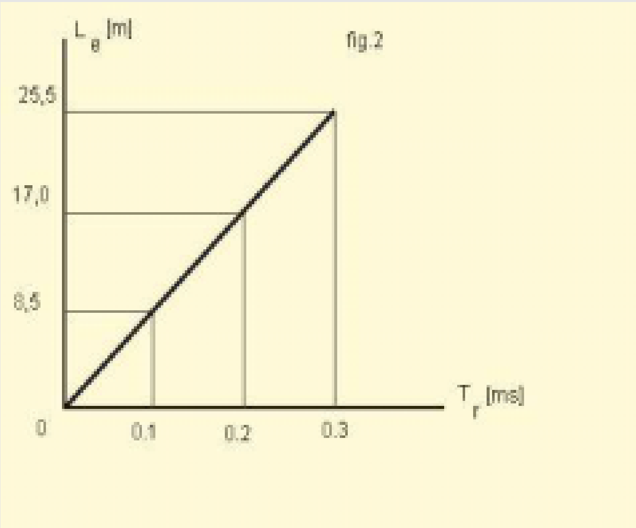
is the capacitance between two-power conductor of the motor cable, measured at 1kHz by means of a RLC bridge (100-160pF/m for cable section of 1.5-10mm2; it also depends on the insulation material).

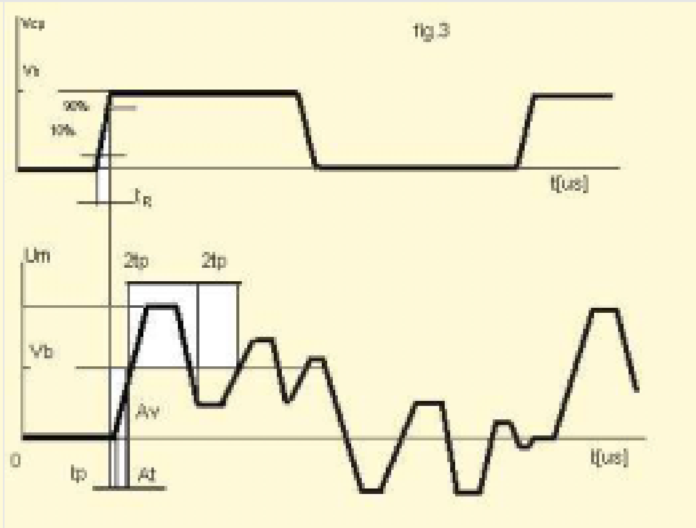
Figure 4 Output inductor (a) and its effect on the servo motor voltage (b).

The waveform of Figure 5 gives an example of the described phenomenon: in this case the peak voltage is 1050V and the rate of rise is 6.3kV/μs.

Figure 6 shows the positive effect of a three-phase inductor LF=80μ H: the peak is reduced to 785V and the $\Delta V/\Delta T$ to 1.5kV/μ s.

$\hat{V}_m$





Each voltage pulse travels along the power cable at about half light velocity (V =150-200m/ μ s, i.e. typically 170m per micro second) and after reaching the servo motor terminals in a time tP=lC/V, re_ flects back to the drive because of the motor surge high impedance ZM (ZM=10-50.ZC, where ZC=50-100 Ω is the characteristic impedance of the power cable).

The reflected wave plus the incident wave can double the voltage at servo motor terminals, especially if Tp>Tr/2 ; this ratio defines the critical cable length lc beyond which the phenomenon occurs (Figure 2).

Figure 2 Critical cable length versus voltage rise time at n =170m/ms.

The reflected overvoltage reaches the drive, where it is again reflected back to the brushless motor but in a negative sense, because of the low impedance ZD of the drive (Zd≅Zc/10) , so that when it reaches the motor for the second time, the overvoltage is cut below VB. This causes another reflection and so on, each reflection reducing itself in amplitude. The typical motor terminal voltage is that of Figure 3.

If the phase-to-phase values of the rate of change of voltage ΔV/ΔT[Kv/μs]and/or of the peak voltage Vm [kV] are bigger than those guaranteed by the servo motor manufacturer (typically: 5-10 kV/ μ s and 1-1.5kV), then the winding loses its insulation, usually on the first coils of the phases. In order to avoid this risk, the manufacturer of the machine using the servomotor has to verify, by means of an oscilloscope, the maximum values reached at the winding terminals.

Figure 3 Pulse voltage waveform at the brushless servo motor terminal.

EXHIBITIONS

MAVILOR IN JAPAN

Applications

Infranor USA

Packaging Concept application from Infranor Inc. using a BL-112 special motor

Packaging Concept

Packaging Concept

Jardis Industries, Inc.
Infranor USA
Full Speed Flying Paster With Built-in Infeed,

application from Infranor Inc using a MSA-45 motor.