



# Introduction

This month, Mavilor Motors presents an article by Prof. Brian Chalmers on the simplified evaluation of motor efficiency.

As always, Prof. Chalmers' expertise and experience are greatly appreciated.

Also in this month's edition, we have highlighted the success of our participation in the trade shows and exhibitions of our distributors, including the excellent work done by Esi-D Czech

Republic in the "Trade Show MSV Brno 2003" and by Infranor Spain in the "Cumbre Industrial 2003 in Bilbao".

We would also like our readers to get to know us better, and to this end we have included an article on the optimization of our production system.

Thank you very much, Mavilor Team.

## Simplified Evaluation of AC Motor Efficiency

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### Introduction

Use of the per-unit system enables the performance of different types of ac motors to be evaluated and compared very easily. In the theoretical treatment in this article, rated values of input voltage  $V$  and current  $I$  per phase are taken as base values, equal to 1 per unit, and all calculations are expressed in per-unit terms. The analytical work is then demonstrated by practical examples.

### Induction motor with fixed-frequency supply

The design of an induction motor to be operated with fixed-frequency sinusoidal supply is necessarily a compromise because of the interconnectio between running performance, starting performance and breakdown torque. The important machine parameters are leakage reactance  $X$  and rotor resistance  $R_2$ . Neglecting stator resistance, starting current is equal to  $V/X$ , starting torque is  $(V/X)^2 R_2$ , breakdown torque is  $V^2/2X$  and fractional slip at rated power is equal to  $R_2$ . This means that  $R_2$  must have a sufficiently large value to achieve a required value of starting torque and the rotor loss  $I^2 R_2$  at rated power is correspondingly increased.



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In a typical example, with  $V=1$ , leakage reactance  $X$  is 0.2 in order to limit starting current to a value of 5 per unit. Breakdown torque is then equal to 2.5. If a starting torque of 1.5 is required, the rotor cage must be designed to give  $R_2 = 0.06$ . Taking stator resistance  $R_1 = 0.03$  and  $P_o$  (ie. iron loss + mechanical losses) equal to 0.04, for illustrative purposes, motor losses at rated power are then:

$$\text{Stator } I^2 R_1 = 0.03$$

$$\text{Rotor } I^2 R_2 = 0.06$$

$$P_o = 0.04$$

$$\text{Total losses} = 0.13$$

Efficiency is approximately 0.87, or 87%, and power factor is typically also about 0.87 for a 4-pole motor.

#### Induction motor with variable-frequency supply

If it can be assumed that, with variable frequency supply, the motor will always be started with a low supply frequency then the breakdown torque is available at starting and the starting torque constraint is removed. Rotor resistance may then be designed to have a low value, thereby reducing the rotor losses and the slip at rated power.

For example, if the above value of  $R_2$  is reduced to 0.03, the losses become:

$$\text{Stator } I^2 R_1 = 0.03$$

$$\text{Rotor } I^2 R_2 = 0.03$$

$$P_o = 0.04$$

$$\text{Total losses} = 0.10$$

Efficiency is increased to approximately 0.90 or 90%.



MAVILOR MOTORS MA Series

# INFRANOR SPAIN

## "CUMBRE INDUSTRIAL"

### exhibition in BILBAO

Infranor Spain participated in the Cumbre Industrial exposition from September 24-27 in Bilbao, with a total of 1,140 exhibitors. The Infranor Spain stand presented the new models ML, MLL and actuator: a high-speed model, no cogging model, and servo brushless actuators.

The reception to these new products, on both the national and international level, has been outstanding.



## INFRANOR SPAIN

### IN SALAMANCA MUSEUM

### SOLAC PROJECT

The collaboration of INFRANOR SPAIN in the SOLAC project, presented in our previous issue, consisted of the adaptation of the servosystem SMTBD/100, comprised of a RACK BF 220-35/2-1-E-V01-F35 and a digital module SMTBD1/1a/220/60 r.w.TBS, to the MAVILOR MA-55 motor.

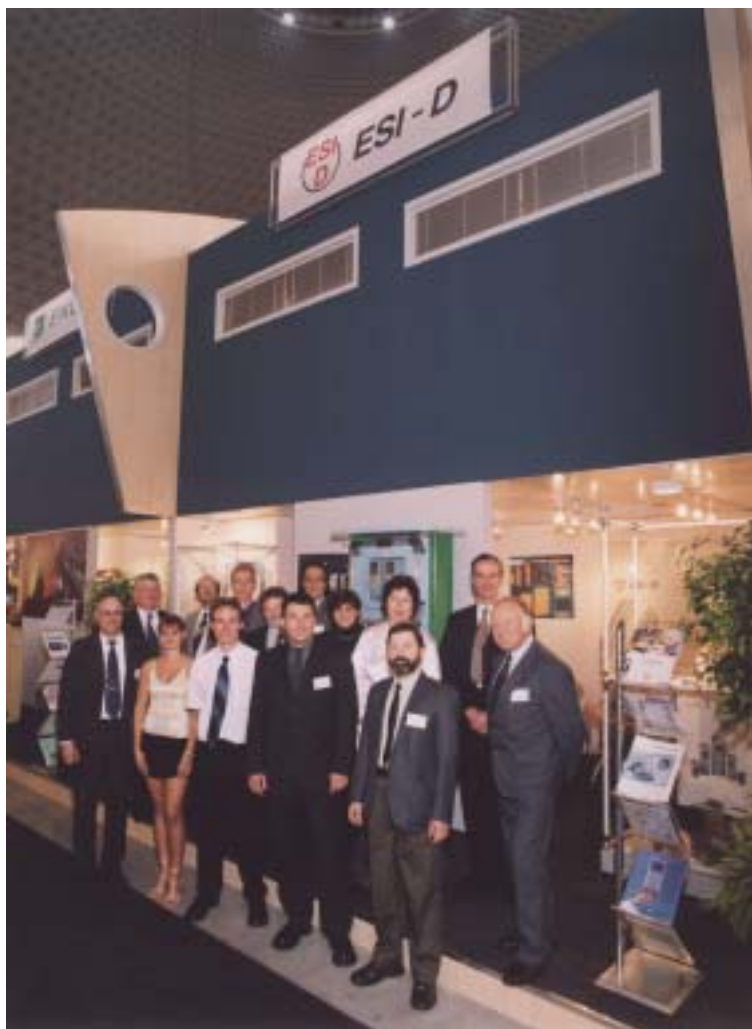


Our participation in the MSV-Brno 2.003 Exhibition, by invitation of our Distributor ESI-D s.r.o., was extremely successful. We were able to contact our current customers and introduce our latest products to the exhibition visitors, including the MSA Axial flux AC brushless servomotors and the BF type stainless steel 'washdown' range.

It was also an enriching opportunity to brief with many senior engineers with extensive experience

in designing and manufacturing. Brno has produced some of the world's most distinguished engineers, whose knowledge and expertise have directly benefited motor companies around the world.

Special thanks to Dr. Ing. Zdenek Zák of EM Brno s.r.o. and Ing. Vladimír Ploteny of VUES Brno a.s. for their time and invaluable collaboration.



**A physical example**

Of course, it is necessary to demonstrate that the theoretical illustration can be realized in a practical design. A real example concerned an induction motor for a compressor drive which was required to deliver 50 hp (37.3 kW) at 1450 rev/min, 30hp (22.38 kW) at 1200 rev/min and 13hp (9.7 kW) at 900 rev/min. The original design had 3-phase, 400V, 50Hz supply and achieved the required output using variable-voltage control and a high-resistance cage rotor with bronze bars and copper endrings. A revised design with variable-frequency supply and copper bars gave much improved performance, as illustrated by the following figures at top speed.

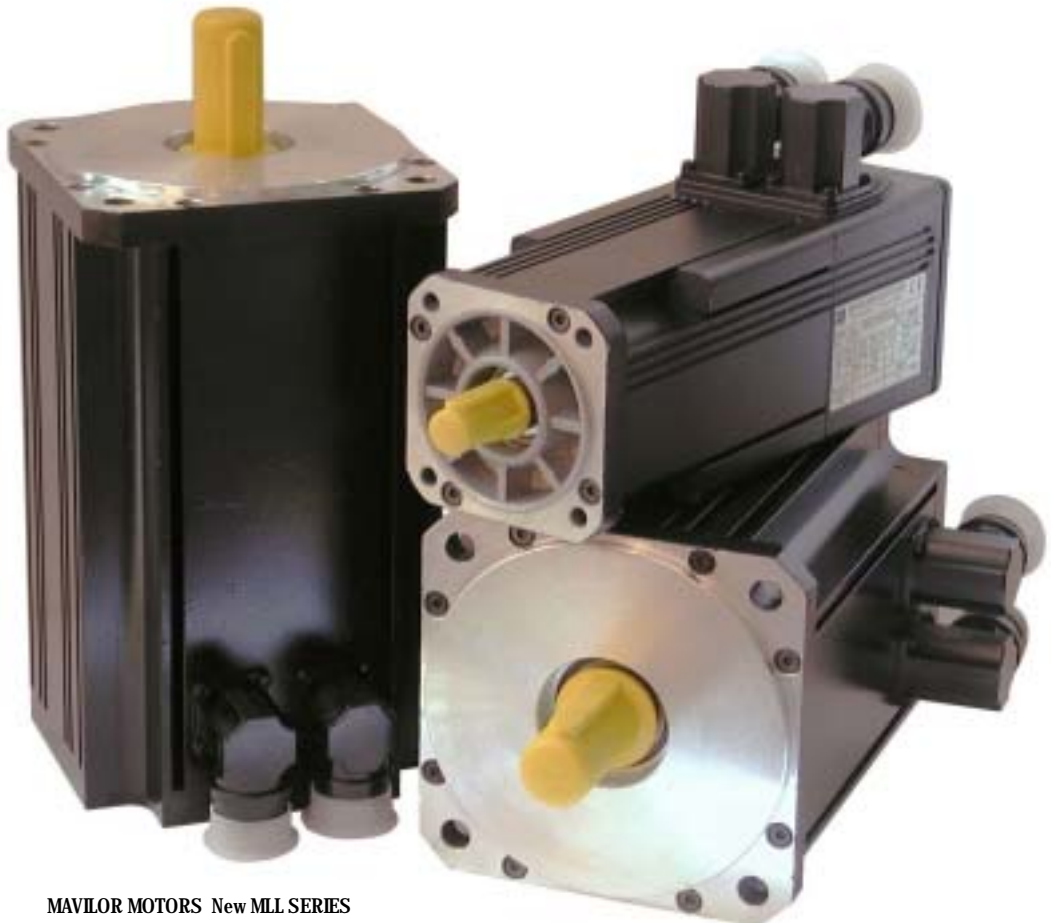
Design	Slip %	Losses kW	Efficiency %	Power factor
Original	3.8	4.60	89.0	0.85
Revised	0.83	2.36	94.1	0.90

**Synchronous motor with permanent-magnet excitation**

In contrast to an induction motor, a synchronous motor with permanent-magnet excitation has no rotor  $I^2R_2$  losses and can be designed to achieve approximately unity power factor at rated power. Stator current at rated power, being inversely proportional to the product of efficiency and power factor, is reduced to about  $(0.90/0.94)(0.87/1.0) = 0.833$  times the previous induction motor's value. Its losses at rated power are then:

- Stator  $I^2R_1$  = 0.02
- $P_0$  = 0.04
- Total losses = 0.06

Efficiency is increased to approximately 0.94 or 94%. A similar argument is applicable to brushless dc motors with permanent-magnet excitation.



MAVILOR MOTORS New MLL SERIES



In a practical example of a 7.5kW, 3-phase, 50Hz, 4-pole motor, a rotor with buried permanent magnets was built and tested [1]. Its measured performance at rated output gave the following results in comparison with those of the standard line-start induction motor using the same stator:

	Efficiency %	Power factor
Induction motor	86.3	0.89
P-m motor	92.8	0.99

These results fully demonstrate the validity of the simplified analysis.

#### Conclusion

The efficiency of a permanent-magnet synchronous motor is higher than that of an induction motor because:

- The starting torque restraint is removed
- The power factor can be close to unity so the stator current is reduced
- There are no rotor  $I^2 R_2$  losses
- The power factor of the induction motor is further reduced by the presence of magnetizing current in the stator.

#### Reference

- [1] B.J. Chalmers and S.K. Devgan: Comparative performances of 7.5kW permanent-magnet synchronous motors with SmCo5 and Nd-Fe-B magnets, Proc. International Conf. on Electrical Machines, Pisa, September 1988, III, pp. 41-43.

# ESI-D s.r.o. with Mavilor Motors at the MSV Brno 2.003 Trade Show, 15 al 19 Settembre.

## CZECH REPUBLIC



Our participation in the MSV-Bmo  
2.003 Exhibition, by invitation of  
our distributor ESI-D s.r.o.,

# Mavilor Motors safeguards against electrostatic discharges

Everyone has experienced static electricity at some time, often when they receive a shock on touching a doorknob or any other conductive element. In certain industrial production environments,

that it generates more, which means that no accumulation takes place. The human body is a good conductor, and in low-humidity environments it can accumulate electrostatic charges that may build up to several volts in power. These charges are generated by foot contact with insulated floors or by the factory operations themselves.

electrostatic discharges can become dangerous if not properly safeguarded against.

The accumulation of electrostatic charges depends on the conductivity between the charged body and its path to the ground. Good conductivity provokes the rapid disappearance of electrostatic charges at the same time

Mavilor has adopted all of the necessary measures to prevent this from occurring in our workspaces. The manipulation and mounting of encoders, resistances and all other materials that are susceptible to these kinds of charges are worked on within a completely controlled environment.



- 1-wheels connected to EPA ground
- 2-surface connected to EPA wheel
- 3- EPA wrist check
- 4-footwear check
- 5-base of footwear check
- 6-cable y wristband
- 7-ground cable EPA
- 8- ground EPA
- 9- EPA ground connection
- 10-cart ground connection
- 11-protective ESD footwear
- 12-Ionizer
- 13-work surfaces
- 14-chairs with feet, back and SEAT connected to EPA ground
- 15- ground
- 16-clothes
- 17-shelves with surfaces connected to EPA ground
- 18-storage elements connected to EPA ground
- 19- EPA sign
- 20-machines

*EPA zone  
(Electrostatic Protection Area)*

