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Brushless Motors for Geothermal Cooling Towers

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ABSTRACT

The object of the project is to design and build a brushless three phase electric motor with a vertical shaft for the direct driving of geothermal cooling towers. This application requires a high load torque at low rpm and the brushless motor is the only AC motor that provides these load characteristics.

The project requires a careful choice of thrust bearings for high vertical loads and high strength materials in order to resist the highly corrosive environment.

This solution eliminates the gearbox and transmission shaft installed within standard configurations, increasing reliability, reducing power losses and cutting down noise.

1. INTRODUCTION

The cooling towers used in the field of geothermal energy are needed to cool the operating fluid in order to thereby increase the efficiency of the plant.

Most of the forced draft cooling towers installed in the world constitute the following:

• an inverter to control the motor rotation speed (at least in towers that have been built recently)

• an induction motor (usually high speed 1500-1800 rpm)

• a drive shaft

• a speed reducer (gearbox) for adapting the speed

• a vertical axis fan

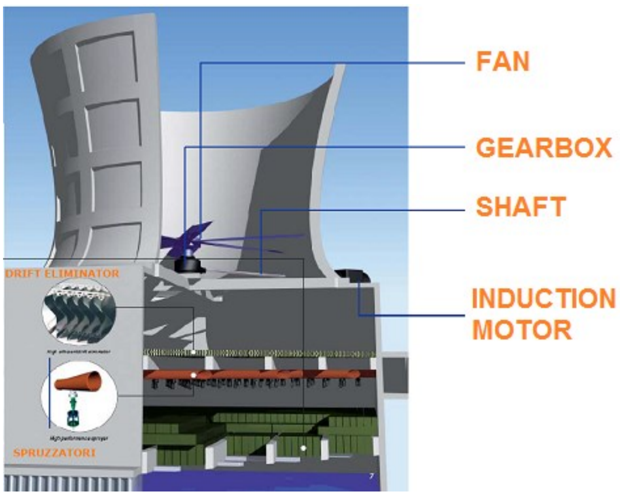


Figure 1 Standard cooling tower operation

The fan features a rotation speed that is considerably less than that of the motor, typically, depending on the diameter of the blades, the fan speed varies from 70 to 200 rpm.

Historically, the standard mechanical drive components and in particular the gearbox represent the biggest problem as regards the maintenance of a cooling tower [1].

The main problems that occur with this type of drive system concern, gearbox breakages, alignment problems, oil leaks, oil contamination, transmission shaft breakages, excessive vibration and elevated noise levels [2].

Figure 2 Gearbox breakage

The objective of this work is to improve the reliability and efficiency of the overall system and reduce the noise pollution level by using an electric motor which acts directly on the fan itself (direct drive).

In the past such a solution was very difficult in that this type of application requires the development of a high degree of torque at very low speeds.

Old technology did not permit the use of induction motors directly connected to the fan featuring these torque/speed characteristics, it was in fact essential to employ a speed reducer (gearbox) in order to adapt the rotation speed and therefore the torque.

Today however, thanks to the development of more efficient and high-performance permanent magnets, the use of permanent magnet motors (also called brushless motors) is spreading into many applications. Brushless motors are characterised by:

• high power density (and hence lower weight and volume for the same amount of power)

• better torque/inertia ratios and better dynamic performance

• practically zero rotor losses (higher yield)

• lower noise emissions

• no need for an excitation magnetising current source

Permanent magnet motors are electrically much more efficient than induction motors.

Below there is a comparison in terms of performance between permanent magnet (PM) motors and the standard motors used in industry [3]

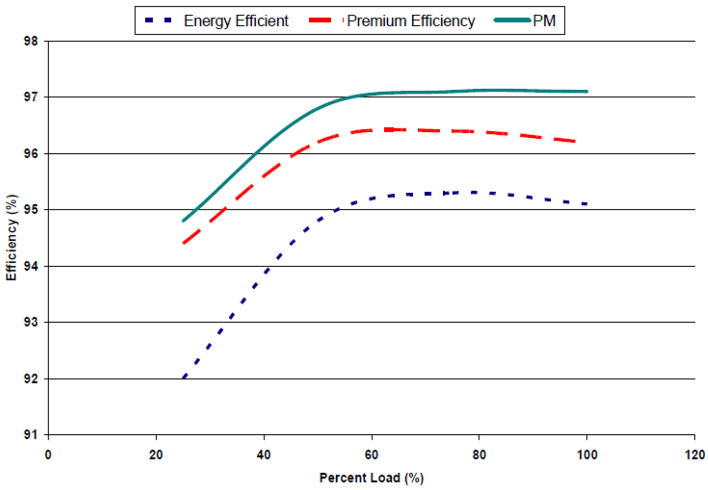


Figure 3 Induction and PM Motor efficiency [3]

2. CASE STUDY - PM MOTOR VS INDUCTION MOTOR

The case study concerns a cooling tower at the geothermal power plant in Vallesecolo 1 (Larderello - Italy), which was built in the 1990s

The power station takes the form of two identical 60MW generators with 8 cooling towers for each generator.

The aim of this document is to make a comparison of the main technical parameters (absorption, vibration and noise) of the same cell driven in the first case by a standard type of drive system (induction motor with a drive shaft and gearbox) and in the second case driven by a vertical axis permanent magnet motor that acts directly upon the fan.

Figure 4 View of the geothermal power plant in Vallesecolo - Larderello (Italy)

2.1 Technical characteristics

Fan Diameter: 9.145m

Fan speed 100rpm

CASE 1 – Induction motor	CASE 2 – PM Motor
Electric induction motors Nominal Power 160/50kW – 50Hz Speed 1480/980rpm Gearbox Ratio – 14.2:1 	Permanent Magnet motors Nominal Power 147kW Speed 100rpm – Torque 14,046Nm 

For the implementation of case 2 (PM Motor) an off the shelf motor electrically compatible with the application (torque/speed) was chosen and then mechanically redesigned for the elevated degree of effort required for this application. In particular the following changes were made:

- the redesign of all of the bearings including the thrust bearing
- the modification of the materials coming into direct contact with the highly aggressive environment (STAINLESS STEEL)
- the adaptation of mechanical fan interfaces

2.2 Results

The absorption current, mechanical vibration and the sound emissions were recorded for both types of drive system.

A power meter was used to record the current consumption data taking care to maintain a constant fan speed and blade pitch. The results obtained are summarised within the table below:

	Volts, rms	Current, A rms	Power kW	Power factor	Vibration mm/s
INDUCTION MOTORS	400	137	**83**	0.88	3.5
PM MOTORS	400	106	**71**	0.97	1.1

Figure 5 PM Motor installed within the Vallesecolo power station

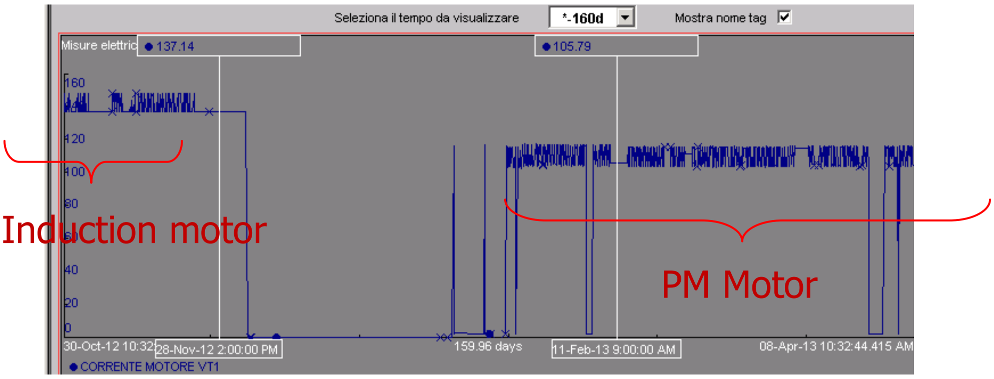
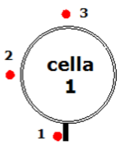


Figure 6 Current absorption graphs for both types of drive system

An active power saving of 12kW (about 14%) was measured. These savings are attributable to the absence of the speed reducer (gearbox) and the higher performance of the motor (rotor losses virtually nonexistent) [4]

The reduction in the level of vibration (from 3.5 to 1.1mm/sec) is significant as is the noise level reduction (from 90.3 to 72dB(A))



MEASUREMENT POINT	**INDUCTION MOTOR**	**PM MOTOR**
1	90.3dB(A)	72dB(A)
2	70.6dB(A)	69dB(A)
3	69.5dB(A)	66.5dB(A)

CONCLUSIONS

In order to increase geothermal plant availability and reduce the overall energy consumption levels of auxiliary systems it is very important to optimise the electric drive of cooling towers. To this end present technology provides us with new types of drive systems that are based on the use of permanent magnet motors that are connected directly to the fan itself (direct drive technology). Such a solution allows for the elimination of those mechanical components (gearbox and transmission shaft) that give rise to most maintenance problems. In addition, in order to improve the acoustic impact of the power station, the reduction of noise emission levels proves significant.

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