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PUBLICATION

# THE ADVANTAGE OF PMSM TECHNOLOGY IN HIGH RISE BUILDINGS

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## ABSTRACT

In 1995 KONE introduced PMSM technology in the low rise volume market with its revolutionary MonoSpace®. The small EcoDisc® machine allowed the complete elimination of the machine room, as it fitted in the hoistway. Gearless EcoDisc® technology reduces the energy consumption by some 50 to 60% compared to conventional geared and hydraulic installations.

The next stage was the introduction of EcoDisc® PMSM elevator technology in medium and high rise buildings. In the gearless high speed range, the EcoDisc® technology, reduces the energy consumption by no less than 30 to 40%, while reducing the machine weight by approximately 50% in comparison to already very efficient asynchronous VVVF gearless technology. The smaller energy losses and the smaller electrical requirements also provide considerable savings in machine room cooling, emergency power generators and the machine room riser sizes. PMSM motor technology with its excellent controllability will also provide enhanced ride comfort.

Keywords: PMSM, Permanent Magnets, EcoDisc®, Energy efficiency, High Rise, KONE

## 1 INTRODUCTION

It is at the moment necessary to use a variety of different hoisting technologies in High Rise buildings. Parking shuttles can be either hydraulic or geared. The main groups and service elevators utilize geared elevators in the low speed range or gearless elevators when the speed exceeds a certain barrier, the barrier being slightly different for the different manufacturers. The limits of the different technologies are mainly set by economical and/or technical reasons. Hydraulic lifts are more economical until plungers buckle or get too big and pumps become too expensive. The technology then changes to geared and again here technology and economics fix the upper limits. At this point gearless technology steps in. Different manufacturers introducing new equipment, such as for example helical gears, expanding the geared range into the conventional gearless area have tried the technology borders. None of these attempts however have eliminated the need for multiple technologies in High Rise buildings.

KONE has now made gearless Permanent Magnet Synchronous Motor (PMSM) technology economically feasible throughout the complete load speed range. From the smallest and slowest elevator required up to the biggest and fastest. PMSM motors are extremely efficient reducing energy consumption to an absolute minimum. KONE has already proven this with its MonoSpace® and MiniSpace™ gearless elevators eliminating the need for low efficiency hydraulic and medium efficient geared elevators. The purpose of this paper is to show that the introduction of the very compact PMSM technology provide us with considerable total energy consumption savings compared to already efficient asynchronous VVVF gearless technology generally used nowadays in High Rise buildings.

## 2 THE ECODISC® MACHINE AND MONOSPACE®

In 1995 KONE introduced the MonoSpace® machine-room-less elevator. This innovation was only possible due to the development of a very flat gearless machine, which could be placed between the hoistway wall and the guide rail. The development of this type of machine was triggered by the Launch of the Linear Induction Motor Elevator (LIM) by Otis in 1992.

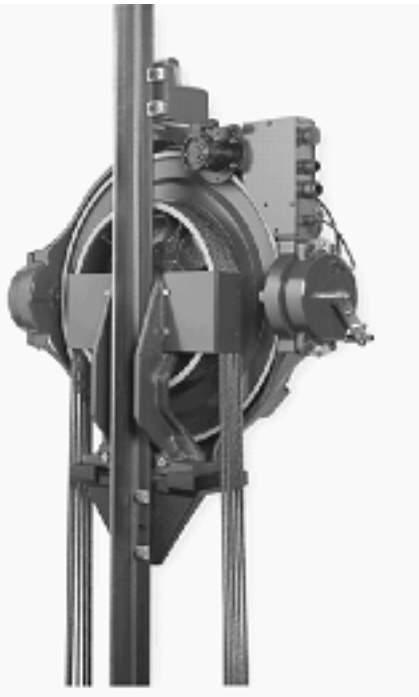

***Figure 1. EcoDisc®***

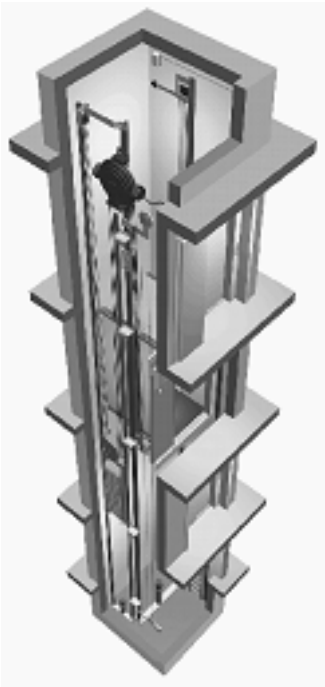

***Figure 2. MonoSpace®***

The idea of using linear induction motors in elevators was not something new. Already in 1971 a German company by the name of “Firma Kleemann’s Vereinigte Fabriken” patented a counterweight with an integrated linear motor. Earlier feasibility studies had shown that this technology would be too expensive. The stator of the motor had to be as long as the hoistway, making the elevator much more expensive than traditional elevators. The Otis LIM launch therefore took the industry by surprise.

The launch of the LIM triggered the registration of more than 200 different linear motor patents in the years to follow. KONE also started the development of linear motors, but a new feasibility study at KONE immediately showed that the old problem was still there. The hoistway long stator was financially unbearable. In KONE Harri Hakala was given the study to check what could be done. As a result of this study, he got the idea to curl the linear motor. He

created a rotating linear motor that could be fitted within the counterweight. Soon his team noticed that axial motor design could flatten the motor dramatically. Further studies showed that by using permanent magnets the thickness of the motor could be reduced even further.

The result was a very flat gearless Linear Permanent Magnet Synchronous Motor of axial design. The team had actually created a “Motorized Traction Sheave”.  Soon they found that the counterweight was not the best place for the motor. The motor would not be easy to reach, if something would go wrong, while the motor had to be fed by a travelling cable going to the counterweight. Subsequently the motor was then placed in the pit directly under the counterweight. It was now easily accessible and it had fixed electrification.

One of the remaining problems however was that the number of pulleys needed was rather big, which considerably shortened rope life. The most serious problem however was that service personnel would have had to work under the car when for example adjusting the brake. This was considered to be an unacceptable safety risk. The final solution found was the present place of the motor, as it is nowadays placed in the MonoSpace® elevators (see figure 2). By locking the car to the rail during service we created a temporary machine room and a lift which is safe under all conditions.

As the EcoDisc® is a gearless machine, it does not have the gear train losses of a geared traction unit. The motor is a synchronous motor using permanent magnets, and as such does not have the losses we normally get when creating the rotor field, nor do we have slip losses found in asynchronous motors. The EcoDisc® motor efficiency is therefore much higher than that of an asynchronous motor. These factors together help producing a highly efficient elevator package using only about 50% of the total energy consumed by similar geared elevators or some 40% of that of similar hydraulic elevators (all energy, including light, fans, controllers, brakes, hoistway efficiency, machine etc, see figure 3).

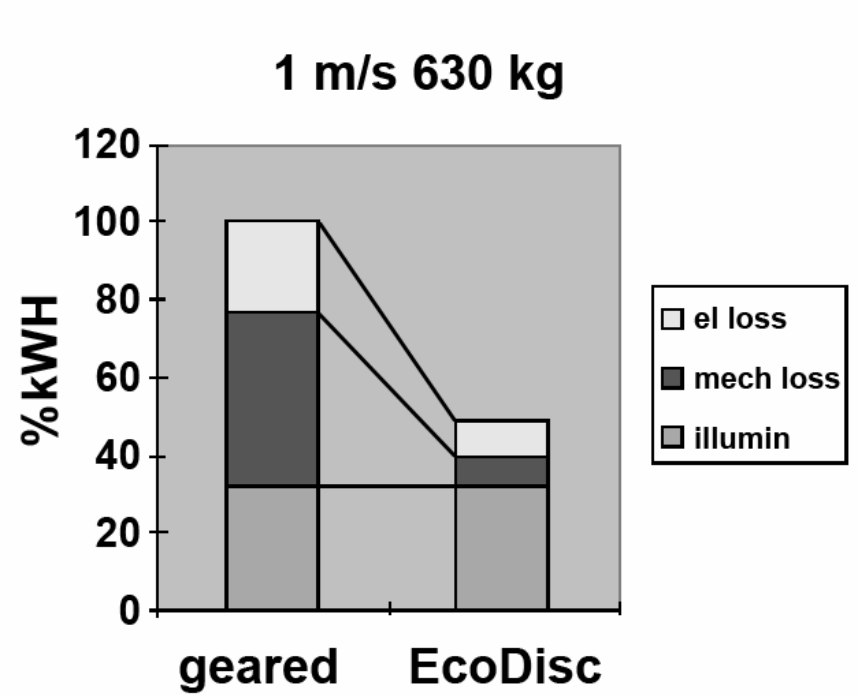


***Figure 3. Energy comparison***

CADETT IEA/OECD FI98.501/3B.F02 Result 314 states the following:

*A German consultancy Dr.-Ing. Winfried Deutsch, Ingenieur- & Servicebüro, measured the energy consumption for both conventional and MonoSpace lifts during 3 months from April until June. For 27,444 rides, a conventional lift consumed 3.45 GJ (958 kWh) of energy. The MonoSpace lift operated far more efficiently consuming only 1.61 GJ (447 kWh) for the same number of rides. Energy savings mount to 53.3% for the MonoSpace lift.*

As the machine is much more compact its weight is less than 50% of that of a conventional machine.

At the turn of the millennium, just 4.5 years after the first launch, no less than 20.000 EcoDisc® machine were sold, with the production rate being at 340 units per week. At present 3 sizes of EcoDisc's are manufactured in the MonoSpace® range. The units are MX05 for loads up to 6 persons, MX06 for loads up to 8 persons, MX 10 for loads up to 13 persons.

As a result of his findings on PMSM machines, Harri Hakala did his Ph.D. at the Tampere University of Technology in 1995.

## 3 EXPANDING ECODISC® TO MID RISE ELEVATORS

The logical step for KONE to take, knowing the advantages EcoDisc® had over geared applications, was the expansion of the range beyond that of MonoSpace®. The result was the creation of larger MX18 machine. Due to the necessary increase in size this machine can no longer fit between the guide rail and the wall. The machine is still considerably smaller than conventional machines and at least 50% more efficient than conventional geared machines. The higher efficiency resulted in a very compact drive/controller cabinet.

With both the machine and the drive/controller cabinet being much smaller than similar conventional units, the machine room size could be drastically reduced. The overhead machine room no longer needed to extend beyond the size of the hoistway. The machine room could just be a vertical extension of the hoistway, and this up to speeds of 2.5 m/s and rated loads of 1800 kgs. (see figure 4).

In the side drive application (side machine room) the space required is even smaller. All that is required is a 1100 mm deep room where the second dimension is either the width or the depth of the hoistway (see figure 5).

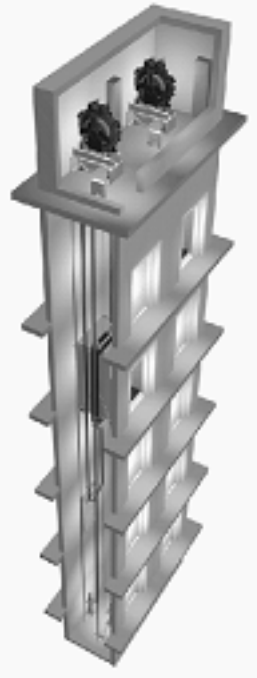

***Figure 4. MiniSpace®***

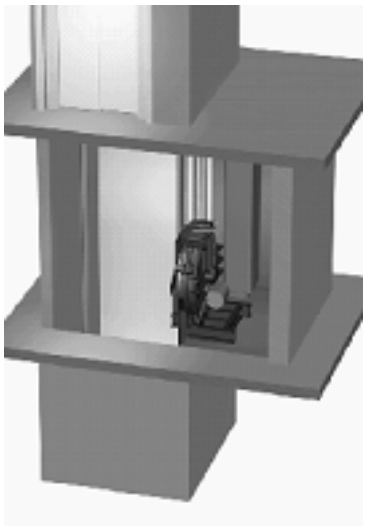

***Figure 5. Side machine room***

The MiniSpace™ elevator was first launched in February 1998, and no less than 1500 units were already sold by the turn of the century.

## 4 EXPANDING ECODISC® TO HIGH RISE ELEVATORS

Applying EcoDisc® technology to replace already very efficient gearless technology was not an obvious step to take. Increasing the disk-shaped motor further would have led to impractical diameters while the axial force caused by the permanent magnets would have increased dramatically, requiring big and expensive bearings. The solution was found with the application of the dual rotor concept. The stator diameter dimensions fitted nicely, while the magnet forces of the two rotor parts balanced each other.

***Figure 6. Dual rotor EcoDisc®***

Even though present asynchronous VVVF gearless technology is very energy efficient the motor efficiencies usually remain in the order of 0.8. The Dual rotor EcoDisc® machines can have efficiencies of up to 0.93.

Even if the difference does not seem to be significant, the effect on the energy consumption is dramatic. High speed gearless installations always regenerate energy back to the network. The difference in energy taken from the network and returned to the network, throughout the day, are the efficiency losses of the elevator system.

In a high speed systems the major part of the losses are caused by the motor efficiency, the hoisting efficiency being the second largest loss factor. If the machine efficiency changes from 0.8 to 0.9, the energy changed into heat by the motor will reduce by 50% (1-0.8 =0.2 while 1-0.9=0.1). This will lead to total energy savings (for the complete elevator system) of no less than 30 – 40 % compared to VVVF asynchronous gearless systems. In high speed installations the total heat output is usually considerable.

Reduced energy losses automatically translate in reduced cooling requirements. As the thermal efficiency of cooling systems is limited by nature, each kWh saved in the machine room produces appoximately half the kWh

saving on the cooling system side. This reduces both the investment costs and the running costs of the cooling system.

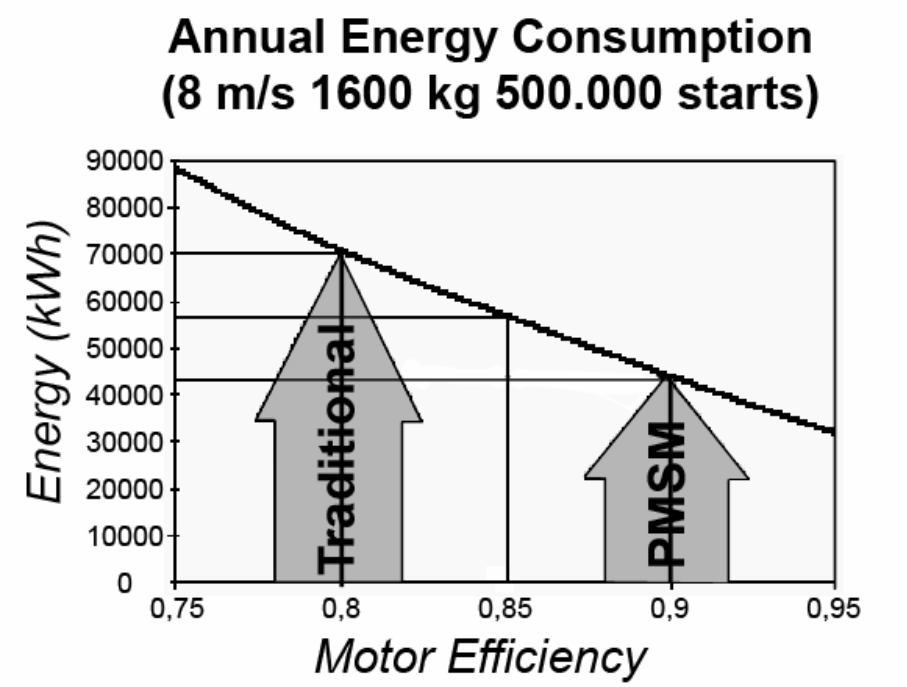


***Figure 7. Energy savings with EcoDisc® PMSM motors***

*In a high rise building, with approximately 20 units, the energy savings (machine + cooling) of PMSM technology will pay-back the costs of a complete high rise elevator within a period of 7 to 10 years.*

Improved efficiency also reduces the currents taken from the line. This will often reduce the size of the emergency power generator and of the risers. These investment savings can be significant.

The weight of the dual rotor machine is much less than the weight of an asynchronous VVVF gearless machine with the same duty. EcoDisc® PMSM machines produce approximately twice the torque per kg machine weight. In other words, EcoDisc® PMSM machines weigh approximately half of the weight of a similar duty VVVF machine. A MX40 dual rotor EcoDisc® machine with a duty of 2000 kg 1:1 at a speed of 10 m/s will weight only 2600 kg. Similar VVVF machines will usually weigh 5000-6000 kg. The large capacity Double Deck MX100 machine, capable to power a 2 x 30 person double deck lift with a speed of 10 m/s, will weigh only 6000 kg, less than half the weight of the machines in the Petronas Tower.

The dual rotor EcoDisc® machine has a symmetrical built around the traction sheave. It therefore does not have the usual motor-end extension. As a result the motors will always fit directly over the hoistway, without the need to step-

out walls to fit the machines, and still having a lot of space around the machine. The machine can easily be fitted into any machine room, even rooms where other will have problems fitting their machines.

EcoDisc® machines are synchronous machines with much larger pole pare numbers than used in conventional VVVF machines. The controllability of these machines is therefore easier than that of conventional machines. Ride comfort features of these machines are therefore better than those found with conventional machines.

## 5 CONCLUSION

EcoDisc® PMSM technology has the following advantages compared to present day technology used in High Rise building:

- The energy consumption can be reduced by up to 60% when replacing hydraulic elevators.
- The energy consumption can be reduced by up to 50% when replacing geared elevators.
- Up to loads of 1000 kg and speeds of 1.6 m/s the machine room can be eliminated.
- The energy consumption can be reduced by 30-40% when replacing VVVF asynchronous gearless elevators.
- The machine room sizes for elevators with machine room can be much smaller than for those using conventional technology.
- The forces on the structure are reduced due to the low weight of the machine, in the higher rises the differences can be considerable.
- Cooling requirements are much smaller giving considerable payback.
- Power requirements are smaller, reducing the riser and emergency power generator requirements.
- Application of a single technology platform instead of multiple technology platforms.
- Ride comfort is clearly enhanced.

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## BIOGRAPHICAL DETAILS

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