

DIRECT DRIVE – TREND IN MODERN ELEVATORS

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1. Introduction

The electrical elevator driving mechanism is basically a separate/partial technical system with essential criteria of power on driving sheave (output torque T_{iz} , rotational speed ω_{iz}). Apart from that it must satisfy various additional criteria in accordance with customer's requirements (Fig. 1). The function of the driving mechanism as a product is an objective feature which can be formulated through a definite number of criteria set by the customer, which does not have a singular qualitative and quantitative evaluation.

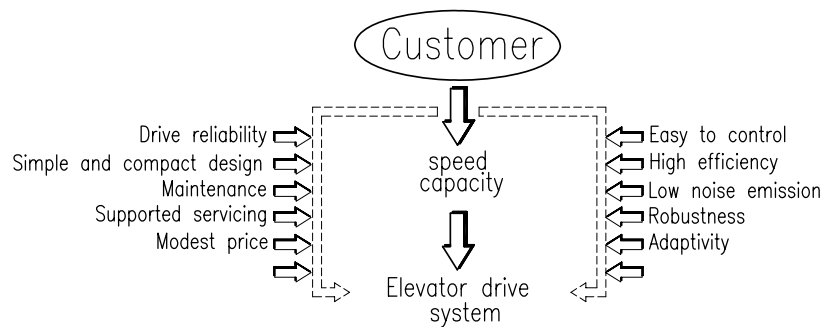


Figure 1. Criteria for choice of driving mechanism

2. Driving mechanisms configurations

Since mid 19th century till today, design of the elevator driving mechanisms (Tab. 1) has been different with respect to the type of the drive (steam, hydraulic and electric), technological parameters such as capacity, speed and travel height as well as architectural solutions inside buildings.

Table 1. Elevator drives comparison

Elevator driving mechanism				
Drive type		Mechanical drive	Direct drive	Hydraulic drive
Drive characteristics	Elevation speed	≤ 4 m/s	≤ 10 m/s	≤ 1.5 m/s
	Acceleration	≤ 2 m/s ²	≤ 5 m/s ²	≤ 0.1 (0.3) m/s ²
	Elevation height	Without limit	Without limit	≤ 25 m
	Capacity	≤ 2.5 t	≤ 2.5 t	≤ 8 t (...30 t)
	Positioning	± 30 mm	≤ ± 1 mm	± 5 mm

	accuracy			
Advantages		<ul style="list-style-type: none"> - High adjustability (large number of variants) - Competitive price - High efficiency 	<ul style="list-style-type: none"> - Compactness - High efficiency - Good controllability with high dynamics - Small number of built-in parts - Low noise emission level 	<ul style="list-style-type: none"> - High specific power - Good mass and volume - Low noise emission (without hydraulic power unit)
Disadvantages		<ul style="list-style-type: none"> - Low compactness - High noise emission level - Complex maintenance - Influence of elasticity and hysteresis effects to drive system 	<ul style="list-style-type: none"> - Not standardized - High purchasing price - Long delivery time 	<ul style="list-style-type: none"> - Low efficiency - Long response time - Complex maintenance - Sealing problems

The problem of vertical communication of people in high buildings, which is partially a result of architectural solutions, needs to be dealt with seriously. Since this problem has not yet been fully solved even in countries of high technical standard, the future development of elevators, apart from speed increase and development of new control systems, is accompanied with installation space reduction and operating noise reduction.

Installation space reduction with retaining/increasing driving reliability and safety is imposed as an architectural trend, which has been accepted by leading elevator manufacturers. Architectural solutions of buildings, i.e. the well, are trying to supersede "classic" machine room, by placing the driving mechanism in the space which does not affect building plan, i.e. in the well, on the elevator cabin or in the well pit for additional noise reduction.

The hydraulic elevators have limited travel height ≤ 25 m which restricts their use on lower buildings. In 80 % of most frequently used electromechanical drives, so called conventional drives of electrical elevators, the driving sheave, mechanical transfer with gears or worm gears, brake and driving electric motor make the assembly which occupies a lot of installation space (Fig. 2a, b). This structure defines space needed and the type of installation inside of a building.

The 1980s solution with standard synchronous or direct current electric motor drives as a direct drive (Fig. 2c) has not been well accepted due to high installed power, big and expensive regulators, although this type of driving mechanism made possible to minimize the mass up to 40 to 45 % of conventional drive mass (Fig. 2a).

The aim of future development of driving mechanisms is to achieve the smallest, and also the more compact make with all driving elements integrated in one installation unit (Fig. 2c,d). By using high torque motors with permanent magnets, a short cylindrical hollow shape is formed, where the elements of driving mechanism are placed (Fig. 3a). The rotor of electric motor together with driving sheave is made as one unit without connecting elements which increases mechanical reliability.

Assembling time of a conventional driving mechanism takes 7 to 8 times longer than assembling of direct drive, while assembling on building site, i.e. in the machine room, is 3 times shorter for direct drive. This indicates a significant reduction of delivery time for an elevator with direct drive. In addition, since the number of built-in rotating parts is reduced, the working reliability increases alongside with reduced wear and maintenance.

The minimization of driving mechanism dimensions leads to necessary additional analysis of strength, i.e. deformations of driving mechanism structure in normal driving conditions and urgent disconnection under full load. The purpose of this analysis is to reduce dimensions of the driving mechanism elements, i.e. to reduce the dimensions and weight of driving mechanism. This type of direct drive reduces the weight from 70 to 80% in comparison with conventional drives.

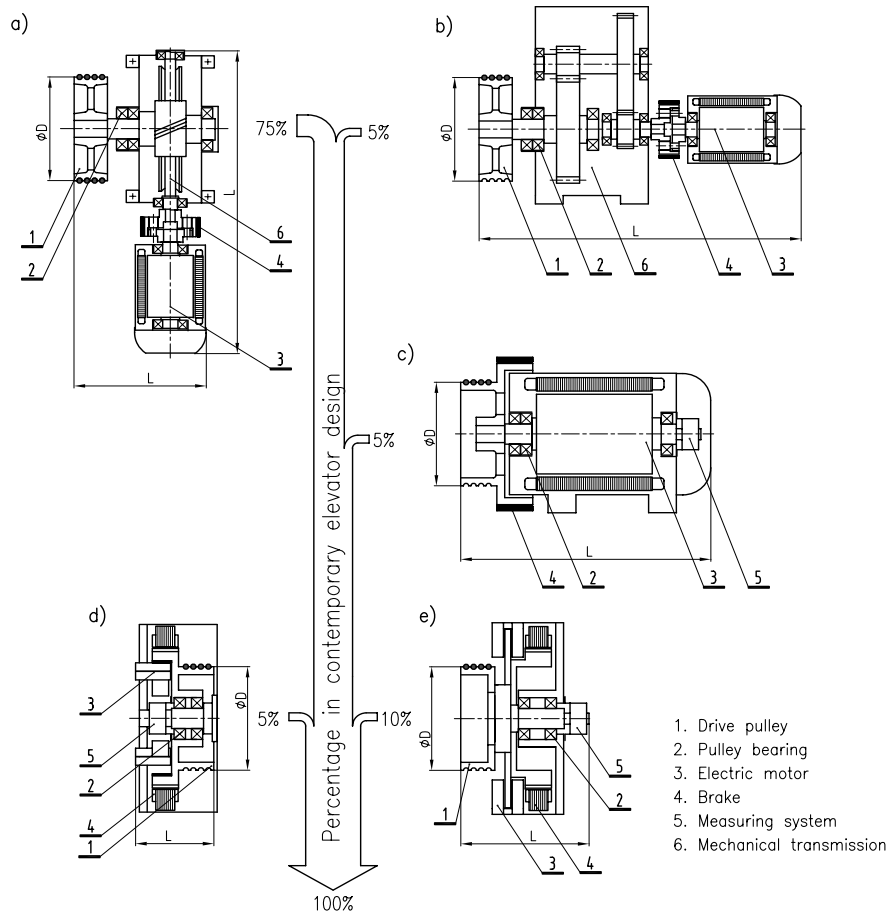


Figure 2 Elevators driving mechanisms configurations
a), b) Conventional driving mechanism with mechanical transmission
Direct drive with standard synchronous electric motor
d), e) Direct drive with high torque electric motor



Figure 3a. High torque motor in kit make

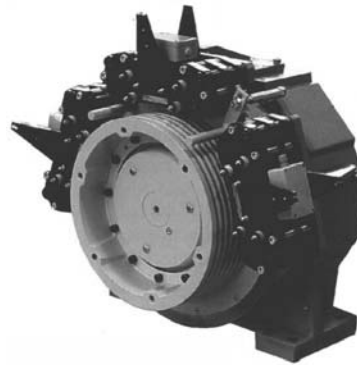


Figure 3b. Driving mechanism with outer disc brake

3. High torque electric motor as direct drive

The acting principle of high torque electric motors is based on application of high density rotational magnetic field Ψ_p between stator and rotor which is made with permanent magnets alloyed with rare soil - lantanides (i.e. NdFeB). Cylindrical shape of the stator plates package with coils and rotor package with permanent magnets in combination with large number of pole pairs $p > 20$, provide the basic characteristic, high torque: $T_{iz} = \frac{2}{3} \cdot p \cdot \Psi_p \cdot I_d$, even at low rotational speeds: $n_{iz} = f/p$ with additional drive characteristics:

- Large diameter of stator and rotor package, hollow shape (the biggest produced diameter of package of 3000 mm is used for telescope drive);
- High specific rotation torque in permanent operation 2,2...2,7 Nm/kg, or 8,3...9 Nm/kg for peak torque;
- High efficiency;
- Clearance free drive due to direct connections on driving element and precise positioning with high grade of reoccurring up to 0,001°;
- Very small electrical time constant, hence fast dynamic response with high acceleration and deceleration (2,5...4,5 times higher trip torque against asynchronous motor $p = 2$ of the same power);
- High rigidity of drive (rigidity $\geq 10 \cdot 10^6$ Nm/rad);
- Because of compressed conductors in stator coil, with bigger current I_d through conductors, the losses in copper are doubled. Developed thermal load must be transferred through water cooling or by keeping current in stator coil I_d in the limits of allowed warming;
- The pole step of 10...20(49) mm provides constructions suitable for use in practical technical systems. Controlled voltage frequency in range of 0...200 Hz, provides the change of rotational speed in range of 0...20 s⁻¹ (0...1200 min⁻¹), which contributes to the drive comfort.

High torque synchronous motors with permanent magnets for driving elevators (and other equipment) are operated with frequency converters which work on the principle of rotational magnetic field vector control. During this, the current vector through stator coil I_d is vertical on magnetic flow vector, and enforced current is proportional to torque T_{iz} . The required value of controlled voltage is defined by demanded torque, which is uniquely defined by the torque constant for mentioned motor type.

The three-phase voltage is transformed by means of the controller to direct voltage, and by further transformation - "cutting" it is transformed into required voltage (42...700 V) with controlled frequency in prescribed limits. At starting, the voltage impulse can grow extremely high up to 6 kV/ μ s or more, which is reduced by installing the filter and motor muffler in the circle. In order to avoid damage of the stator coil, a high breakthrough persistence of the coil isolation is required, which is ensured through new technologies and isolation materials.

As it is always a servo drive, every motor is equipped with measurement system (Fig. 4), which controls the revolutions/position of the motor rotor. The installed incremental encoder with sinusoidal signal and information of absolute position is a required signal for control of the synchronous motor drive with the aim of recognizing the rotor position according to position of stator rotational magnet field. The encoder signal simultaneously provides elevator cabin positioning in encoder accuracy limits, which is for standard makes within limits of ± 1 mm, i.e. the signal is used for programmable speed control (Fig. 4).

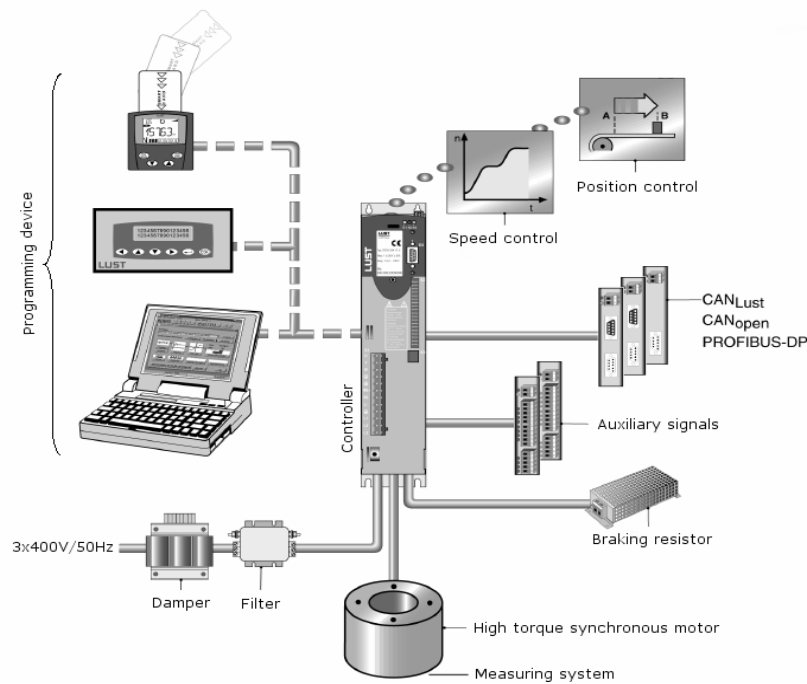


Figure 4. Structure of system for high torque motor control

4. Development of drive mechanisms

Rapid development of civil engineering, which can be seen in the construction of higher buildings, imposes the need of more comprehensive solution of vertical transportation. Since the efforts are made to establish complete connection between architecture and vertical transport in buildings, the present tendency in the development of new technical solutions is justifiable. The increase of criteria both in its quantity and demands set by the client, contributes to more qualitative technical solutions of the driving mechanisms and inside with direct drive high torque synchronous motor with permanent magnets.

The technical solution and future trends in development of elevator driving mechanisms is based upon:

- Application of new construction materials and manufacturing technologies with the aim of improvement of characteristics and reduction of manufacturing expenses;
- New elevator concepts derived from architectural and other demands;
- Improvements in construction and manufacturing of the driving mechanism elements with the aim of improvement of driving safety, noise reduction and vibration in building itself and the elevator cabin;
- By use of better control systems through implementation of modern achievements in the field of microprocessor technique;
- Attempt of standardization and unification of the overall system as well as of the driving mechanism elements with the purpose of better manufacturing quality, lower price and the exploitation expenses of maintenance;
- Driving mechanism and elevator element design by means of modern computer software and methods.

The advantages of driving mechanisms with mechanical transmission in comparison with direct drives should not be neglected. They are manifested through series of facts and each participant in the process should take them into consideration:

- Relatively good and simple thermal heat transfer from the driving electric motor;
- Up to threefold lower purchasing price due to use of standard parts;
- Large number of in short time available make and combination variants;
- Low brake and hold torque on drive shaft.

5. Conclusion

Direct drives with high torque motors with permanent magnets is a new solution for elevator driving mechanisms, that is the drives which demand small installation space, high torques with high drive comfort. The key advantage of the direct drive is reduced number of mechanical parts, thus making the maintenance easier and cheaper. Additional important advantage of these drives is noise reduction during operation < 60 dB(A) primarily because of reduced number of components which produce noise (gears, belts, worm gears). Despite its simple and compact construction, direct drives with high torque synchronous motors with permanent magnets are not competitive with conventional drives in the terms of price primarily due to custom made and low capacity production with high development expenses. Increased market demands, inevitably leads to introduction of serial production followed by significant price reduction.

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