

LANDING FLOOR STOP ACCURACY

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In February 2004, , in Italy , a judge of the Justice of the Peace condemned joint-owners and a maintenance company because, due to a difference in level of 4 centimetres between a car floor and a landing floor, a joint-owner stumbled and suffered a 2% biological injury¹.

Grounds for the verdict of guilty: unprofessional maintenance.

1. SINGLE OR TWO SPEED LIFTS

We do not want to discuss the merits of this verdict, of standards, of the duty of the owner (joint-owners) and of the maintenance company, as they have already been widely discussed in previous articles by famous authors. As an engineer, I would add some details I have already discussed some years ago in an article titled: "Evolution of traction systems ".

In Italy, hundreds of thousands of systems installed have the following technical characteristics:

- a) traction method with gear and suspension ropes;*
- b) machine position top or bottom of the shaft;*
- c) electric motor single or two speed.*

1.1 Single speed operation

In single speed systems, with 4 or 6 pole motors, the electric motor is directly connected to the mains when starting. Limits to the acceleration and jerk values is dependent on the maximum torque the motor can supply when starting, resulting from the fly-wheel masses and from the mains voltage. While approaching the floor, the power to the motor is disconnected and the mechanical brake is closed. Motor speed is not controlled and depends on:

- I) Electric mains voltage; a decrease voltage by 10% leads to a torque reduction of 20% (motor torque varies with the square of the voltage) and a subsequent reduction in the motor speed (slip increases);*
- II) Type of motor installed; there are motors that at full load have a slip of 4% and motors that at full load have a slip of 12%;*
- III) Car load;*
- IV) Car direction.*

Taking an extreme case, I give an example. A person enters the building and, as the car is not at the ground floor, he/she calls the lift. In a few seconds the empty car arrives at the floor in one of the above ways. When the mechanical brake closes, it has only to provide part of the energy of the moving parts, as the torque required by the motor is the rated torque and it has to operate as a brake. This is because the counterweight with empty car is heavier than the car by 50% of its capacity. Thinking again that previous single speed motors had an average slip of 8-10%, motor speed when the brake closes again will be 1,350-1,380 rpm.

Stopping will require a certain distance, depending on the braking torque, the moving masses, the load, the brake and shoe temperature, and the motor speed. If the same person on a future occasion finds the car occupied as it approaches the ground floor on stopping, he/she will note that the car level is not the same as in the previous case. In this case, we would have a motor speed near to the synchronous speed (1,500 rpm), while the torque required to the motor is a braking torque.

In this case, the energy to be dissipated is higher than in the previous case because, apart from the usual mechanical masses (which are anyway higher by 8-10%), the brake has to dissipate also the car load energy, as the car at full load is heavier than the counterweight, whereas the empty car helps with a braking action.

This simple example helps us to understand that the stopping distance is certainly different in the two cases (empty car/full loaded car). If we add that the mechanical brake torque varies with the temperature, which varies the friction of the brake linings, we can understand that perfect levelling between landing floor and car, floor, in any direction and any load condition, is virtually impossible.

¹Editor's Note - 'A judge of the Justice of the Peace pronounced a judgement in a civil cause on a joint ownership, in the person of the administrator pro tempore and on the company in charge of the lift maintenance, concerning the compensation for all damages suffered following the accident occurred when the user of a lift going out of the car, due to the non levelling of the same car with the landing floor, stumbled over it and fell to the ground. The judge in his action wrote " (...) at the time of the injurious event, an anomaly in the correct operation of the lift occurred and the same company does not deny this anomaly, asserting nevertheless that the difference in level occurred at the lift platform measured just four centimetres, within the limits allowed by standards regulating lift operation and maintenance.

According to this deciding person, the difference in level occurring in the lift car, even if not excessive, caused the fall of the actress, producing a contract responsibility of the defending company, which did not professionally carry out the six-month inspection of the system. In this connection, it is to be underlined that, at present, law in force regulating lifting systems is the DPR n. 162/99 which, for safety reasons, provides for more strict rules with respect to those contained in the DPR 7497/63. It is to be recognised an equal responsibility with the participation of the above mentioned Joint-owners, who are obliged to supervise a perfect lift operation which, by its very nature and due to a possible failure of the mechanisms, could cause damage to third parties. (...) It is true that omitted surveillance and poor maintenance of the lift resulted in the occurrence of the injurious event, creating a concealed hazardous situation, i.e. a hazard neither objectively announced, nor foreseeable by people normally using a lift whose platform must be aligned and should not present any difference in level, even if a minimum one: this in the respect of safety measures that, according to recent standards - the above mentioned DPR n. /62/1999 are more strict (...)"

1.2 Two speed motor operation

To partially solve the problem of the stopping difference in level, the 1950s two speed motors have been used, i.e. with two stator windings. In these motors, on starting the low speed winding is connected (usually 4 poles). At a certain distance from the landing floor, power from the high speed pole winding is disconnected and the low speed winding is connected (usually 16 poles).

The motor decelerates gradually according to the car load and to the motor fly-wheel masses, until reaching a low speed. When the car reaches the landing floor, power to the motor is disconnected and the mechanical brake is closed again. There is thus a higher stopping accuracy, and less energy is dissipated by the brake (as the speed is reduced by one quarter). The brake thus heats up less and its characteristics are more stable with time.

Again in this case, perfect levelling between car floor and landing floor is not attainable, because the motor speed depends on the load, the type of motor, the type of gear, etc...

My experience teaches me that by using a two speed motor it is easy to see cars "missing" the floor by some 4-5 cm.

2. LIFTS WITH RE-LEVELLING

It has always been difficult to solve the problem of a good levelling between car floor and landing floor and of having good travelling comfort. Thirty years ago, systems with different methods designed for this purpose were manufactured, but none of them could assure what was desired. We can list the most common methods:

2.1 Rated speeds lower than 1 m/s

For a rated speed lower than 1 m/s, good comfort and acceptable accuracy were obtained with enhanced fly-wheels which, in correspondence of a better comfort, caused an overheating of the motor. So in summer time and/or in high traffic periods from time to time they stopped "to draw breath". Asbestos brake-shoe linings assured a greater friction, little sensitive to the variation of temperature and thus providing a good stopping sensation.

2.2 For rated speeds higher than 1 m/s or rated capacity greater than 630 kg

For a rated speed higher than 1 m/s or for a load greater than 630 kg, different methods were used.

a) Starting stator resistances both on low and high speed winding. Their inconvenience was their variation in value with temperature. It often happened that, a hot motor, i.e. when a higher voltage would have been necessary to have the same torque, in fact had less voltage, with the consequent problems both at starting and at deceleration. Moreover, stator resistances installed in the controller used to dissipate a great deal of heat, which was difficult to dispose of, etc.

b) 4/24 pole or 6/36 pole motors, i.e. with a levelling speed of 1/6 and not 1/4. These motors were more expensive, they had a low starting torque on the 24/36 pole winding and needed enhanced fly-wheels or decelerating stator resistances. Nevertheless their stopping accuracy was significantly greater.

c) Where it was required to have an absolute landing accuracy with any temperature, direction and load condition (i.e. goods lifts with a guide-way, for loads with pallets, etc.) to compensate the elongation and the contraction of ropes on the variation of the load, re-levelling was used, occurring stopping or after goods, or people, had loaded/unloaded perfectly re-levelling the car to the landing floor.

2.3 Re-levelling

There were many ways to obtain a re-levelling. We list three.

2.3.1 Method with auxiliary gear

The method with auxiliary gear was the most common. It consisted of an auxiliary gear with reduction ratio of approximately 1150, whose slow shaft was connected through joints and/or clutches to the main motor shaft.

At the landing floor, some seconds before stopping, the auxiliary gear connected to the motor and the car perfectly levelled to the floor, moving the car up or down at a speed of 1/50 (one fiftieth) of rated speed.

The same method was applied during the loading and unloading of goods when, because of the elasticity and of subsequent elongation/contraction of ropes, the car moved from its perfect position at the floor.

2.3.2 Method with hydraulic unit

There was also the method with a hydraulic unit used in some cases (generally with large loads), since the 1970s. It was preferably installed, instead of an auxiliary gear, which by a hydraulic piston moved one of the fixed ends of the ropes.

The operation was similar to the previous case, in this case lowering or rising the fixed end of the ropes so to constantly level the car to the floor.

2.3.3 Method with speed regulator

In this case, re-levelling was also achieved with a speed regulation of the motor. Generally dc motors with a Ward Leonard system or static converter, but since the 1970s also using asynchronous motors for lifts with ACVV types of regulator, have been used. The principle is totally different from that of the previous cases, as in this case no additional equipment is required; the same motor, appropriately controlled, carries out the re-levelling of the car in case that it is not perfectly levelled at the floor. In the case of ACVV regulated asynchronous motors, significant motor overheating occurred.

I would ask a question to the judge: "If, in order to obtain good levelling between the landing floor and the car floor, it is sufficient to have good maintenance, why were so many arrangements studied over time? "

3. STOPPING ACCURACY AT PRESENT

To get good travel comfort and an excellent stopping accuracy, systems have, for some years, been equipped with the following types of traction:

- Asynchronous motors with two speeds for lift (4/16 poles) for maximum rated capacities of 400-480 kg and maximum speed of 0.8 m/s, or for higher rated capacities with reduced rated speeds (0.2-0.3 m/s);
- Asynchronous or synchronous single speed VVVF regulated motors for the rest of the systems.

In fact, the old non-regulated single speed systems and direct current motor systems disappeared. Firstly because they did not provide a perfect travel comfort, and secondly for their high cost.

In the newer systems, stopping accuracy is good. In some systems with long travel, high rated capacity, special goods lifts, etc. re-levelling is added, which operates well, is cost effective and is only used to compensate the elongation/contraction of ropes upon load variation.

The problem remains with all the older systems (some hundreds of thousands), especially on those with a single speed motor, in which it is impossible to provide a proper stopping level with a stopping accuracy of ± 10 mm. This accuracy is a requirement of the new EN 81-70 standard (to be in force in the near future) concerning lifts accessible to the disabled.

How to solve this problem? By acting on the old saying that "nothing is technically impossible, it is just a matter of money ", I suggest the following.

3.1 Replacement of nearly the whole system

That is replacement of the single speed motor with a two speed motor, changing the controller, all the well equipment and car guide shoes, as well as the electric system of the machinery room (the old system remaining being: guide rails, car, counterweight and doors).

3.2 Replacement of the controller

Replacement of the controller, all the well, car and machinery room equipment, installing a frequency converter in the new controller (it is not necessary to replace the gear box, if any).

3.3 Installing a speed regulator

Installing a speed regulator on the motor allowing a perfect levelling to the floor, so preserving the rest of the system. This last solution is a partial solution because 30 or 40 years old machines and controllers will be shortly replaced. This allows to be able to get a very good cost effective modification, to be obtained because we reach an excellent stopping accuracy (certainly higher than that possible with a new two speed motor) at very low cost. Installing a motor speed regulator was a solution already tried in the 1980s with unexciting results, as at that time VVVF with IGBT did not exist. So ACVV systems were mainly used, which , had the following limitations:

- Need to fit to the shaft, or on the motor shaft, a speed sensor: tachometer or digital encoder;
- Motor noise, because mains voltage distortion introduces ' harmonics in a higher range which are not "agreeable " to the motor;
- Motor overheating, due to both harmonics resulting from distortion, and to dissipated energy on the rotor and stator during decelerating and motor stopping phases, especially when the motor is driven by the load.

Some installers did not have many exciting experiences with ACVV and VVVF systems at that time, so that now they are reluctant to accept this kind of solution. Today, it is possible to find on the market some complete upgrading kits for single and two speed systems that, apart from the VVVF speed regulator, also contain an adaptation board to the existing controller, regardless of its age and type, connection power cables (strictly shielded in compliance with EMC standards), control cables, etc., which make their application to the old controller extremely fast and easy. In a few hours, you have a complete transformation of the system as if you had installed a new system!

Moreover, the motor heats up less, it doesn't make any noise and there is a clear reduction of the starting current, which changes from approximately four times the rated current to 1.2-1.5 times, which, in some cases, can also lead to a reduction in the power used.

With frequency regulators of the new generation, there is a total adaptability to old motors, i.e. it is possible to obtain the same comfort and motor torque results as on the new motors designed for VVVF regulators.

EMC certification assures total conformity to standards.

Very often installers tell me: "When installing a VVVF regulator, it is better to also change the motor, because, with the regulator, the motor loses power and cannot manage any longer".

I usually say: Nonsense! These are urban myths! If the system has been working for thirty years, how can the machine suddenly lose torque?

I want to remind you that when a motor is VVVF regulated, the starting torque is not sensitive to mains voltage variations. Among other things, new systems designed with VVVF motors, system capacity and rated speed being equal, need a motor power of approximately 10-20% less than with respect to a corresponding 4/16 pole motor. Thus the old motor is in principle more powerful than new motors.

!t is also true that sometimes, at full load, the car does not move upward, while earlier it used to move without any difficulty. Possible causes to this phenomenon are to be attributed to:

- VVVF with a current not sufficient to drive the motor, i.e. motor with 11 A rated current and inverter with 9A rated current;*
- VVVF with poor starting power; current necessary to generate the torque to overcome friction of first motion can be approximately twice the rated current. If the VVVF can supply a maximum current of 1.5 times the rated current, it is clear that it can not manage;*
- Poorly parametrised VVVF, i.e. wrong values for some parameters were inserted: empty and loaded motor current, loaded motor revolutions, $\cos\Phi$, etc.;*
- Poor quality VVVF. There are on the market cheap VVVF drives which are unable to evaluate the required torque, the number of revolutions etc.... They only control voltage and frequency, they do not optimise the current and the torque of the motor, that is why at low speed they can not drive the motor;*
- Motors having wrong data on their rating plate. Many old motors have on their rating plate revolutions/minute 1,500. This is a false detail because no asynchronous engine can make 1,500 revolutions/minute at full load. Others have incorrect current data, power factor, etc.;*
- Totally unbalanced systems, with large currents on travelling up with full load. In this case the current absorbed by the motor must be measured in those conditions and a relevant driving system chosen.*
- If the VVVF is of good quality, the correct current is the one required by the motor, and the parameters are correctly obtained, then the motor operates well and it is able to drive the system especially at very low speeds.*

4. CONCLUSIONS

EN 81-70 and EN 81-80 standards, to be published in the near future, will compell joint-owners to modify the system in order to obtain a landing stopping accuracy within $\pm 10\text{mm}$. No old single speed system can assure such an accuracy. Also because old brake shoe linings were asbestos based which, fortunately, today can not any longer be installed. On the other hand, new linings create a lower friction which varies in a more sensitive way with temperature causing a greater stopping inaccuracy.

Regardless of the modification chosen, I want to emphasise that maximum comfort and accuracy can be obtained by regulating the motor speed with the VVVF system.

"Good" regulators drive the motor to a very low frequency of 2-3 Hz with subsequent perfect levelling of car at the floor with any load and travel direction condition. This is certainly not obtainable with traditional two speed motors (4/16 poles). New generation frequency regulators, mainly if assisted by a special software for lifts, assure total motor silence, very low starting currents, management of braking, diagnosis of entry/ exit phases. They are able to assure, under any condition, maximum operational safety. The number of advantages of the frequency regulator are: controlled departures and arrivals and the brake closing on a stopped motor, resulting in a significantly longer life of all the moving mechanical parts (ropes, pulleys, gear, etc.); lower starting currents which, apart from reducing energy consumption, make the life of motor power contactors longer. The only disadvantage of a frequency regulator remains the EMC problem and "ageing" of the motor insulation, avoidable with appropriate filters.

The choice to add only the VVVF regulator with an application kit allows joint-owners to immediately conform to standards at low cost.

When the controller is replaced, the regulator can be recovered and installed in the new controller without additional expense. As possible solutions are all technically valid, it will be up to joint-owners, on economic availability and according to the status of the system, to choose their best solution.

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