Energy Saving through the Application of Variable Speed Technology

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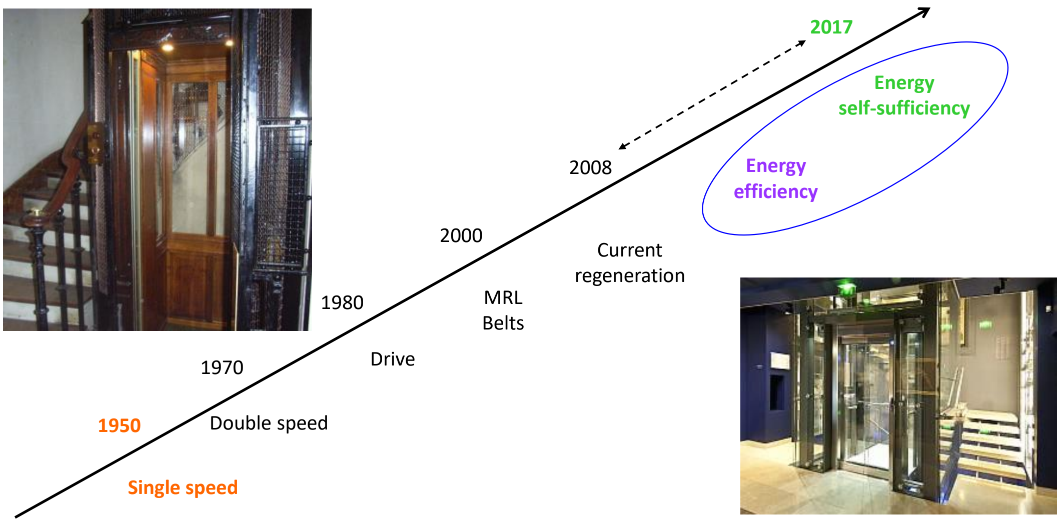
Abstract. Saving energy is a worldwide challenge for everybody, in particular, the lift profession. Different technologies exist on the market and are used to reduce the lift energy consumption. For example, we can note different algorithms as group control systems, regenerative device to batteries or power network, standby power cutting when the lift is not working, etc. After reading the VDI 4707, we have understood in 90% of use, the carload was under or equal to 50% of the rated load, meaning a lot of energy was lost to move only the counterweight. To try and find a solution to solve this problem, we decided to work on a new kinematic lift device to reduce the balancing of the counterweight. In parallel, we designed a special motor with a range of velocity adapted to the torque. For every trip, the motor torque is monitored by the drive to calculate the real load in the car and in function of the direction (up or down), the velocity is calculated in relation with the maximum power machine. To optimize the energy consumption through a reduced counterweight, the kinematic is based on a traction-closed loop. For example, the reducing of the lift balancing up to 32% can save energy consumption of up to 30%. This technology is applied to gearless synchronous motor. Different motors exist to allow the connection from the three phases 400V or single-phase 220V power supply network. Due to the small energy consumption, "*the speed technology*" lift is compatible with all other renewable energy power supplies. Solutions incorporating photovoltaic solar energy are currently being investigated.

1 Lift Technological Developments History

Since 1950, the lift technology has continued to move and to stick to the evolution of society:



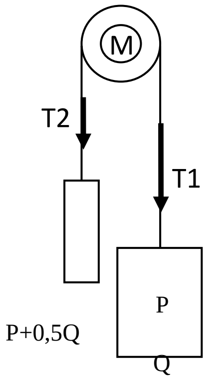
At the moment, all tasks are focused on the energy consumption and the autonomy for lift.

The Concept of "*The Speed Technology*"

Load in % of nominal load	Trip ratio in %
0	50
25	30
50	10
75	10
100	0

Figure 1 – Lift Using in Residential Buildings

<table>
<tr><th colspan="2">Traction drive calculation</th></tr>
<tr><th>Traditional concept
Open loop</th><th>Proposed concept
Closed loop</th></tr>
<tr><td>



Empty car : $\frac{T2}{T1} = \frac{P+xQ}{P}$

Full car : $\frac{T1}{T2} = \frac{P+Q}{P+xQ}$

P = Weight of the car (N)
Q = Rated Load (N)
X = Balancing (%)

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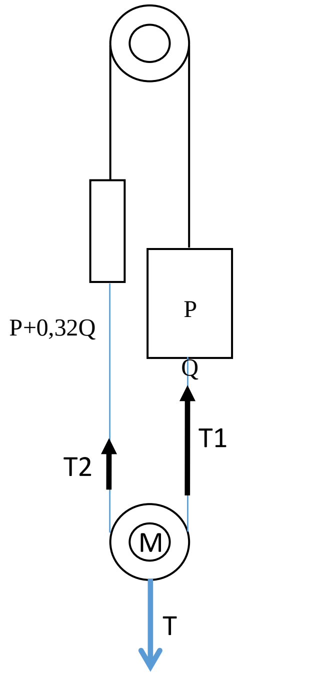

Empty car: $\frac{T1}{T2} = \frac{T+gxQ}{T-gxQ}$

Full car : $\frac{T2}{T1} = \frac{T+g(1-x)Q}{T-g(1-x)Q}$

Q = Rated Load (N)
X = Balancing (%)
T = Tensioner (N)
g = Gravity of acceleration (m/s²)

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Figure 2 – Traction drive calculation

We had this idea while reading the VDI 4707 [1] which showed that in residential buildings, the lift moves in 90% of using with a carload under or equal to 50% of the rated load (see figure 1). In this case, we understood that the energetic balance was not optimized and that 50% of trip used power energy to move just the counterweight. Therefore, we decided to optimize the energy consumption by reducing the weight of the counterweight.

Unlike a traditional lift where the traction drive depends on the car weight and the balancing (often 50%), the proposed concept is based on a closed loop of the traction device. In this case, the car weight is out of the traction drive calculation. Only the tensioner of the belt, the rated load and the balancing are taken into account in the traction drive calculation (see figure 2).

With this approach, if in 90% of cases, the car moves with a carload under or equal 50% to the rated load, then there are 10% of cases with a carload above 50%. With a balancing of 32% in the counterweight, the full car is equivalent to 68% of the rated load for the torque of the motor (see figure 3). In these conditions and in up direction, the power of the machine and the current increase by 36% compared to a lift with 50% of balancing ($\frac{68-50}{50}$).
Actually, with a balancing of 32%, the torque for a car loading is not the same in up and down direction.

	Empty car	Full car
Up Direction	Resistant torque for 32% of rated load	Motor torque for 68% of rated load
Down Direction	Motor torque for 32% of rated load	Resistant torque for 68% of rated load

Figure 3 – Difference of Motor Torque

	In 90% of cases Load ≤ 50%	In 10% of cases Load > 50%
Up Direction	Ω = 1,6 m/s 32% rated load ≤ C ≤ 18% rated load C*Ω ≤ Rated power Motor operation (load > 32% rated load) Generator operation (load < 32% rated load)	1,6 m/s < Ω ≤ 0,7 m/s 18% rated load < C ≤ 68% rated load C*Ω ≤ Rated power Motor operation
Down Direction	Ω = 1,3 m/s 32% rated load ≤ C ≤ 18% rated load C*Ω ≤ Rated power Motor operation (load > 32% rated load) Generator operation (load < 32% rated load)	Ω = 1,6 m/s 18% rated load < C ≤ 68% rated load Generator operation

Figure 4 – Speed and torque control

In order to not oversize the power of the machine to cover the 10% of use with carload above 50%, we decrease the speed to reach the maximum power of the motor. Therefore, the concept of the "*speed technology"* is based on a specific motor design capable of producing for the maximum power (see figure 04 and 5):
=> A maximum torque with a minimum
speed,
=> A minimum torque with a maximum speed

$P = C_{maxi} \times \Omega_{mini} = C_{mini} \times \Omega_{maxi}$
P = Rated power (W), Ω = Motor speed technology (m/s), C = Motor torque (Nm)

	630Kg - 1.6m/s	
Speed / Vitesse	0.7	1.6
DATA LIFT / DONNEES ASCENSEUR	Rated load : 630Kg Rated speed : 1.6 m/s Main Shaft load : 2500Kg	
SUSPENSION	Susp : 1/1	
MACHINE GEARLESS MACHINE DATA / DONNEES MACHINE	Voltage : 220V 50Hz Motor frecency : 23.5Hz Poles number : 20p Rpm : 141 tr/mn Rated power : 4Kw Rated current : 32.8A Rated torque : 270Nm Machine weight : 173Kg	Voltage : 220V 50Hz Motor frecency : 53.5Hz Poles number : 20p Rpm : 321 tr/mn Rated power : 4.4Kw Rated current : 16.5A Rated torque : 130Nm Machine weight : 173Kg

Figure 5 – motor data sheet

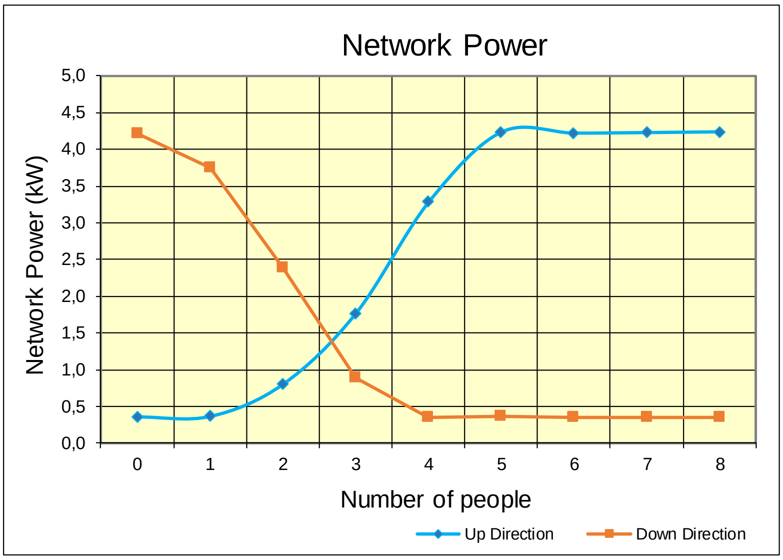

Figure 6 – Network power according to the carload

Before each start, the controller measures the load inside the car and calculates the maximum speed of the motor in accordance to the rated power without ever exceeding it (see figures 6 & 7).

Many measurements have been done on our test tower in Valence to compare the performance between lifts at 1 m/s, at 1,6 m/s and a lift with "*the speed technology"*.

Details of the lifts and the test tower :

Lifts : 3 lifts with the same kinematic and with a traction drive in closed loop [2],
Rated Load : 630 Kg, Car Weight : 731 Kg, Balancing: 50% for rated speed 1 m/s and for 1,6 m/s,
Balancing : 32% for the lift with the "*speed technology"*.
Shaft : Rise : 24 m, Number of level: 8.

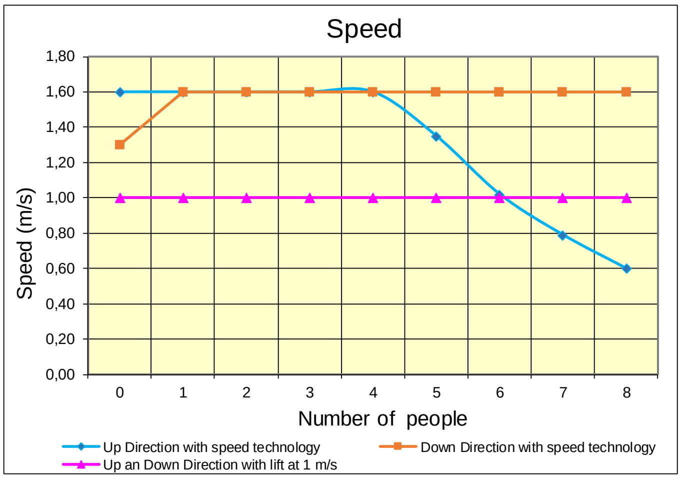

Figure 7 – Speed according to the carload

The Energy consumption was mesured in compliance with EN ISO 25745-1 [3] and EN ISO 25745-1 [4] for the following trip cycle:

1) Begin of reference trip with open lift door
2) Closing lift door
3) Trip up or down using the full lifting height
4) Opening and immediate closing of the lift door
5) Trip up or down using the full lifting height
6) Opening lift door

To attest the results, tests and measures were done and provided by an independent third party [4].

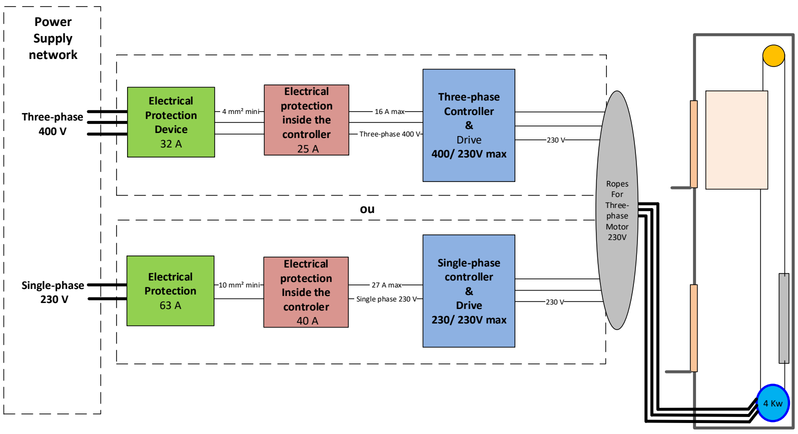

Figure 8 – Power supply network for 630 Kg lift

We apply this technology on a gearless synchronous three-phase 220V motor. Therefore, it is easy to connect the installation to a three phases 400V or single-phase 220V power supply network (see figure 8). As a result, it can be connected to renewable energy power supplies. Solutions incorporating photovoltaic solar energy are currently being investigated.

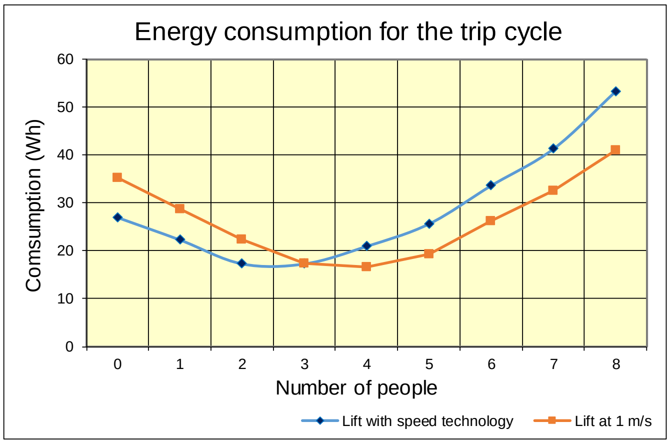

Figure 9 – Energy consumption for the Trip Cycle

When the car is empty, the figure 9 shows that the difference of energy consumption for the trip cycle is close to 30% between a lift at 1 m/s and a lift with the "*speed technology*":

Lift at 1 m/s with 50% balancing = 36 Wh
Lift with "*speed technology*", 32% balancing = 26 Wh

The difference is equal to 27.8 %

When the car loading reaches 32%, the trend is reversed. Then the lift at 1 m/s consumes the least per trip cycle.

Even if the result above is interesting for a trip cycle, it is important to compare simulation in terms of energy consumption and in terms of traffic on a day. To do it, we used a popular simulation tool [6], and compared different templates for the same previous lifts (lifts at 1 m/s, 1,6 m/s and lift with "*speed technology*"). For simulations, we fixed the speed at 1,6 m/s for the lift with "*speed technology*" because even if the car is full at a moment, at the next floors for stopping, some passengers will go out and the speed will quickly increase to 1,6 m/s [see figure 7].

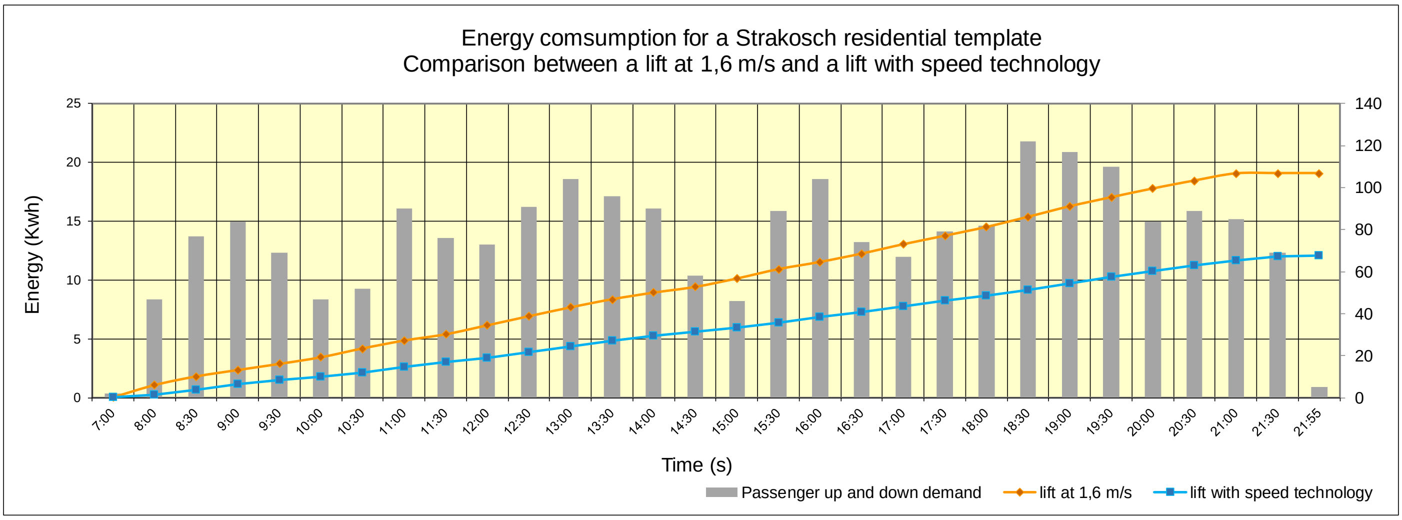

Figure 10 – Energy Consumption for a Strakosch Residential Template [6]

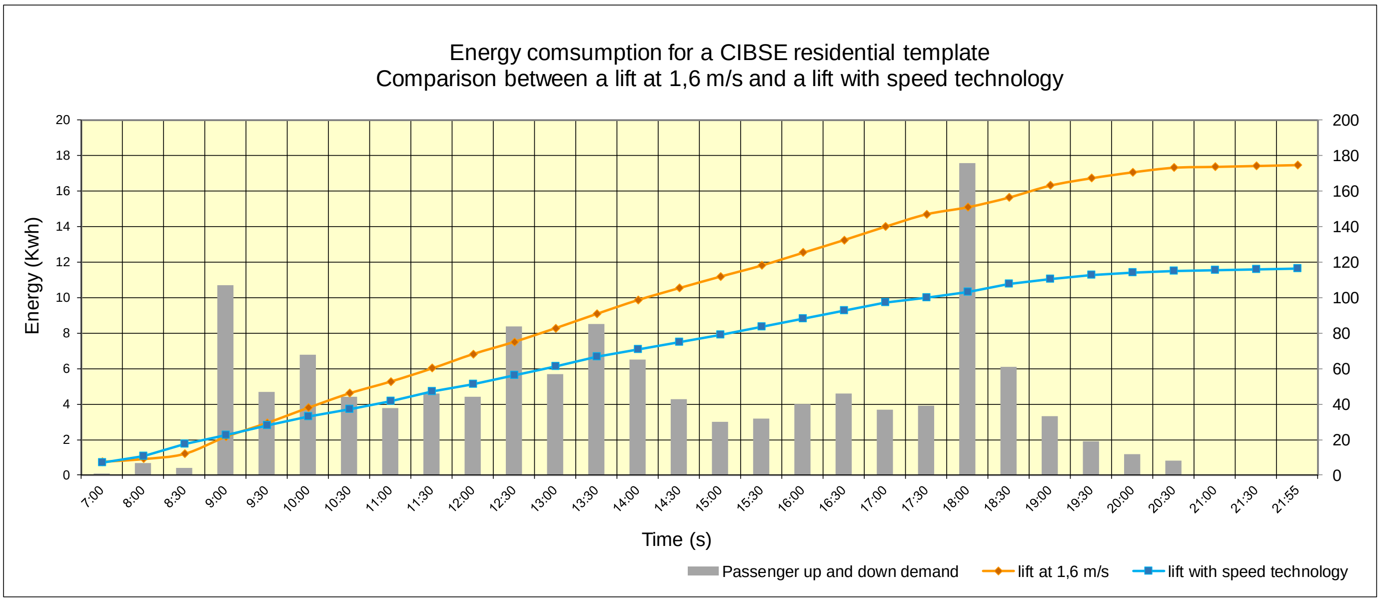

Figure 11 – Energy Consumption for CIBSE Residential Office Template [6]

For Straksoch residential template (see figure 10) and for CIBSE residential template (see figure 11), the energy consumption (cumulated) is more important for the lift at 1,6 m/s than for the lift with "*speed technology*".

	Energy consumption(KWh)		
	Lift at 1,6 m/s	Lift with speed technology	Saving
Strakosch Residentiel	19,1	12,1	37%
CIBSE Residential	17,5	11,6	33%

Figure 12 – Energy consumption comparison

At the end of the day, we note results of energy consumption on the figure 12.
Even if we did some assumptions like the speed used in the simulation tool, the results are very promising for the two types of template.

The average of saving for the lift with "*the speed technology"* is close to 35% a day.

On below, two simulations to compare traffic of a lift at 1 m/s and a lift with "*the speed technology"* for office building.

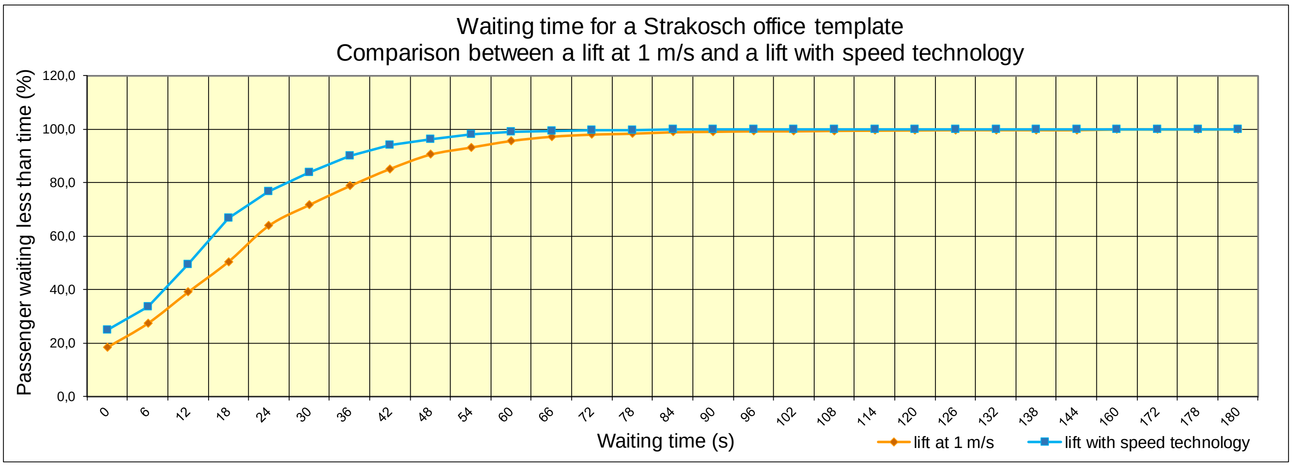

Figure 13 – Waiting Time for a Strakosch Office Template [6]

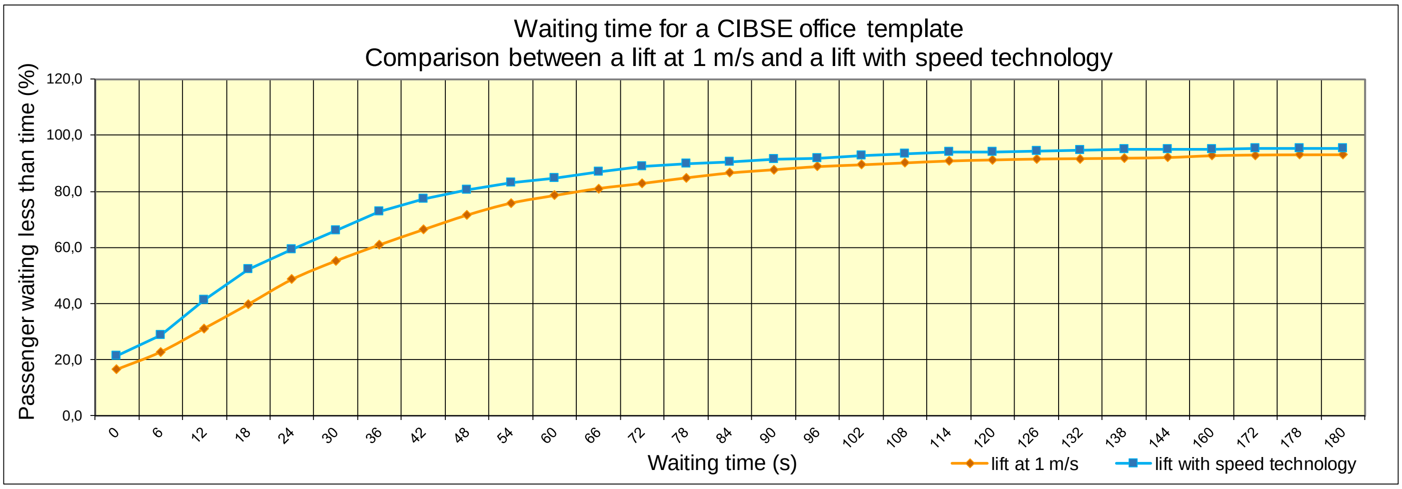

Figure 14 – Waiting Time for a CISBE Office Template [6]

For Straksoch office template (see figure 13) and for CIBSE office template (see figure 14), the waiting time is always more important for the lift at 1 m/s than the lift with "*the speed technology"*.

	Average Waiting Time (s)			**Energy Consumption (KWh)**		
	Lift at 1 m/s	Lift with speed technology	Saving	Lift at 1 m/s	Lift with speed technology	Saving
Strakosch Office	99,7	57,4	42%	11,17	10,72	4%
CIBSE Office	104,7	64,4	38%	13,2	11,6	12%

Figure 15 – Energy Consumption Comparison

We note the results of the average waiting time (ATW) on the figure 15.

Even if we did some assumptions like the speed used in the simulation tool, the results are very promising for the two types of template.

The average waiting time for the lift with "*speed technology"* is close to 40% less than the lift a 1 m/s.

For this important gain of traffic, we can note that the energy consumption at the end of the day is very similar (the differences are only 4% and 12% in favour of "*the speed technology"*).

2 CONCLUSION

In conclusion, the results of "*the speed technology*" is very promising. Indeed, in these simulations we can note that for different examples of using (Strakosch and CIBSE templates for residential and office building):

1. For a same traffic, "*the speed technology"* consumes an average of 35% less than the lift at 1,6 m/s,
2. For a same energy consumption, "*the speed technology"* has a traffic 40% more important than the lift at 1m/s.

In addition, in reference to the ISO 25745, with the "*speed technology"*, the energy consumption for the trip cycle when the car is empty, is 27.8 % less than a lift at 1 m/s.

Still under development, "*the speed technology"* is very promising and we will continue to investigate on this way.

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[6] ELEVATE™, Elevator traffic analysis & simulation software – Peters Research Ltd

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Stephane REAU, Technical Director in SODIMAS, in charge of innovation and research and development department.
Engineer from the ENSEM School in France (Electricity and Mechanic degree) and graduated from the University of Nancy in the field of Electricity.
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