ENERGY CONSUMPTION OF DIFFERENT TYPES OF LIFT DRIVE SYSTEM

D.A.Doolaard, Liftinstituut (Netherlands Institute for Lift Technology),
Amsterdam, The Netherlands

ABSTRACT

Large differences are discovered when the energy consumption of different types of lift drive are compared. In general the question is: what is the most energy and cost-saving solution for a lift drive system? Using a special measurement set-up and a computer program to standardise the results, a comparison has been made between single-speed, two-speed, chopper and VVVF drives. The results of the test showed clearly the advantages and disadvantages of the various drive systems.

1 General introduction

For a very long time now, there have been three general types of lift drive: Traction, drum and hydraulic.
Every type of drive uses an electromotor for driving the machinery.
Nowadays ride comfort is of ever increasing interest for the lift owner and user. In order to give the passenger more ride comfort there is a tendency to fit the abovementioned lift motors with an electronic type of speed control.
These controls greatly influence the comfort of the lift user, but as the years have gone by, energy consumption has become of more and more interest; sometimes, for example in apartment buildings, even prevailing over ride comfort.

In order to gain some insight into this matter, an investigation into energy consumption in various types of lift drive system was carried out on behalf of the Netherlands Institute for Lift Technology.

2 Speed control of lift motors

A complete cycle in a lift ride consists of the following stages:
- Acceleration from zero to nominal speed;
- Constant speed during the ride;
- Deceleration from nominal speed to standstill.

As is generally known, there are several ways in which the speed of asynchronous (lift)motors can be controlled:
- No control (one-speed);
- Control by switching over to other windings (two-speed);
- Chopper drive & eddy current braking;
- Frequency control;
- DC control.

2.1 Two-speed drive

For this kind of drive a pole-changeable motor is used.
The most commonly-occurring pole numbers are: 4/16 and 6/26.
These numbers of poles result into a synchronous revolution-speed of 1500/375 and 1000/250 rpm, respectively.
Acceleration is achieved by switching on the high-speed windings, whilst deceleration is made possible by first switching from high-speed to low-speed windings, followed by switching off the motor and using the brake to stop the machine.
A relatively 'smooth' ride is achieved by mounting a large flywheel on the motor axis.
The resultant speed pattern is given in the following figure (fig. 2.1)

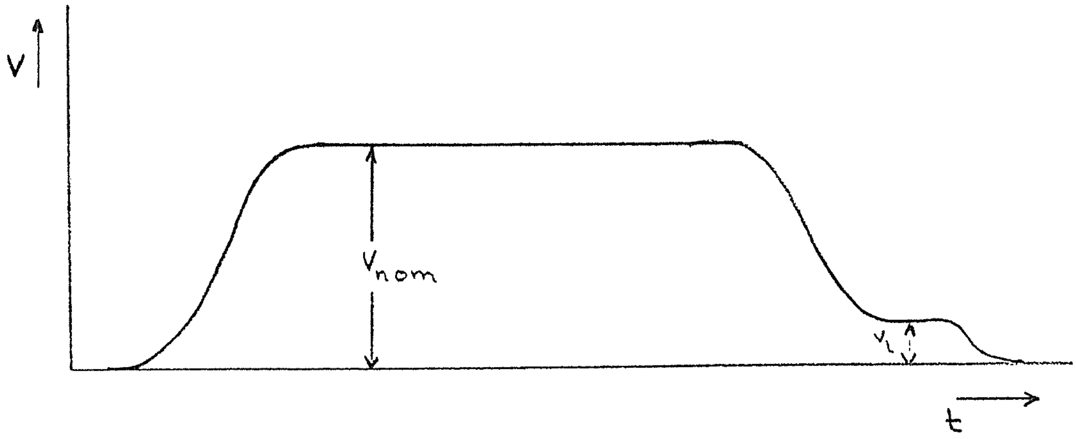


Fig.2.1 Speed pattern

The disadvantage of this type of drive is that correct stopping at floor level is greatly dependent on the load of the car.
On the plus side, investment costs are low.

2.2 Chopper drive & eddy current braking

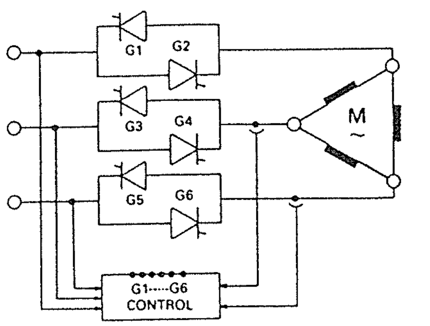
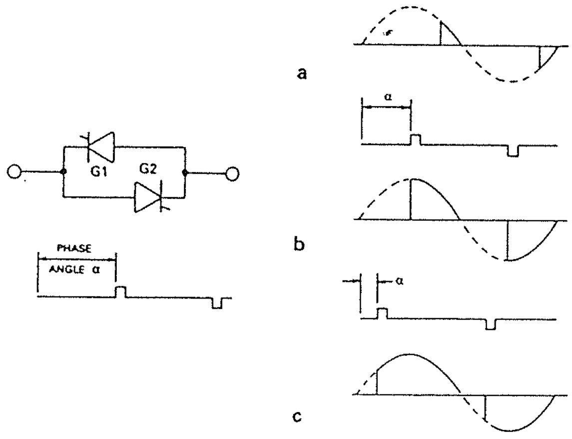


Fig. 2.2.1

At present, this is the most commonly-fitted control system, used in new lift drive systems. The switching-driving circuit generally consists of like an anti-parallel set of thyristors (see fig. 2.2.1)

Because firing the thyristors at the correct moment is of vital importance, feedback of the actual speed into the drive electronics is necessary.
By shifting the ignition-angle of the thyristors, motor energisation can slowly be increased, so that the lift accelerates smoothly to contract speed.



Output voltage control: a 25% b 50% c 75%.

Fig 2.2.2

As soon as the lift approaches the desired floor, the ignition angle of the thyristors is shifted back so that motor energisation, and thus lift speed are reduced. There is only one "but" in this process: whilst motor energisation is reduced, the braking force is also proportionally reduced. This problem can be solved, i.e. correct braking is ensured, by passing direct current into the low-speed windings of the motor. The braking power of the resulting eddy current forces reduces the speed of the motor.

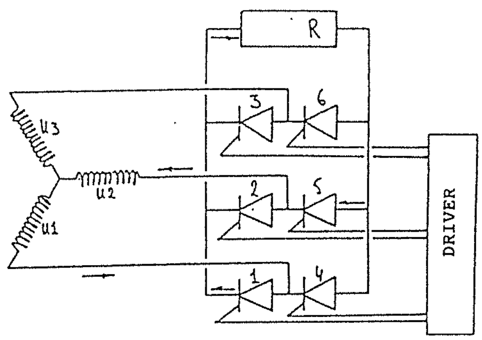


Fig. 2.2.3
Eddy Current braking

The advantage of this type of drive is, that stopping accuracy is assured.
On the other hand, because of the higher transients caused by the electronic drive system and destruction of rotation energy, it has the disadvantage of severely overheating the motor. At the same time the electricity generating and supply companies are unhappy about the disturbances to mains electricity by the chopper.

2.3 Frequency control

At the moment frequency control is one of the most expensive forms of motor drive. However, this disadvantage is balanced out by lower energy costs.
The fact that speed can be varied by varying the frequency of the power supply can be derived from the following equations:

$$n_s = \frac{60 * f_s}{p} \text{ [rpm]}$$

where:
n_s = number of revolutions per minute by stator field [rpm]
f_s = frequency of stator field [Hz]
p = number of poles

The torque of an asynchronous motor depends on the voltage and frequency, as indicated by the following equation:

$$T = C * \frac{U^2}{f^2} \text{ [Nm]}$$

From this equation we can see that torque and subsequently speed can be very effectively controlled by changing the frequency.

Because only frequency alteration is used to control speed, a single-speed motor is sufficient.

Figure 2.3 below is a circuit diagram, indicating the various components which make up the entire system.

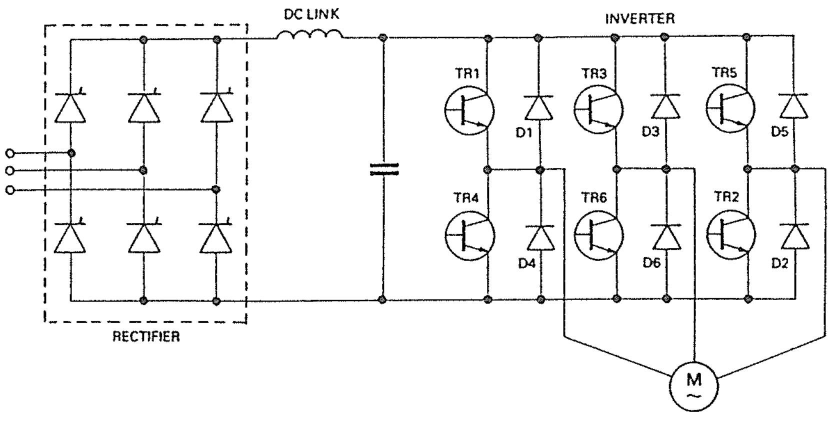


Fig. 2.3 Basic frequency control

The components are:
- a rectifier bridge to convert three-phase mains current into direct current.
- a DC link which forms a DC buffer, for
- the inverter which in turn creates a three-phase AC circuit to feed the motor.

3. Research on energy consumption.

3.1 Strategy to be followed

Before research on energy consumption could start, a research strategy plan had to be drawn up.

3.1.1 Selection of lifts

In order to gain some insight into the energy consumption of lifts, an arbitrary selection of the lifts included the inspection cycle of the Netherlands Institute for Lift Technology was made, purely on the basis of motor drive type.

3.1.2 Method for measuring results.

At the selected installations, power consumption had to be measured as a function of time. For this purpose a measurement system up was designed. (See figure 3.1.2)

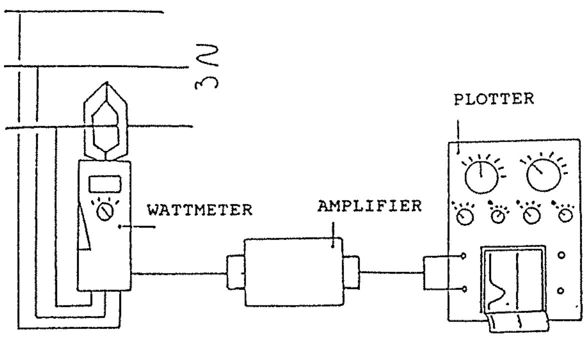
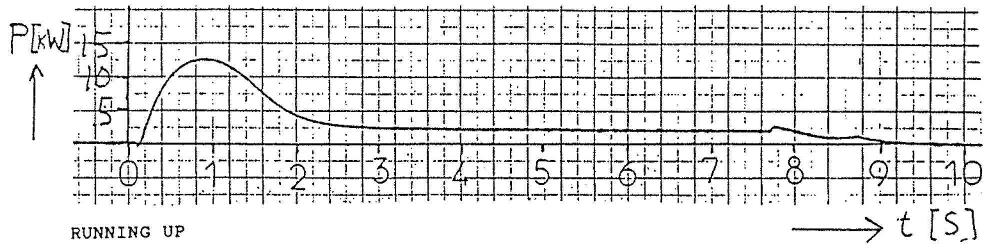


Fig. 3.1.2 Measurement system

A combined powermeter and ammeter with an analog voltage outlet was used for measuring the power consumption of the installation.
The analog voltage was amplified 20 times by a separate amplifier, and the amplified voltage was subsequently used to feed a plotter.

3.1.3 The measurements

Measurements were always taken on the main fuses. In this way even energy flowing back to the mains could be detected.
Initially, the lift was halted at the middle stop.
After setting the meter at the desired power range, the empty lift was sent up three stops. This ensured that the lift was travelling at nominal speed. After reaching its standstill position, the lift was returned to the middle stop. The same procedure was followed, but this time the empty cage was sent three stops, and subsequently returned.
Afterwards, the same lift cage movements were repeated, in order to measure the current fed to the motor with the lift running.
The results are given in figure 3.1.3.



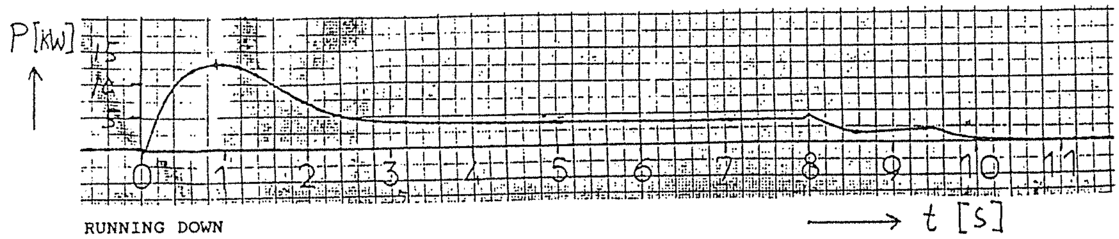


Fig. 3.1.3 Measured power consumption

3.2 Evaluation of the measured results.

In general, it can be said that the area blow the curve of the resultant graph represents a measure for the energy consumed by the system. This is shown by the equation: $E = P * t$ [J] For each test cycle the area below the curve of the graph was measured, always subtracting the area below the zero values.

3.2.1 Calculation of energy according to the area below the curve.

The amount of energy used during the total test ride cycle of the lift is, as stated above, indicated by the surface below the curve of the graph. (Power as function of time)
In order to get an overall view of the energy consumed, a computer program, written in Basic is used to calculate the total area. For this purpose the time axis of the graph is divided into millimetre sections. Above each millimetre, the height of the varying curve is measured. Any height below the zero-line is given as a negative value. In order to calculate the amount of energy using the calculated areas, the following pre-set meter values must be taken into account:

- Speed of paper in the plotter
- Number of Kw/digit in plotter (varies for the different rated loads)

The programme gives the energy consumed during each part of the total test-cycle in KJ, specified for acceleration, contract speed and deceleration.

3.2.2 Energy correction

In order to convert travelling time and total energy consumption for each test cycle into a value comparable with other lifts, another computer program in Basic was written.
Whilst the speed is constant, after acceleration and before deceleration, it is easy to convert the total energy consumption of this period, by making the varying part of the graph into a standard length. The constant part therefore is stretched or shrunk.

3.3 Preparation of the results

The main problem in processing the results was the diversity of the installations on which the tests had been carried out.
The following differences had to be considered:
- different masses of lift cages and counterweights;
- different contract speeds;
- different lift capacities;
- absence of counterweights in hydraulic lifts.elevators

As energy consumption depends on a very large number of parameters such as mass in the complete system, friction between guides and guiding shoes and efficiency of the traction gear, it is very difficult to create a standard model for the calculation of theoretical energy consumption, because these parameters vary constantly during the lift ride.
These problems made it impossible to give an efficiency percentage for the lifts on which the research was carried out. A formula was therefore drawn up, which eliminates the specific characteristics of a given lift installation.

The only results used are the energy required to bring the empty lift cage to the desired floor and back to the starting point again.
By relating this energy to the weight of the cage (constant part of mass to be accelerated) and the nominal speed it is possible to compare the energy consumption of one type of lift with another type.
This value is given by the formula $E = m * v^2$.
This figure has been given the name "Lift Energy Number", LE_h and defined as: The quantity of energy necessary for move an empty cage up and down over a defined distance specified per kilo.
By relating the Lift Energy Number to the nominal speed we can see how energy consumption varies with increasing speed. At the same time it is possible to compare different types of lifts travelling at the same speed.

The results for traction lifts will, in practice, be better than those for hydraulic lifts. This is caused by the balancing of traction lifts, such that increasing load has proportionally less influence upon a traction lift than on a hydraulic lift.

3.4 Test results

The calculated values per type of lift are given in the following tables

no.	v_{nom} [m/s]	m_{cage} [kg]	E_{tot} [kJ]	LE_h [J/kg]
1	0,63	645	109,2	169
2	0,63	600	78,0	130
3	0,56	700	90,4	129
4	0,80	678	113,1	167
5	0,63	618	72,7	118
6	1,22	900	129,4	144
7	0,75	695	102,9	148
8	0,50	450	54,9	122
9	1,80	1255	335,3	267
10	0,80	1680	273,3	163

Fig. 3.4.1 Two-speed lifts

no.	v_{nom} [m/s]	m_{cage} [kg]	E_{tot} [kJ]	LE_h [J/kg]
12	1.4	1560	167.1	107
13	1.6	1425	163.8	115
14	1.6	2580	377.2	146
15	2.25	1550	467.7	302
16	1.0	1400	160.0	114

Fig. 3.4.2 Chopper drive & Eddy current-controlled lifts

no.	v_{nom} [m/s]	m_{cage} [kg]	E_{tot} [kJ]	LE_h [J/kg]
17	0.8	735	57.1	78
18	1.75	1050	78.5	85
19	1.6	630	71.5	83
20	1.0	850	58.2	79

Fig. 3.4.3 Frequency-controlled lifts

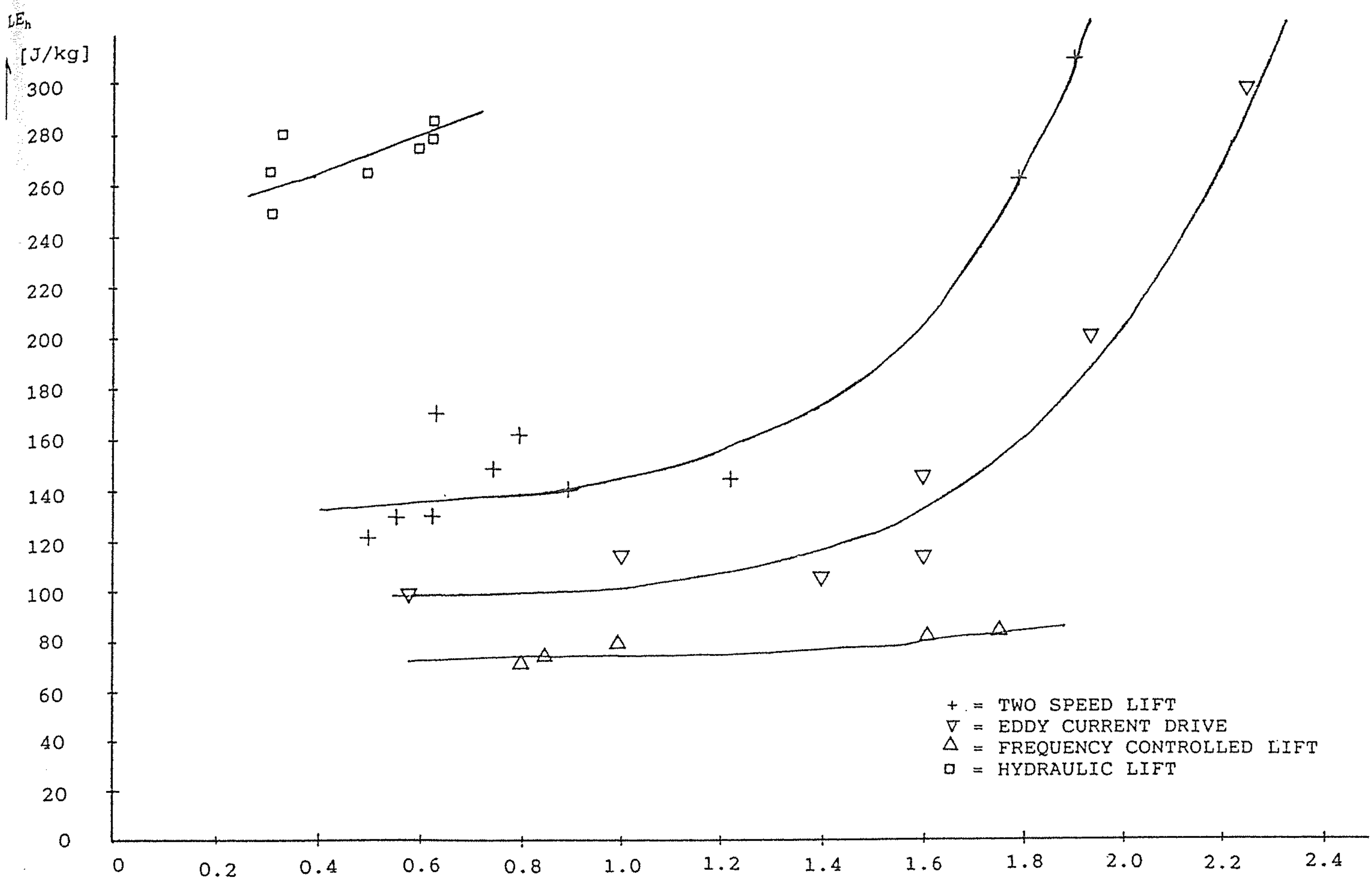


Fig. 3.4 Energy consumption of different types of lift → V_{nom} [m/s]

4. Conclusion

Energy consumption of hydraulic lifts travelling at the same nominal speed is over two times the consumption of conventional two-speed lifts.

Traction lifts with an electronically-controlled drive system in general use less energy than two-speed lifts.

Energy consumption of chopper drive & eddy current-controlled lifts is approximately 70 % of two-speed lifts.

Frequency-controlled lifts show even more sophisticated energy consumption, even at high contract speeds. Compared to two-speed installations frequency controls use 50 % less energy.

Biographical details
D.A.Doolaard, born in 1952. Obtained a higher technical education in electronics. In 1978 became an Inspector and in 1988 Adjunct Chief Inspector at the Liftinstituut (Netherland Institute for Lift Technology). He is a member of several technical committees.