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Analysis of the Potential for Savings in Electrical Energy Consumption in Lifts: Case Study in Indonesia

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ABSTRACT

Regenerative Drive is a motor drive system in an elevator that can also generate electrical energy while consuming electrical energy in the elevator machine, Regenerative Drive converts gravitational potential energy into electrical energy by utilizing the operating characteristics of the lift and the weight difference between the lift cage and the load balancing (Counterweight).). The resulting regenerative power is recovered by returning to the building electricity and being used in other electrical equipment. Regenerative drive lift test location is located in Building which has an elevator using Regenerative Drive. With a motor power of 38.6 kW and can produce regenerative power of 29 kW.

INTRODUCTION

Elevators or lifts are vertical transportation that is commonly used in every multi-storey building. The elevator work system is the same as the work system of a scale where if one side is heavier, the other side will lean towards a heavier lift. This principle is utilized and implemented in the elevator system to make the elevator more efficient at using electrical energy in the building [1-5]. The use of elevators in multi-storey buildings has the advantage that is obtained when the motor in the elevator turns into a generator, and takes advantage of the mechanical force on the elevator ballast load caused by the gravity force to go up to the top floor to generate electrical energy again, so that the electrical energy used in the elevator to be efficient and environmentally friendly [6-10].

Permanent Magnet Synchronous Magnet (MSMP)

Permanent Magnet Synchronous Magnet (MSMP) is the type of motor most commonly selected in modern elevator drives [11]. MSMP has a sinusoidal return GGL (electromotive force) and requires a sinusoidal stator current to produce a constant torque. It has a robust and simple construction, a very high efficiency factor with excellent torque control over a wide range of speeds. Other advantageous features include very high power density and low noise. With the voltage equation as follows:

$$v\varphi = E + jXSIA + RAIA \quad (1)$$

$$EA = V\varphi + jXSIA + RAIA \quad (2)$$

$$P = \sqrt{3} \times V \times I \times \cos\theta \quad (3)$$

Where:
$v\varphi$ = Input voltage
EA = Excitation voltage
RA = Stator resistance
XS = Stator reactance

Drive Elevator

a) Non-regenerative Drive
Non-Regenerative Drive generally consists of an IGBT bridge at the output end of the motor side, with an electrolytic capacitor DC link

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voltage, the converter diode bridge input as shown in Figure 1. Additionally, there is a dynamic brake unit external to the drive [12-14].

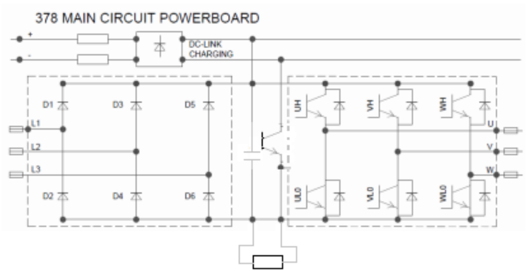

Fig. 1. Non-Regenerative Drive

b) Regenerative Drive

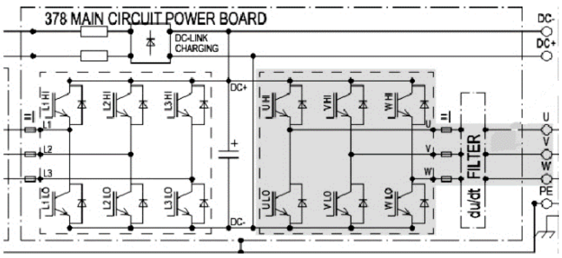

Fig. 2. Regenerative Drive

In the first three-phase input circuit, the three-phase input in the L1, L2, L3 areas, the three-phase input is rectified by a rectifier bridge that can work at one time (L1D1, L2D3, L2D5) [15-17]. And on the diodes L1D2, L2D4, L3D6 work will have a cathode closed which is connected to the lowest phase tension so that when current cannot be passed. One transistor at the top that can work at a time UHi, VHi, and WHi and vice versa also on the bottom transistor at one time ULo, VLo, and WLo.

When the inverter circuit will provide line to line voltages at the U and W terminals, the IGBT UHi transistor provides a positive voltage to the U winding and returns to the IGBT WLo transistor. Furthermore, the work cycle of the IGBT transistor works alternately. The situation of the regenerative mode in the elevator system can be shown in Figure 3 [18].

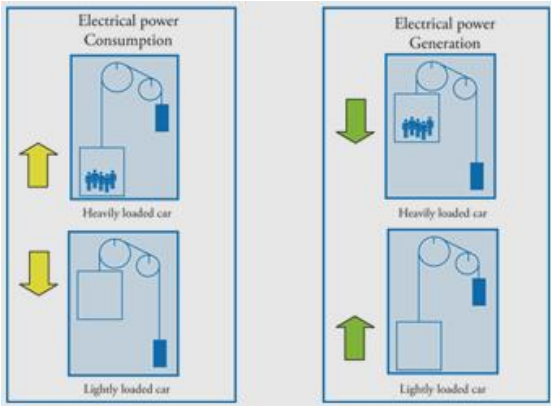

Fig. 3. Regenerative Conditions

EXPERIMENTAL METHOD

Table 1 and Table 2 below show the motor data that will be used in testing as a motor lift. In motor Table 1, the data collection process is carried out at the Building project on Jakarta. And in motor Table 2, the data collection process was carried out in the Building project on Jakarta, which are both lift passanger types with a total of 20 floors.

Table 1. Regenerative Motor Plate Name

No	Motor Data	Score
1	Machinery type	MX18
2	Nominal motor rotation speed	194 rpm
3	Nominal motor frequency	38.8 Hz
4	Nominal motor output power	38.6 kW
5	Nominal motor voltage	340 V
6	Nominal motor current	82.5 A
7	Motor power factor	0.88
8	Motor source voltage	292 V
9	Traction shave diameter	690 mm
10	Resistor resistance	0.12 Ohm
11	Stator reactance	1.16 Ohm

Table 2. Non-Regenerative Motor Plate Name

No	Motor Data	Score
1	Machinery type	MX18
2	Nominal motor rotation speed	147 rpm
3	Nominal motor frequency	29.4 Hz
4	Nominal motor output	30.8 Kw

	power	
5	Nominal motor voltage	294 V
6	Nominal motor current	78.3 A
7	Motor power factor	0.87
8	Motor source voltage	246 V
9	Traction shave diameter	650 mm
10	Resistor resistance	0.154 Ohm
11	Stator reactance	1.2 Ohm

In the first stage of testing, the load or capacity in the lift cage is 0%, 50% and 100% [19]. Data retrieval and measurements are taken twice, namely when the elevator position goes from the ground floor to the top floor and when the elevator position is on the top floor to the ground floor.

RESULTS AND DISCUSSION

Calculation of power in the lift when operating a load of 0% (0 kg), namely when the position of the lift from the ground floor to the top floor of the building. Can be calculated using equation (3).

Starting power

$$P = \sqrt{3} \times V \times I \times cos\varphi$$

$$P = \sqrt{3} \times 228 \times 5 \times 0{,}88$$

$$P = 1.737\ watt$$

$$S = \frac{P}{cos\varphi}$$

$$S = \frac{1.737}{0{,}88}$$

$$S = 1.974VA$$

Power running

$$P=\sqrt{3}\times V\times I\times cos\varphi$$

$$P = \sqrt{3} \times 290 \times 48 \times 0.88$$

$$P = 16.680\ watt$$

$$S = \frac{P}{cos\varphi}$$

$$S = \frac{16.680}{0.88}$$

$$S = 18.955\ VA$$

The regenerative power supplied back to the building can be calculated by means of running power minus starting power:

$$S_{reg} = S_{run} - S_{start}$$

$$S_{reg} = 18.955 - 1.974$$

$$S = 16.981\ VA$$

Based on the measurement results in Table 3 obtained when testing the load on the elevator, the initial power consumption of the building is 1,737 VA which is used to pull the cage load to the top floor of the building. When the motor rotates constantly (synchronously) the motor slowly changes its function to a generator due to the absence of torque when pulling the thought of the elevator to the top floor by utilizing the mass on the counterweight and gravity as the heaviest load puller to fall down so that the elevator machine does not need to use power from the building to pull the cage towards the top floor of the building, and use the regenerative braking system to keep the elevator speed at the set value.

Table 3 shown the results of measurements and calculations in testing, and the results with a minus sign (-) are a sign that the direction of flow in distribution to the lift is the opposite of the direction of the current being returned to the building nets.

Table 3. Test results and power calculations on regenerative motor drives

Motor Load		Dir	Motor Current		Source Voltage		Power Calculation		Pseudo Power Calculation		S_{reg} (KVA)
%	kg		Start (A)	Run (A)	Start (V)	Run (V)	P_{start}	P_{run}	S_{start}	S_{run}	
0	0	Up	5	-48	228	228	1.7	16.7	1.9	18.9	16.9
		Dn	90	60	228	228	31.2	20.8	35.5	23.7	
50	800	Up	40	10	230	228	14	3.4	15.9	3.9	
		Dn	40	12	228	228	13.9	4.1	15.8	4.7	
100	1600	Up	95	58	229	228	32.4	20.1	36.8	22.9	
		Dn	10	-50	229	228	17.4	17.4	3.9	19.7	15.8

Regenerative Power Calculation

The result of the percentage of regenerative power generated at operation with a load of 0% (0 kg) with a ratio of up and down activity can be calculated:

$$\%reg = \frac{Sreg^{UP}}{Stotal^{DN}} \times 100\%$$

$$\%reg = \frac{16.9\ KVA}{59.2\ KVA} \times 100\%$$

$$\%reg = 28\ \%$$

And the result of the percentage of regenerative power at operation with a load of 100% (1800kg) with the ratio of activity up and down can be calculated:

$$\%reg = \frac{Sreg^{DN}}{Stotal^{UP}} \times 100\%$$

$$\%reg = \frac{15.8KVA}{59.7KVA} \times 100\%$$

$$\%reg = 26\,\%$$

Then it can be calculated the total power released by the lift with regenerative drive when regenerative occurs:

$$Total\ S_{reg} = S_{reg} load\ 0\% + S_{reg} load\ 100\%$$

$$Total\ S_{reg} = 16.981\ VA + 15.779\ VA$$

$$= 22.76\ kVA/22.760\ \text{VA}$$

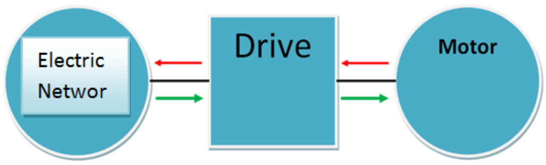

Fig. 4. Direction of regenerative drive current

Regenerative Motor Drive Power Consumption Calculation

The electric power consumed by the elevator motor while working can be calculated:

$$D_{total} = 59.2\ kVA + (19.8\ kVA + 20.5\ kVA) + 59.7\ kVA = 159.4\ kVA$$

Motor Power Measurement With Non-Regenerative Drives

Calculation of power when the load is 0% (0 Kg) The test is carried out on a non-regenerative lift and can also be calculated by equation (3).

Starting power

$$P = \sqrt{3} \times V \times I \times cos\varphi$$

$$P = \sqrt{3} \times 228 \times 5 \times 0.87$$

$$P = 1.717\ Watt$$

$$S = \frac{P}{cos\varphi}$$

$$S = \frac{1.717\ Watt}{0.87}$$

$$S = 1.974\ VA$$

Power running

$$P = \sqrt{3} \times V \times I \times cos\varphi$$

$$P = \sqrt{3} \times 228 \times 0 \times 0.87$$

$$P = 0$$

$$S = 0$$

From the measurement results in Table 4 on testing each load and no regenerative results are generated on the elevator machine which is returned to the building's electrical grids.

Table 4. Test results and power calculations on non-regenerative motor drives

Motor Load		Dir	Motor Current		Source Voltage		Power Calculation		Pseudo Power Calculation		S_{reg} (KVA)
%	Kg		Start (A)	Run (A)	Start (V)	Run (V)	P_{start}	P_{run}	S_{start}	S_{run}	
0	0	Up	5	0	228	228	1.7	0	1.9	0	
		Dn	75	40	228	228	29.6	15.8	25.7	13.7	
50	800	Up	30	8	228	228	10.3	2.7	11.8	3.1	
		Dn	28	10	228	228	9.6	3.4	11	3.9	
100	1600	Up	78	45	230	228	27	15.5	31	17.8	
		Dn	8	0	229	228	2.8	0	3.2	0	

In the elevator using a non-regenerative drive the regenerative result is not returned to the electrical nets of the Building but instead converts the energy output into waste energy. Can be seen in the illustration of Figure 5.

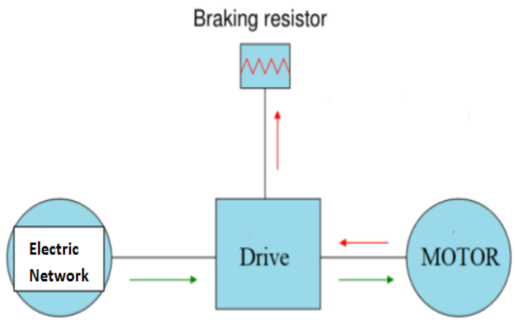

Fig. 5. Illustration of non-regenerative drive current direction

Non-Regenerative Motor Drive Power Consumption Calculation

The electric power consumed by the elevator motor while working can be calculated:

$$D_{total} = (1.9\ kVA + 39.4\ kVA) + (14.9\ kVA + 14.9\ kVA) + (48.8\ kVA + 3.2\ kVA) = 231.1\ kVA$$

CONCLUSION

The regenerative results in the lift with regenerative drive are 16.7 kW (28%) of the total power used at 0% load conditions. And as much as 17.4 kW (26%) of the total power used at 100% load conditions. Lifts with non-regenerative drives do not generate energy back to the nets of the building, but the regenerative products are discharged into heat energy. Non-regenerative drives require a lot of additional cooling due to heat dissipation on the braking resistor component.

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