

Elevator Drive Systems Energy Consumption Study Report

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EECE 492

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Prepared for EECE 492

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2 Acknowledgement

This project is a study to investigate the power and energy consumption of different elevator drive systems. This project was initiated by UBC Plant Operations. Through the efforts of UBC SEEDS (Social Ecological Economic Development Studies) Program, this project became a collaboration of Vertech Elevator Services Inc. and UBC Electrical Engineering.

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3 Introduction and Purpose

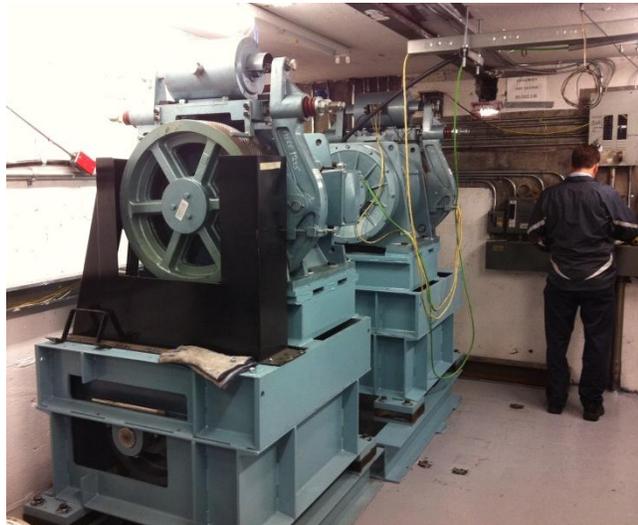
In this elevator energy consumption study, the electrical energy and power consumptions of different elevator drive systems are measured. Measurements were taken on elevator equipment shortly before they were upgraded with new control and drive systems. The measurements were taken before and after changes were made to the elevator in order to compare the relative power consumption of the old and new elevator drive systems. The measurements taken allow us to compare each system and draw a quantitative conclusion for any potential energy saving of newer elevator drive systems.

4 Methodology

There are three (3) different case studies presented in this report. For each site, a power logger was used to measure the instantaneous voltage and current of the AC line the elevator is connected to. This report considers three (3) different case studies:

1. UBC Gage Tower – the equipment was upgraded to an AC Variable Frequency Drive with a Regenerative Drive add-on from a DC Variable Voltage system with a motor-generator set.

2. Panarama Tower – the equipment was upgraded with a new Permanent Magnet AC Gearless machine and an AC Variably Frequency Drive with a Regenerative Drive add-on from a geared machine and a DC Variable Voltage system with a motor-generator set.



Picture 5.1: New Traction Machines in Panarama Tower, Burnaby.



Picture 5.2: New Drive System in Metro Tower 1, Burnaby.

3. Metro Tower 1 – the equipment was upgraded to an SCR Drive from a geared machine and a DC Variable Voltage system with a motor-generator set, while retaining the original DC Gearless machine.

The elevator power consumption was measured while the equipment was idle and when the equipment was operating. This allowed us to calculate the power consumed while travelling the full height of the building,

and allowed us to see what the ambient “standby” power consumption of each elevator system.

4.1 Data Measurement and Collection

In this study, Fluke 1735 Three Phase Power Logger is used to measure energy consumption of elevator drive systems. Fluke 1735 measures instantaneous voltage and current of each phase of the AC line the elevator drive system is connected to. It has a sampling rate of 10.24 kHz and averaging period of 0.5 second. It records average voltage and current of every 0.5 second to estimate power, energy, and harmonics distortion of voltage and current.

When measures are performed, the Power Logger is connected to the AC line as shown below (the diagram shown below was extracted from the Fluke 1735 Manual):

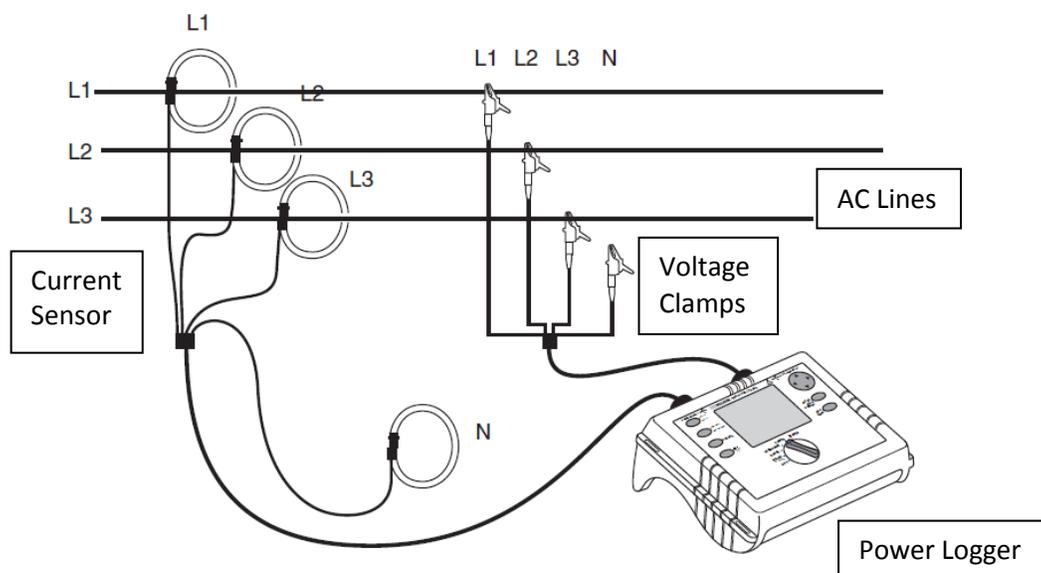


Figure 5.1: Power Logger Connection Diagram.

When we first began the study, we connected the meter to one (1) elevator at the mainline disconnect and set up the meter to measure the power consumption over an extended period of time, up to three (3) weeks. When we downloaded the data for processing, we realized that we could not answer the fundamental question of “how much energy does an elevator require”. When we set the meter up for extended periods, we found that the sampling time of once every 30 seconds or one (1) minute could produce skewed results as the elevator’s operation is not constant. The meter could sample to points in time when the elevator is idle, when in between sampling, the elevator was travelling between the intervals thus showing only the ambient power consumption.

To fairly compare the energy consumption of two drive systems, the activities of the two systems must be the same. As a result, when a drive system is measured over a period of time without the details of

the elevator activities, the data obtained cannot be used to compare with another measurement of the same type. Therefore, no conclusion regarding the energy consumption is drawn from the measurements over a period of time.

It was decided that we should focus on reducing the sampling frequency to the fastest sampling rate of 0.5 seconds to measure the voltage and current at all points of an elevator trip. With the data measured this way, we were able to calculate the power consumed for each elevator trip. Under controlled circumstances, we were able to calculate the power consumed for an elevator trip (for each direction of travel) and make direct comparisons for the power consumed before and after the elevators were retrofitted.

4.2 Power Consumption Measurements

Measurements are performed under different conditions to provide comparison of different drive systems.

For comparison purposes and for convenience, the elevators in this report were measured when they had empty cars (no load) in both the UP and the DOWN direction.

All the elevators in this case study are counterweighted traction elevators. Elevators are typically counterweighted such that the counterweight is 42% heavier than an empty car. Therefore, when an empty car is travelling in the down direction, it is lifting the heavier counterweight, which is similar to fully loaded elevator travelling in the UP direction. Likewise, an empty car travelling UP is lowering the heavier counterweight. It is in this condition that an elevator can “regenerate” power by converting the energy of the weight travelling down into measurable electrical benefit with a regenerative style of drive.

4.3 Ambient Power Consumption

The power measurements were taken before the elevator started and accelerated and was stopped after the elevator had reached its final destination. In the old configuration with Ward-Leonard drive systems, a field generator is used to control the amount of field current entering field coil of the DC machine; thus, controlling the speed of the DC machine. The operation of the field generator alone uses energy even when the car is not in motion. This characteristic does not exist in the new configurations as the VVVF drive for AC machine and PWM drive for DC machine does not use a field generator to regulate the field current. On Ward-Leonard systems, the generator will not always be running, but will turn on when there is demand on the system, and will turn off after a period of inactivity. The

measurements were able to show the ambient power with the generator off, the spike when the generator started, and the ambient power consumed when the generator remained running while the elevator was idle.

4.4 Processing of Measurement Data

At various times in 2011, measurements were performed on elevators at Gage Tower in UBC, Panarama Towers in Burnaby, and MetroTower1 in Burnaby as shown in table 1. The ambient power consumption in Watts and elevator cab operation energy consumption in Watt-hours are extracted from each of the measurements.

Only consider the consumption and regeneration of active energy. Therefore, reactive energy is neglected in this study. Also, this study does not investigate for the effects of the drives modernization on power quality

Since we cannot synchronize precisely the measurement and the drive system's operation so that the measurement begins when the drive system starts driving the traction machine, the measurements are started before the elevator cab starts moving and ends after the elevator cab stops moving by a few seconds.

In addition, the drive systems consist of transformers and other electronics which consume energy even the elevator cab is not moving (i.e. in idle state). This can be caused by the control system, the door operator and other resistive, eddy current, or hysteresis losses, which are parts of the ambient energy consumption of an elevator drive system.

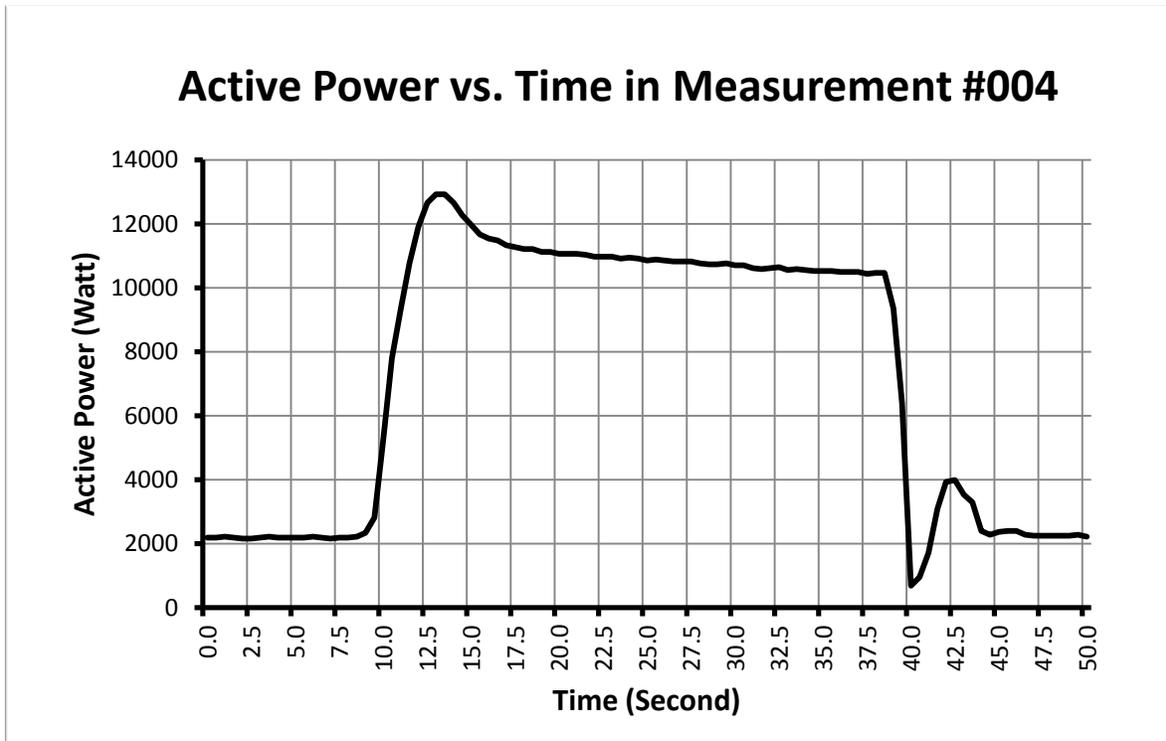
With the ambient energy consumption and the measurement not perfectly synchronize at the beginning and the end, the measurements consist of ambient energy consumption and elevator cab operation energy consumption of the drive system.

To fairly compare the ambient power consumption and the elevator cab operation energy consumption in different elevator drive systems, these two data have to be extracted from each measurement. Notice that the ambient power consumptions are compared in Watts while the elevator cab operation energy consumptions are compared in Watt-hour.

The graph below shows the active power consumed for one (1) elevator trip to show the extraction of ambient power consumption and elevator cab operation energy consumption from a measurement.

Measurement #004 records the energy consumption when an elevator cab was driven down from the

top to the bottom of terminal ending of the hoist way. From the data, power consumption starts increasing at $t=9.5\text{sec}$ and stabilizes at $t=44\text{sec}$. Within this interval, the power consumptions are summed up to produce an elevator cab operation energy consumption of 92.33 Watt-hour. Additionally, the power consumption before $t=9.5\text{sec}$ and after $t=44\text{sec}$ are averaged to result in an ambient power consumption of 2257.27 Watts.



Graph 1: Plot of Active Power Consumption against Time in Measurement #004

Table 1 shows all the ambient power consumption and elevator cab operation energy consumption from comparable measurements.

| Measurement ID | Location | Date | Travel Direction | Drive System | Traction Machine | Energy Consumed per Trip (Watt-hour) | Average Ambient Power Consumption (Watt) |
|----------------|----------------|-------------------|------------------|--------------|------------------|--------------------------------------|--|
| 002 | UBC Gage Tower | May 6, 2011 | Down | VVGFC | Gearless DC | 96.06 | 355.00 |
| 004 | UBC Gage Tower | May 6, 2011 | Down | VVGFC | Gearless DC | 92.33 | 2257.27 |
| 003 | UBC Gage Tower | May 6, 2011 | Up | VVGFC | Gearless DC | 25.53 | 361.50 |
| 005 | UBC Gage Tower | May 6, 2011 | Up | VVGFC | Gearless DC | 23.94 | 2213.04 |
| 011 | UBC Gage Tower | May 16, 2011 | Down | VVVF | Gearless AC | 92.38 | 438.46 |
| 013 | UBC Gage Tower | May 16, 2011 | Down | VVVF | Gearless AC | 93.01 | 452.57 |
| 015 | UBC Gage Tower | May 16, 2011 | Down | VVVF | Gearless AC | 92.56 | 446.72 |
| 010 | UBC Gage Tower | May 16, 2011 | Up | VVVF | Gearless AC | -28.13 | 516.86 |
| 012 | UBC Gage Tower | May 16, 2011 | Up | VVVF | Gearless AC | -27.86 | 434.67 |
| 014 | UBC Gage Tower | May 16, 2011 | Up | VVVF | Gearless AC | -28.21 | 418.64 |
| 024 | Panarama Tower | July 27, 2011 | Down | VVGFC | Gearless DC | 98.60 | 1180.00 |
| 025 | Panarama Tower | July 27, 2011 | Up | VVGFC | Gearless DC | -8.58 | 1150.30 |
| 031 | Panarama Tower | October 5, 2011 | Down | VVVF | Gearless AC | 105.05 | 363.10 |
| 032 | Panarama Tower | October 5, 2011 | Down | VVVF | Gearless AC | 105.01 | 348.46 |
| 033 | Panarama Tower | October 5, 2011 | Up | VVVF | Gearless AC | -33.02 | 355.38 |
| 034 | Panarama Tower | October 5, 2011 | Up | VVVF | Gearless AC | -33.07 | 353.33 |
| 106 | Metrotower 1 | November 15, 2011 | Down | SCR | Gearless DC | 165.47 | 1759.35 |
| 108 | Metrotower 1 | November 15, 2011 | Down | SCR | Gearless DC | 158.48 | 1736.47 |
| 123 | Metrotower 1 | November 15, 2011 | Down | VVGFC | Gearless DC | 267.71 | 6712.32 |
| 125 | Metrotower 1 | November 15, 2011 | Down | VVGFC | Gearless DC | 268.20 | 6683.26 |
| 105 | Metrotower 1 | November 15, 2011 | Up | SCR | Gearless DC | 21.75 | 1832.34 |
| 107 | Metrotower 1 | November 15, 2011 | Up | SCR | Gearless DC | 13.30 | 1745.69 |
| 122 | Metrotower 1 | November 15, 2011 | Up | VVGFC | Gearless DC | -9.27 | 6688.99 |
| 124 | Metrotower 1 | November 15, 2011 | Up | VVGFC | Gearless DC | -17.11 | 6654.95 |

Table 1: List of Measurements with Average Ambient Power Consumption and Energy Consumption.

5 Comparison and Analysis of Results

From all the extracted data, key results are summarized in the table 2 as shown below. Observations at each measurement location are discussed below table 2.

| Location | Power or Energy Consumption of Drive Systems | | | | | |
|----------------|--|--|--|--|--|--|
| | Old Configuration | | | New Configuration (with Regeneration Unit) | | |
| | Average Ambient Power Consumption (Watt) | Average One Trip Up Energy Consumption (Watt-hour) | Average One Trip Down Energy Consumption (Watt-hour) | Average Ambient Power Consumption (Watt) | Average One Trip Up Energy Consumption (Watt-hour) | Average One Trip Down Energy Consumption (Watt-hour) |
| UBC Gage Tower | 358.25/ 2235.0 | 24.5 | 94.0 | 451.0 | -28.0* | 92.0 |
| Panarama Tower | 1165.1 | -8.6* | 98.6 | 355.1 | -33.0* | 105.0 |
| Metro Tower1 | 6684.9 | -13.2* | 268.0 | 1768.5 | 17.5 | 162.0 |

*Negative value represents a regeneration of active energy from the drive system to the AC line.

Table 2: Comparison Summary of Measurement Results.

5.1 UBC Gage Tower

From the UBC Gage Tower measurements, there are a few observations:

5.1.1 UBC Gage Tower - Ambient

In the old drive system, the field generator in the Ward-Leonard drive affects the ambient energy consumption. The field generator is kept operating for a certain period of time after the elevator finish a trip. The field generator is shut down after the elevator is not being called within that period of time.

In table 2, the two numbers shown as the ambient power consumption of the old drive system of UBC represents the ambient power consumptions when the field generator is on and off. When the field generator is not operating the ambient power consumption 358.25 watt, and when the field generator is operating without the elevator cab in motion, the power consumption is 2235.0 Watt.

In the new drive system, there is no field generator. So the ambient power consumption mainly depends on the efficiency of power transformer and the operation of the electronics of the drive system.

Since there are two numbers from the old system for comparison, an estimation can help drawing a conclusion. In this estimation, we assume the field generator operate 8 hours a day and rest of the day (i.e. 16 hours) it is not running. We obtain an estimation as shown in table 3.

| Old Drive System (with field generator) | | | New Drive System (without field generator) | | |
|--|-----------------------|--------------------------------------|---|-----------------------|--------------------------------------|
| Ambient Power (Watt) | Operation Time (Hour) | Resultant Ambient Energy (Watt-hour) | Ambient Power (Watt) | Operation Time (Hour) | Resultant Ambient Energy (Watt-hour) |
| 358.25 | 16 | 23612 | 451 | 24 | 10824 |
| 2235 | 8 | | | | |

Table 3: Estimation for Ambient Energy Consumption Comparison.

From the estimation, the resultant ambient energy consumption of the old drive system is more than two times of the number of the new drive system. This shows a reduction in ambient energy consumption after retrofitting into a new drive system at UBC Gage Tower.

5.1.2 UBC Gage Tower - Up Trip

In the old drive system, even without a regenerative unit, there is regeneration of energy when the elevator cab is braking at the end of a trip traveling up. (See measurement #005)

However, the amount is not enough to cause a net regeneration of energy in any trip measured with the old drive. In other words, there are points of time when active power is being recovered by the old drive, but energy is always consumed within a trip with the old drive system.

In the new drive system, with the aid of regenerative unit, energy is being recovered after the traction machine initiates the motion of the elevator cab and counterweight. At the end of a full trip up the hoist way, there is a net regeneration of energy from the drive system to the AC line. (See measurement 010)

The energy recovered during the trip up by regenerative unit in the new drive system contributes to a significant reduction in energy consumption in a trip up.

5.1.3 UBC Gage Tower - Down Trip

With the old drive, the average energy consumption for an empty elevator cab travelling a full trip down the hoist way is 94 Watt-hour.

With the new drive, the average energy consumption for an empty elevator cab travelling a full trip down the hoist way is 92 Watt-hour.

The results show a minor reduction of average energy consumption for an empty elevator cab travelling a full trip down.

5.2 Panarama Tower

From the Panarama measurements, there are a few observations:

5.2.1 Panarama Tower - Ambient

With the old drive system, there are only measurements performed when the field generator is running. The ambient power consumption is 1165.1 Watt.

With the new drive system, the ambient power consumption is 355.1 Watt.

The results show a significant reduction of ambient power consumption with the new drive systems.

5.2.2 Panarama Tower - Trip Up

With the old drive system, unlike the case in UBC Gage Tower, the measurement for a full trip up shows a net regeneration of active energy of 8.6 Watt-hour. (See measurement #025)

With the new drive system, the average net regeneration of energy is 33.0 Watt-hour per full trip up.

In the new drive system, the regenerative unit allows more efficient recovery of energy to the AC line than the Ward-Leonard system in the old drive system. Therefore, it results in a regeneration of a larger quantity of active energy.

5.2.3 Panarama Tower - Trip Down

With old drive system, the average energy consumption for a full trip down is 98.6 Watt-hour.

With new drive system, the average energy consumption for a full trip down 105.0 Watt-hour.

At Panarama Towers, we were not expecting to see the power consumption one trip in the down direction to consume more power with the new system than the old system.

The equipment was retrofitted with a more efficient gearless machine with a new AC Variable Frequency drive.

The only plausible explanation is that the new equipment was running at contract speed of 350 fpm, whereas the old system might have been running at a slower speed.

It is quite common for older DC Variable voltage systems to degrade in speed without vigilant maintenance or the speeds were purposely slowed down for reliability reasons.

5.3 Metro Tower 1

From the Metro Tower 1 measurements, there are a few observations:

5.3.1 Metro Tower 1 - Ambient

With the old drive system, there are only measurements performed when the field generator is running. The ambient power consumption is 6684.9Watt.

With the new drive system, the ambient power consumption is 1768.5Watt.

The results show a significant reduction of ambient power consumption with the new drive systems.

5.3.2 Metro Tower 1 - Trip Up

With old drive system, there is a net regeneration of energy of 13.2 Watt-hour.

With new drive system, there is no regeneration of energy. Instead, the new drive system consumes 17.5 Watt-hour for a full trip up.

There is no clear explanation why the elevator system would consume energy when traveling up when the regenerative drive system.

5.3.3 Metro Tower 1 - Trip Down

With the old drive system, the average energy consumption for an empty elevator cab travelling a full trip down the hoist way is 268.0 Watt-hour.

With the new drive system, the average energy consumption for an empty elevator cab travelling a full trip down the hoist way is 162.0 Watt-hour.

The results show a significant reduction of average energy consumption for an empty elevator cab travelling a full trip down.

6 Conclusion

Considering all the key results obtained from 3 case studies, we evaluate the percentage change on the ambient power, up trip and down trip energy consumption to aid drawing conclusion from results.

| Location | Percentage Changes on Power or Energy Consumption of Elevator Systems after Retrofitting | | |
|----------------|--|--|--|
| | Average Ambient Power Consumption (Watt) | Average One Trip Up Energy Consumption (Watt-hour) | Average One Trip Down Energy Consumption (Watt-hour) |
| UBC Gage Tower | -54%* | -214%* | -2%* |
| Panarama Tower | -70%* | -284%* | 6% |
| MetroTower1 | -74%* | 233% | -40%* |

*Negative value represents a decrease of new value comparing to original value.

Table 4: Percentage Changes of Power or Energy Consumption of Elevator Systems after Retrofitting.

From table 4, it shows that with the new drive systems, there are substantial energy savings in ambient power consumption when comparing to the old drive systems in all case studies.

However, for elevator trips in up direction, only the new drive systems at UBC Gage Tower and Panarama Tower provide energy saving in form of increases in regeneration of active energy. Exception appears at Metro Tower 1 where the energy consumed for a trip in up direction increases after changing into the new drive system.

In terms of trips in down direction, no significant differences were observed in the UBC Gage Tower and Panarama Tower cases. Nonetheless, a significant energy saving happens in the Metro Tower 1 case.

In conclusion, the AC Variable Frequency Drive with an addition of regenerative drive add-on provides more efficient regeneration as is demonstrated at the UBC Gage Tower. At Panarama, the gearless AC traction machine driven by an AC Variable Frequency Drive provides greater regeneration capability than the original geared DC traction machine and DC Variable voltage system.

7 Discussion and Recommendation

7.1 Discussion

Since one of the purposes of this study is to recommend potential policy changes building construction and operation at UBC. The brief estimation below could help policy makers gaining some insight.

According to UBC Gage Tower Measurements, a round trip of the elevator cab can save 50 Watt-hour. Assuming the elevator cab travels 500 trips per day, it saves 25 kilowatt-hour per day. If we extend this number to a 365-day year, 9125 kilowatt-hour of energy can be saved, which is equivalent to a \$638.75 saving per year based on the electricity price of \$0.07 per kilowatt-hour in British Columbia.

If we consider an add-on regenerative unit for an elevator drive system is \$5000, the payback period is almost 8 years.

Note that in this brief estimation, maintenance costs, additional installation and commissioning costs are not accounted. On the other hand, there are associated advantages not accounted for. For example, installation of regenerative drive systems may help obtaining certification in LEED or other building rating system. In addition, BC power smart program may extend the program to elevator equipment so that owner would receive incentive for the regenerative unit installation.

7.2 Recommendation

This Elevator Drive Systems Energy Consumption study has a narrow scope focusing only on the net active power or energy consumed by the elevator systems. However, there are still other significant electrical aspects of an elevator drive system that can be investigated.

Since power quality is a trending topic in Power Engineering industry, an interesting aspect would be the effect on reactive power generation of elevator system with different elevator drive systems. There is a potential for power electronics elevator drive systems to reduce total harmonic distortion on voltage and current AC line is isolated by the rectifying circuitry. This potential advantage could bring monetary saving to building ownership as it could reduce the installation of power factor correction equipment in building.

8 Appendix I: Processed Data

Due to the size and format of the Processed Data, it cannot be attached within this report.

Please contact [the SEEDS office](#) should you wish to request the processed data for reference.