Energy Efficient Initiative – Installation of Active Harmonic Filter and Real Time Capacitor Bank in High Speed Lift System

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Introduction

Harmonics have been an important issue with the intensive use of non-linear loads in modern buildings. Typical non-linear loads are power electronic equipment, lifts and air-conditioning with Variable Speed Drives (VSD) control, and solutions for filtering has been in search. EMSD issued a Code of Practice (CoP) for Energy Efficiency of Electrical Installations, 1998 Edition with recommended maximum Total Harmonic Distortion (THD_I) of current content for respective electrical loads and circuits as a baseline performance standard.

For the purpose of compliance with the recommended standard of THD_I quoted from CoP and for healthy operation of electrical systems, a high zone lift in a 40-storey office building was under study and assessment. Subsequent tests were carried out with power quality improvement devices to study the feasibility of power factor improvement and harmonic suppression in a typical high speed lift system since January 2001. System analysis was conducted from 14 January 2002 to 12 March 2002 determining the improvement of Power Factor and Harmonic Distortion level of current after new installation of Real Time Capacitor Bank (**RTCB**) and Active Harmonic Filter (**AHF**) at the 800A mains of the high speed lift system.

Background

Lift System Description

The configuration of the lift system in the office building is divided into 3 zones, viz High Zone (28/F-39/F) and Mid Zone (14/F-27/F) supplying from 800A submain and Low Zone (5/F-13/F) supplying from 500A submain. A 2500A Main Incomer Circuit Breaker distributes power to the three (3) lift zones via separate up-feed cables. The high zone lifts have motor power of 85kW, contract speed at 8m/s and contract capacity of 1800kg.

Abnormal Phenomenon

Abnormal phenomenon was observed in the lift system since first installed including unstable power factor and seriously unsteady starting and running current. Thus, the High Zone lifts were selected for study where data logging showing system performance and characteristic were taken for analysis.

a) Fluctuation of Power Factor

Measured power factor was extremely low, tending to around 0.2 - 0.3 lagging on average, and high fluctuation of current was noted. As stipulated in the CoP for Energy Efficiency of Lift and Escalator Installations, 2000 Edition, the Total Power Factor of motor drive lift system measured at the isolator connecting the lift equipment to the building's feeder circuit shall not be less than 0.85 when the lift car is carrying a rated load at its rated speed in an upward direction. In this study, the power factor measured was far below the recommended value.

b) Total Harmonic Distortion of Current

Data logging set at one-minute interval showing the Total Harmonic Distortion (THD_I) of current level was around 20% with surge up to over 40%. According to the CoP, the recommended maximum THD_I (in %) is tabulated as follows:

Circuit Fundamental Current of Motor Drive	Maximum THD (%)
I < 80A	35
80A $\leq$ I < 400A	22.5
400A $\leq$ I < 800A	**15**

For this case, the recommended maximum THD_I for an 800A circuit is limited to 15%.

The lift system under test was a thyristor-controlled type equipped with a typical 6-pulse thyristor bridge. Analysis showed that the dominant distortions occurred at 5th, 7th, 11th and 13th order respectively. Obviously, the measured THD_I from 20% to 40% above failed to comply with the recommended standard.

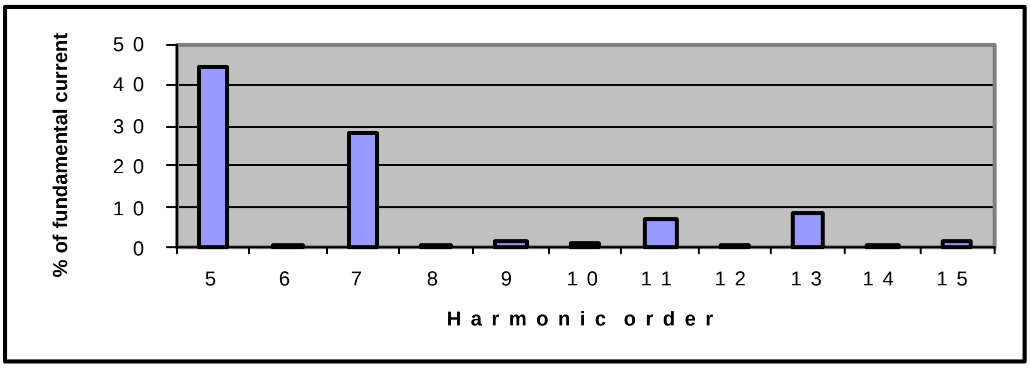


Figure 1 - Harmonic current spectrum of our lift system under test

Approaches to Selection of Devices

With the objective of power factor correction and harmonic current suppression, two approaches were proposed:

Approach 1: *Installation of Real Time Capacitor Bank (RTCB)*
The device is principally intended to provide reactive power for power factor correction. In practice, the network characteristics to allow for a correct sizing of power factor correction bank should be well known in advance. Some data were extracted and recorded, from which the extreme cases were summarized as follows:

Deviation	Date & Time	Measurement			Calculation			
					I	II	III	IV
		Act. P (kW)	Induc. P. (kVar)	P.F.	App. P (kVA)	P.F. (Target)	Induc. P. (kVar)	Cap. P required (kVar)
Max	19:28 on 13/03/01	175	384	0.57	422	0.9	84.76	**299.24**
Min	07:43 on 13/03/01	4	10	0.45	10.77	0.9	1.94	8.06

From sampling data collected and analyzed, a **300kVar** power factor correction bank was selected.

Approach 2: *Installation of Active Harmonic Filter (AHF)*
Active Harmonic Filter is based on the principle with a real-time measuring device and will actively generate a harmonic current spectrum in opposite phase to the measured distorting harmonic current for cancellation. **Fig 2** shows the working principle of AHF:

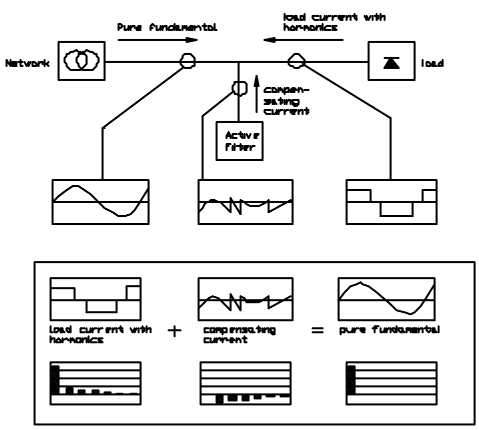
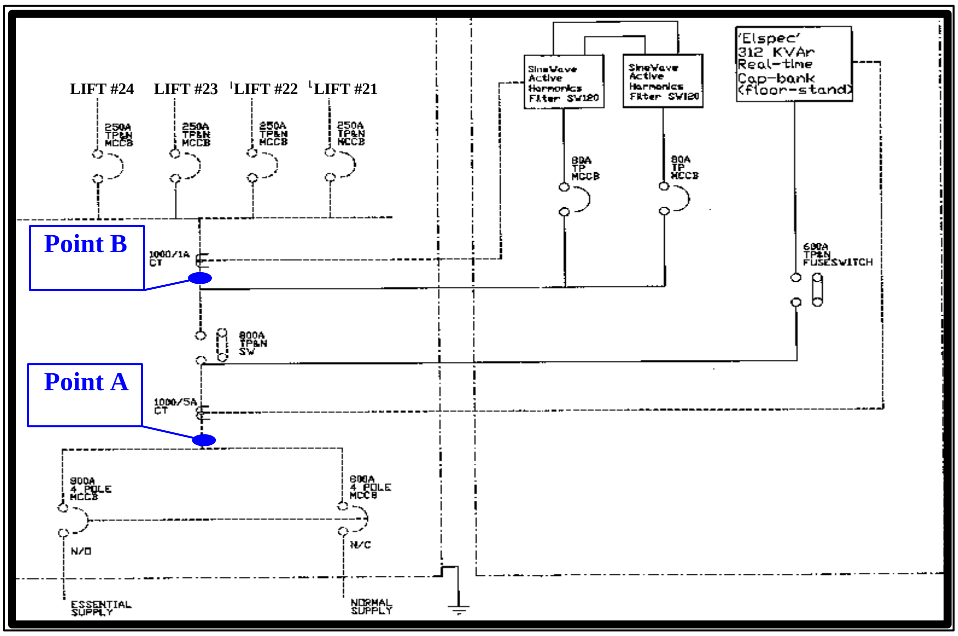


Figure 2 - Working Principle of Active Harmonic Filter

Methodology

In order to monitor the harmonic distortion and power factor in the system, two sets of CM4000 Power analyzer were installed at **Point A** and **Point B** (as shown in the simplified schematic diagram below) for data logging at 1-minute intervals for 7 consecutive days.



Instrumentation used

The Power Analyzer (Schneider - Square D Portable Circuit Monitor CM4000) and software (Schneider - Square D Management Software SMS3000) were used for on-site measurement.

Results

The current, power factor, active power, apparent power, fundamental current, harmonic magnitude, harmonic current and voltage were recorded for analysis. Since the system readings fluctuated from second to second, the average value would be more presentable than the instantaneous value for comparison purpose. Furthermore, because HEC Maximum Demand meter would measure the average value at 30 minutes intervals, in order to simulate HEC Maximum Demand meter's reading were trended with a 30-average-trend-line which averaged readings in past 30 minutes.

The high zone lift system generated extreme fluctuating inductive load current and harmonic current during the operation. However, by using of RTCB and AHF proved that it could effectively improve the power factor and reduce harmonics respectively. **Appendix A** shows the waveform analysis for different scenarios.

It was also observed that amplifying effect on the THD values after switching in capacitor bank was unavoidable. When switching on the capacitor bank, the injected capacitive current would mainly reduce the fundamental inductive current while the THD values will be automatically increased. Hence, the resultant THD_I showed the unacceptable %.

Conclusions

One possible risk for the installation of capacitor bank is parallel resonance which may occur when the system inductive reactance and capacitive reactance are equal at some frequency. If the combination of capacitor banks and the system inductance result in a parallel resonance near one of the characteristic harmonic generated by the non-linear load, that harmonic current will excite the circuit and cause amplified current to oscillate between the inductor and capacitor. This current may cause a serious voltage distortion and breakdown in the capacitor bank. In this study, the possible resonance frequency was calculated to be 211Hz based on 5.65% of reactor used. Theoretically, it would not cause resonance at this capacitance network as 211Hz was not a multiple of 50Hz.

In this study, power factor correction could be achieved the target power factor (0.85 above) by installing RTCB and power quality could be improved by installing AHF. Ability to suppression of THD_I to the satisfaction of CoP recommendations (limited to 15% maximum for an 800A circuit) was achievable. **Appendix B** shows the actual installations on site.

This project is considered technically sound and has been satisfactorily completed with the high appreciation from the EMSD Energy Efficiency Office of the Hong Kong SAR Government. (Letter ref.: EEO/BC/01 dated 30 May 2002 refers)

The Author
Ir K F Yee is elected as an Executive Committee Member of The Building Services Operation and Maintenance Executives Society (BSOMES) and was nominated as one of the Working Committee Group Members for the revision of the CoP for the Electricity (Wiring) Regulations 1997 Edition. Ir Yee was currently appointed by IVE and CityU as a Part-Time Lecturer since 2000 and 2001 respectively. E-mail : yeekwongfai@swireproperties.com

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APPENDIX A

Before Improvement

a) Displacement phase angle between current and voltage was about ¼ cycle, this implied the reactive energy consumed by the system and poor power factor lagging

b) The current waveform was distorted due to the Harmonic current distortion in the system caused by the DC drives thyristor switching.

AHF only

a) The displacement phase angle between the voltage and current was about ¼ cycle phase shift due to switching OFF the Real Time Capacitor Bank.

b) The current waveform was smoothened to more sinewave sharp since the Active Harmonic Filter was switched ON and compensating the system.

RTCB only

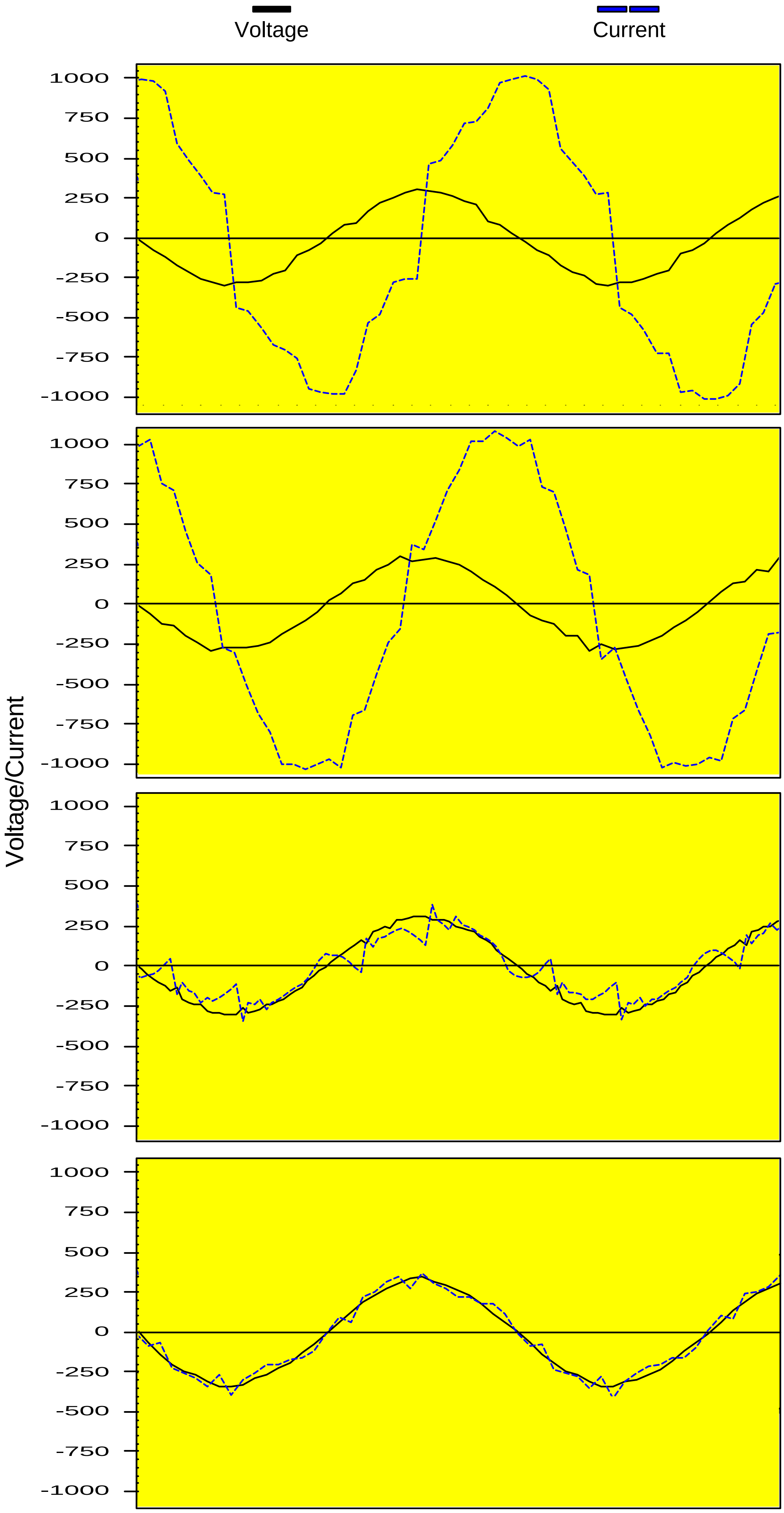
a) The displacement phase angle between voltage and current shift back to in phase, this implied the reactive energy consumed by the system and compensated by the Real Time Capacitor Bank to unity power factor even the Active Harmonic Filter was not compensating.

b) The current waveform was not smoothened since the Active Harmonic Filter was switched to OFF.

AHF + RTCB

a) The displacement phase angle between the voltage and current shift back to in phase, this implied the reactive energy consumed by the system and compensated by the Real Time Capacitor Bank to unity power factor.

b) The current waveform was smoothened to more sinewave shape due to the harmonic current suppression carried out by the Active Harmonic Filter.



Appendix B

Photo#1 - Site Overview(Switchgears inside Lift Machine Room)

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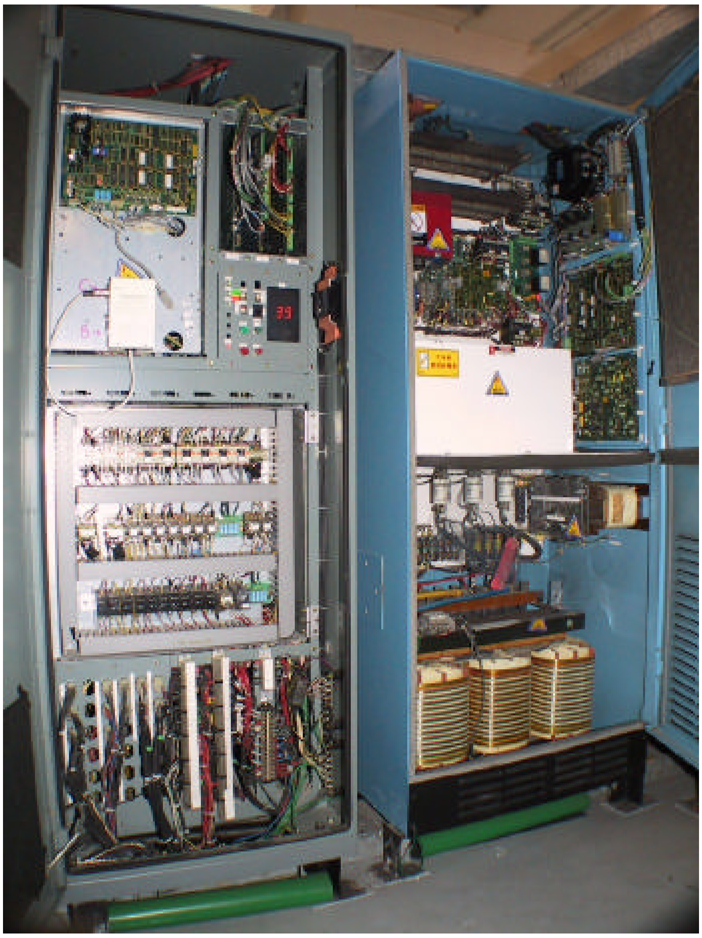
Photo#2 - Measuring Equipment (CM4000)

Photo#3 – Active Harmonic Filter

Photo#4 – Real Time Capacitor Bank

Photo#5 – Lift Motor Drives



Photo#6 – Lift Control Panels