1. Introduction
Variable Air Volume (VAV) systems are now the most popular airside system designs for office buildings. The traditional design and operation of a VAV system works by keeping the supply air duct pressure constant while adjusting the damper of the VAV boxes to control the flow rate of supply air to maintain the desired temperature of the space. This constant static pressure is maintained at all times even in partial or no load condition. Apart from the unnecessary AHU and chiller energy wastage, closing and throttling of the VAV damper will create noise and indoor thermal comfort will be affected.

In recent years, a new controlling concept has developed that the static pressure changes automatically according to the changing internal load, which is indicated by the degree of opening of the VAV box dampers. This allows the pressure to be kept to a minimum and hence less energy to be consumed by the AHU fan.

Air conditioning is essential for Hong Kong’s commercial buildings and it makes up a large portion of total energy consumption. The concept of the VAV air conditioning system was based on Power = Efficiency x Volume Flow Rate x Pressure Difference. VAV system had been adopted in new buildings using Direct Digital Control (DDC) on air conditioning with maximum pressure. However, in these VAV air conditioning systems, pressure difference is a constant (i.e. maximum). In the case of the static pressure reset in VAV air conditioning system, the pressure varies subject to the cooling load. As power consumption varies according to the cooling load and therefore cost for power consumption was reduced.

2. Methodology
The method developed for this control concept requires a network base DDC to be provided to automate the VAV boxes and Building Management System (BMS). Installation of Variable Speed Drive (VSD) in Air Handling Unit is also required.

Data of VAV boxes were collected from the DDC that controlled VAV boxes, and were temporarily stored in the Network Control Unit (NCU). When the storage space of the NCU was full, data would then move to the harddisk of BMS workstation. The retrofit control program of the static pressure reset was also downloaded to the NCU where the program was to run. DDC is also used to control the VSD of the AHU. Data of carbon dioxide level at the return air ducts is also collected.

To adopt this control concept, VAV systems in buildings have to be recommissioned and ensured that they are functioning smoothly.

3. Energy saving after VAV system Retrofitting
“Cityplaza One (CP1)”, probably the first office building in Hong Kong, has installed and implemented such system successfully and resulted in a significant energy saving.

CP1 is a Grade-A 21 floors commercial building in Hong Kong with an approx. Gross Floor Area (GFA) of 56,700m². The air conditioning system equips with single duct VAV system with terminal heaters (2kW) in the perimeter zone with DDC control. VSD is installed for all AHUs. Total numbers of VAV in the building is 1,344 and the static pressure set point is 250pa and the airflow rate is 9,100 l/s.

Retrofitting of CP1 VAV system control was introduced to all typical floors and the exercise was completed in June 2000. Energy saving in CP1 after retrofitting is shown in table below:
Energy Saving of CP1 under Retrofit Control

<table>
<thead>
<tr>
<th>Month</th>
<th>Energy Consumption of All AHU Motors in Office Floors</th>
<th>Energy Saving Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Year 2000 (kWh)</td>
<td>Year 2001 (kWh)</td>
</tr>
<tr>
<td>July</td>
<td>176,730</td>
<td>130,790</td>
</tr>
<tr>
<td>August</td>
<td>190,370</td>
<td>152,430</td>
</tr>
<tr>
<td>September</td>
<td>177,630</td>
<td>133,800</td>
</tr>
<tr>
<td>October</td>
<td>166,010</td>
<td>125,010</td>
</tr>
<tr>
<td>November</td>
<td>147,870</td>
<td>122,220</td>
</tr>
<tr>
<td>December</td>
<td>130,730</td>
<td>99,540</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Year 2001</th>
<th>Year 2002</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>138,840</td>
<td>121,580</td>
</tr>
<tr>
<td>February</td>
<td>123,370</td>
<td>107,410</td>
</tr>
<tr>
<td>March</td>
<td>124,430</td>
<td>111,910</td>
</tr>
<tr>
<td>April</td>
<td>106,860</td>
<td>103,560</td>
</tr>
<tr>
<td>May</td>
<td>138,400</td>
<td>134,770</td>
</tr>
<tr>
<td>June</td>
<td>132,910</td>
<td>131,480</td>
</tr>
<tr>
<td>Total</td>
<td>1,754,150</td>
<td>1,474,500</td>
</tr>
</tbody>
</table>

4 Cost
Initial installation cost of this project was HK$69,400, which included Building Management System (BMS) upgrading, works and the cost for installing software in the BMS. There was no operation and maintenance cost on the existing VAV system as minor parts renewal and defect rectification works were all done by our in-house staff.

5 Benefit
5.1 Energy Saving and environmental friendly
A saving of 279,650 kWh in energy was recorded from July 2001 to June 2002 after retrofitting and these figures were compared to those from July 2000 to June 2001. This saving is also equivalent to preventing a total of 120,000kg CO₂ emission from a coal-fired power generation plant every year.

5.2 System operates smoothly after VAV re-commissioning
The control logic of this static pressure reset system was so designed such that if any of the VAV boxes were found malfunctioned or operated improperly, the static pressure would stay at its maximum limit. Our technicians will then be acknowledged by checking in the BMS and they will have it rectified afterwards.

5.3 Indoor thermal comfort was improved.

5.4 Noise was reduced in office area during part load or no load condition as the static pressure was reduced accordingly.

6 Conclusion
The concept of static pressure reset had been around for some time. However, due to technical difficulties and systems are not equipped with DDC, the static pressure reset in VAV air conditioning system was not adopted widely in existing commercial buildings in Hong Kong. In addition, there is no standard control software available in the market. Innovative elements were to design and develop the control logic and technique to overcome difficulties when implementing the system.
START

All Damper ≤ 80%

Yes

P > 120 Pa
Set
P_{n+1} = P_n - 10Pa

No

For Damper ≥ 80%
Count n ≥ 3

Yes

P < 250 Pa
Set
P_{n+1} = P_n + 10Pa

No

Set
P_{n+1} = P_n

AHU 'ON'?

Yes

Set
P_{n+1} = 250Pa

No

END

Schematic Diagram of VAV System

P - Pressure sensor, T - Temperature sensor, CV - Control valve, VSD - Variable speed Drive