# Cx for energy efficiency of air handing terminals in HVAC systems

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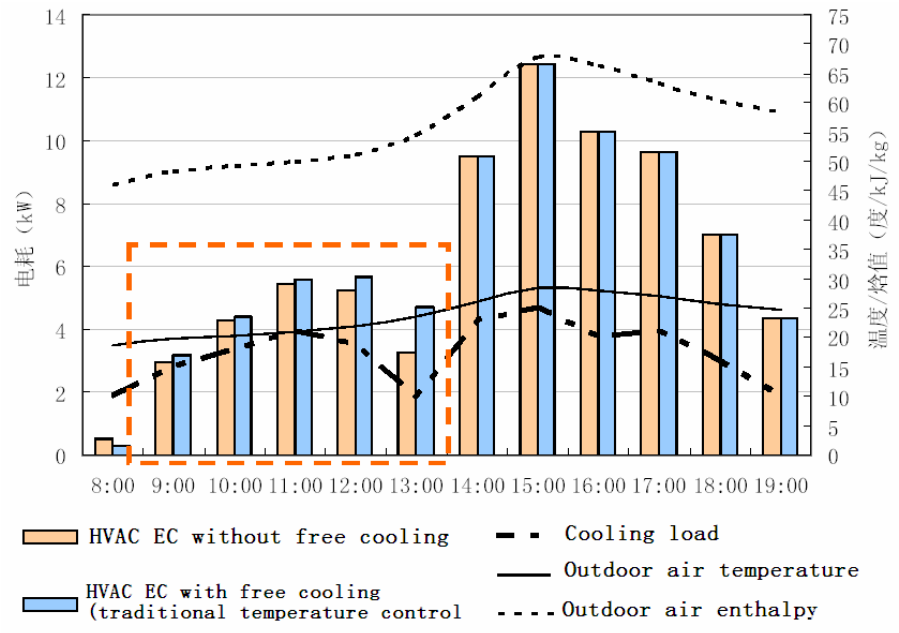
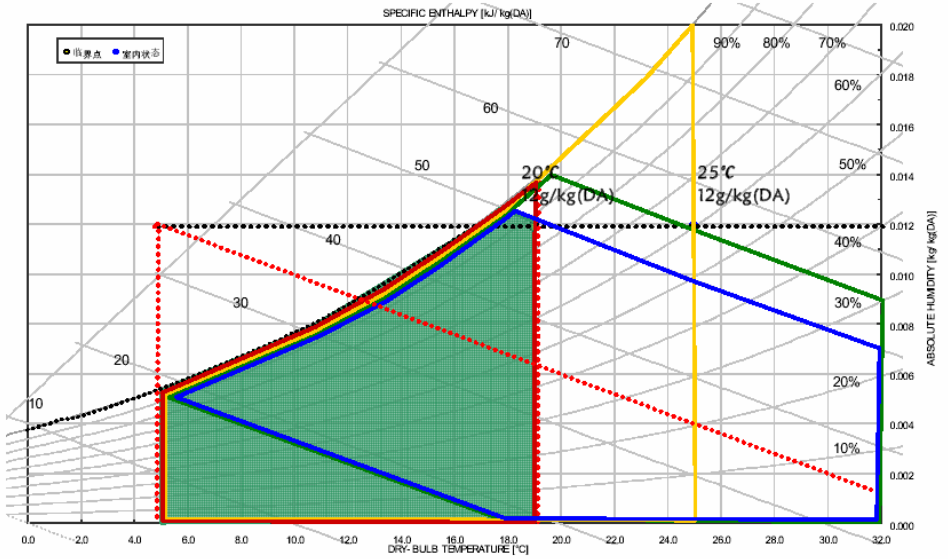
- Air side free cooling is usually not free
  - Case 1.1~1.4
- Optimization of AHU control parameters
  - Case 2

# Why free cooling is not free?

- Free cooling by enlarging outdoor air volume or introducing heat exchange equipments will save cold or heat, but may cost more fan power
  - Free cooling was always suggested when the temperature or enthalpy of outdoor air is lower than return air to save cold/heat
  - In most cases, this saves energy only when the temperature difference is large enough
  - The EC of cooling and heating source and fan power should be balanced

# Case 1.1: office building, VAV (independent OA fan), Beijing 2007




Where free cooling really saves

Traditional temperature control strategy

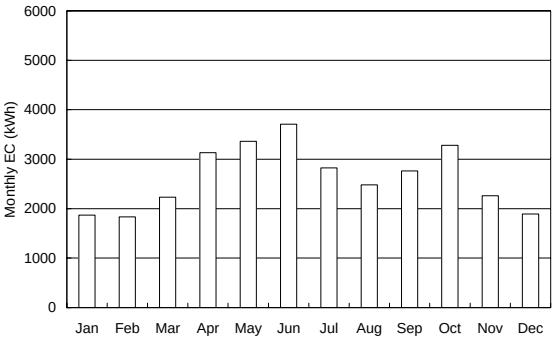
Traditional enthalpy control strategy1

Traditional enthalpy control strategy2

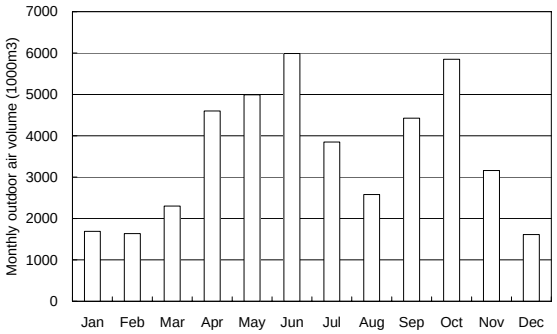
Design method and feasibility study on outdoor air utilization, HanZheng(2008)

# Case 1.2: Office building, VAV (independent exhaust fan), Japan 2009

- The OA volume has nothing to do with AHU fans' power consumption, but affects exhaust fan power.

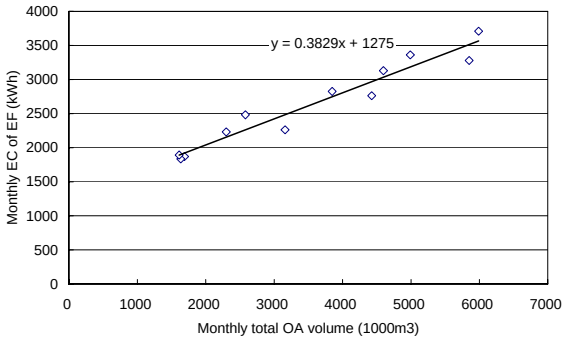



Monthly EC of exhaust fans

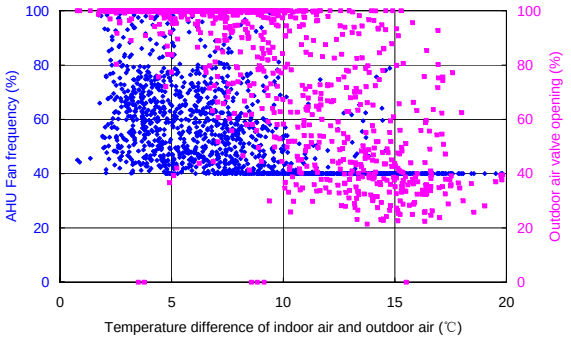



Monthly outdoor air volume (accumulated)

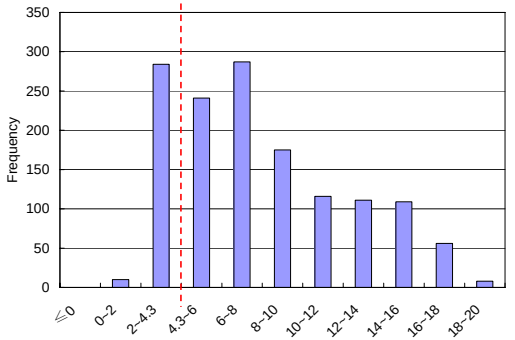
Curve fitting




DHC EER: 4.07
Free cooling EER = (冷0.36Wh/m3.℃* Δ t) / (风机0.38Wh/m3)
Critical Δ t: 4.3℃

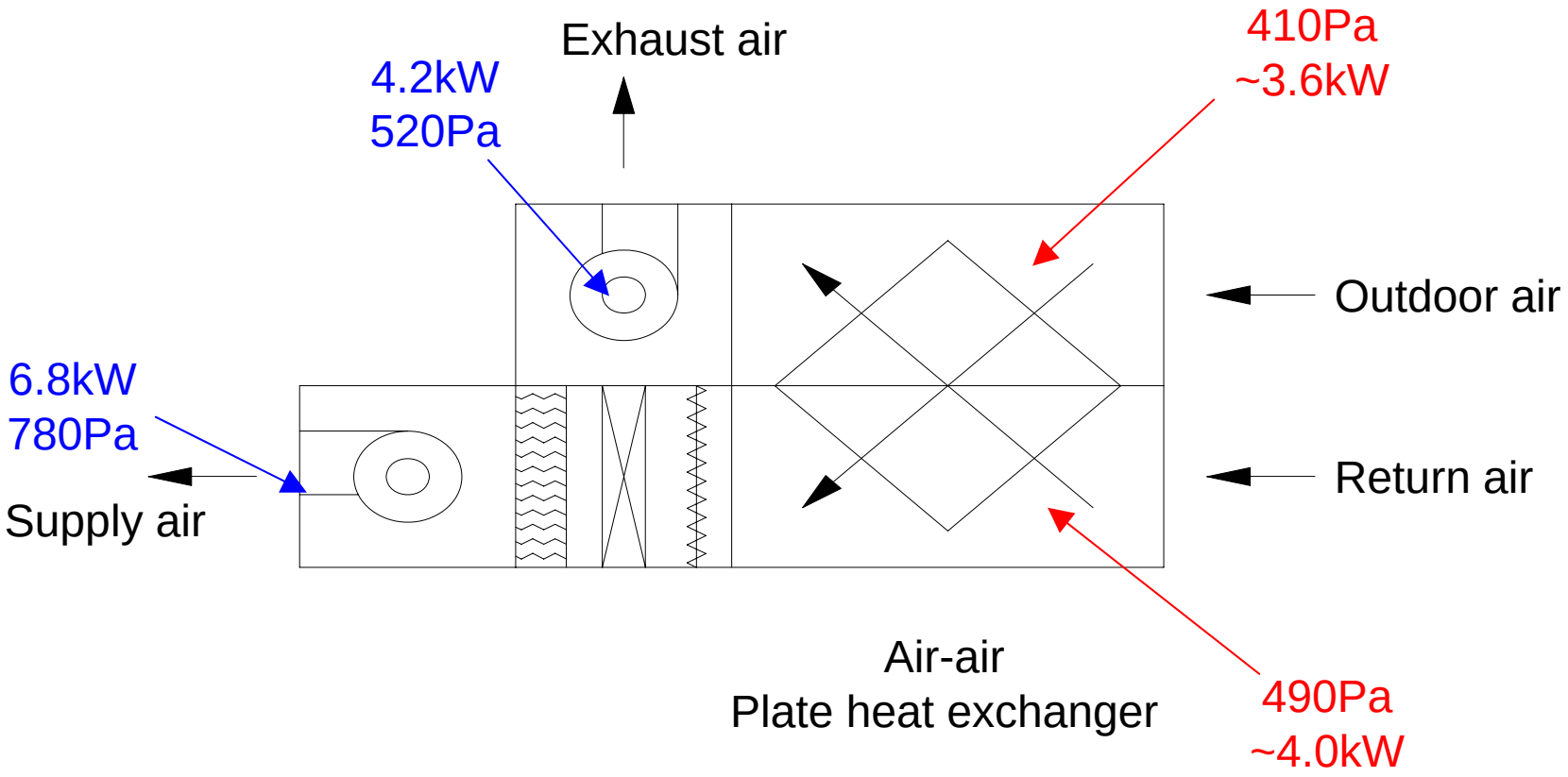



Annual work point distribution of a typical AHU




Δ t distribution of free cooling mode

# Case 1.3: high standard apartment, radiation ceiling+OA, Beijing 2006

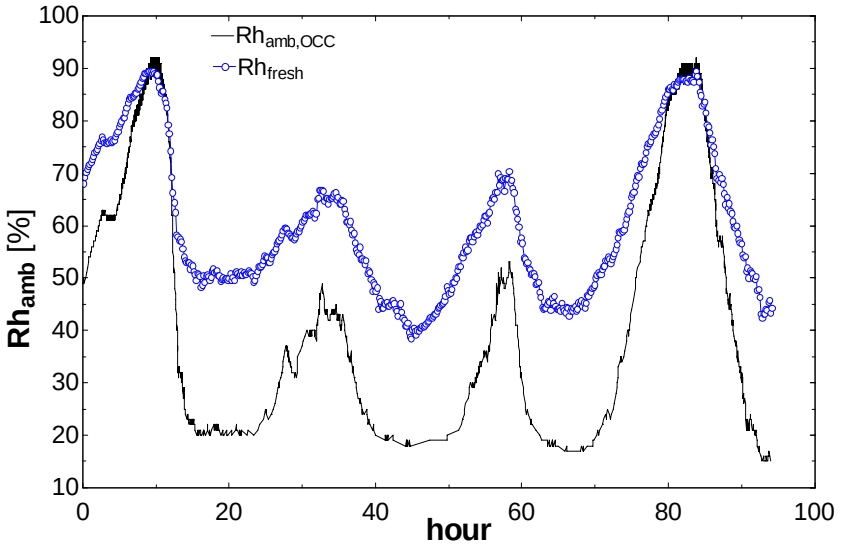


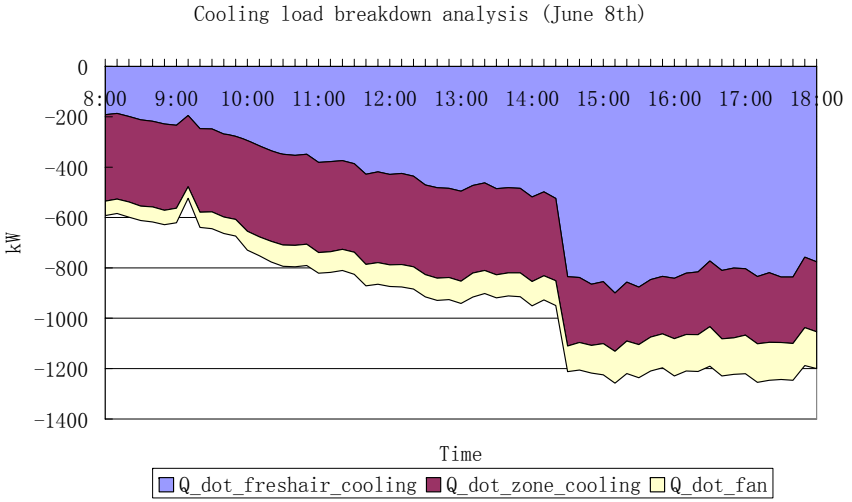

Largest heat recovery: (Winter: 78kW,Summer: **20kW**)

Fan power lost: ~7.6kW→can produce **22kW** cold in summer

# Case1.4: Office building,VAV, US 2008

- Risks of humidity sensors

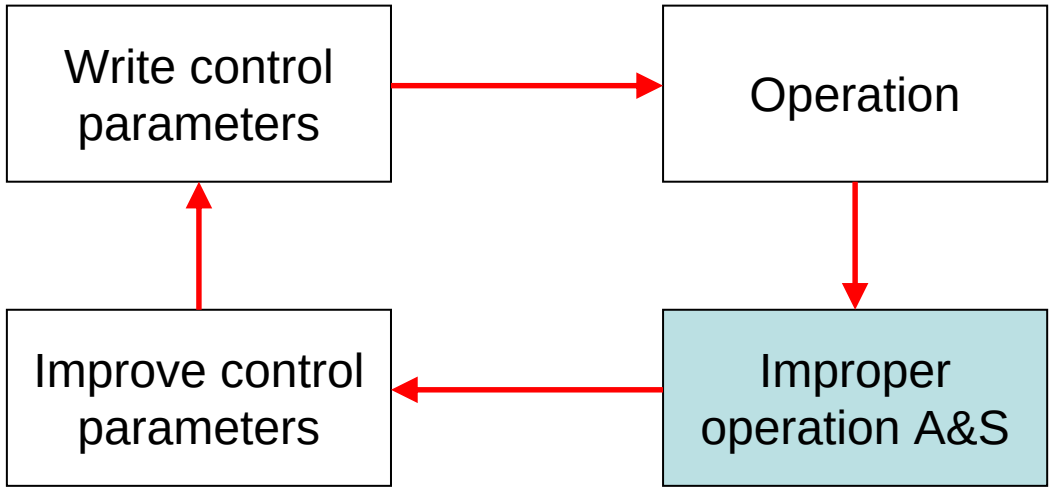



- Temperature control is more recommended

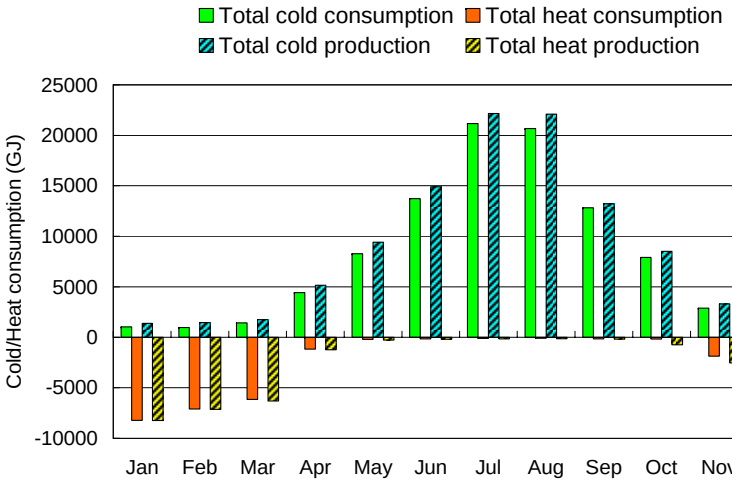
# How to optimize AHU control parameters?

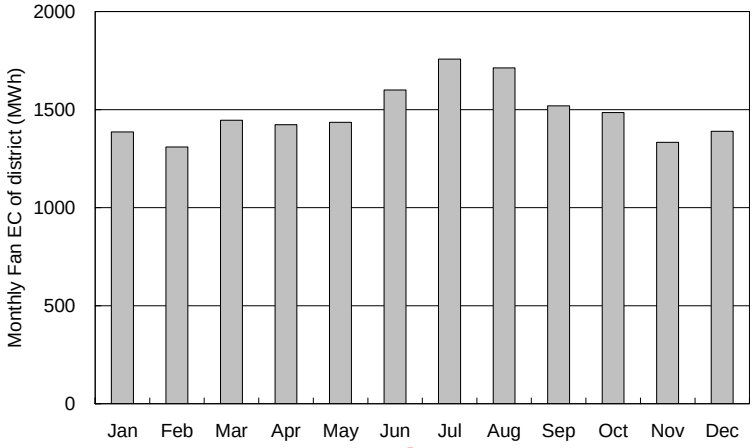
- Large amount high quality BMS data offers an opportunity

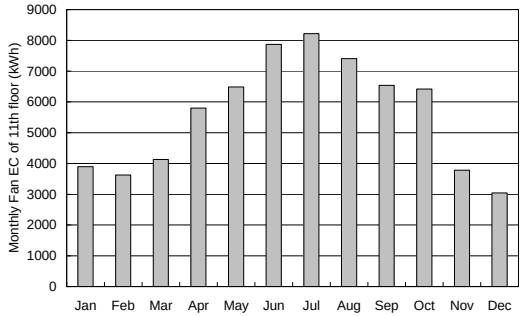


# Case 2: Office building, VAV (independent exhaust fan), Japan 2009

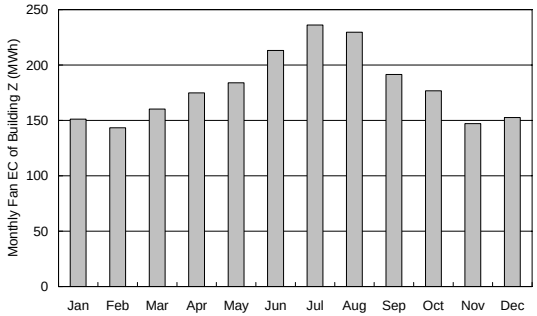
- EC characteristics



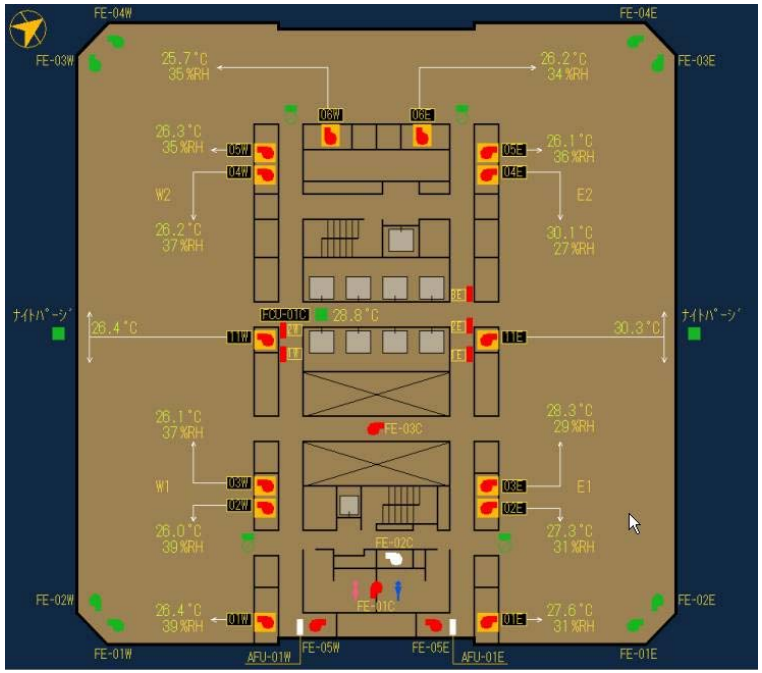



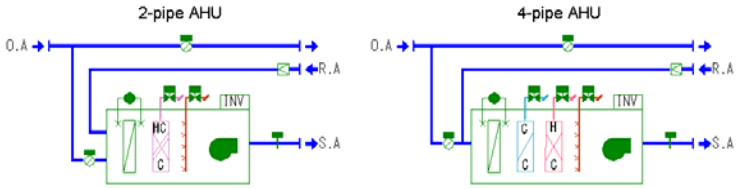

Floor 11



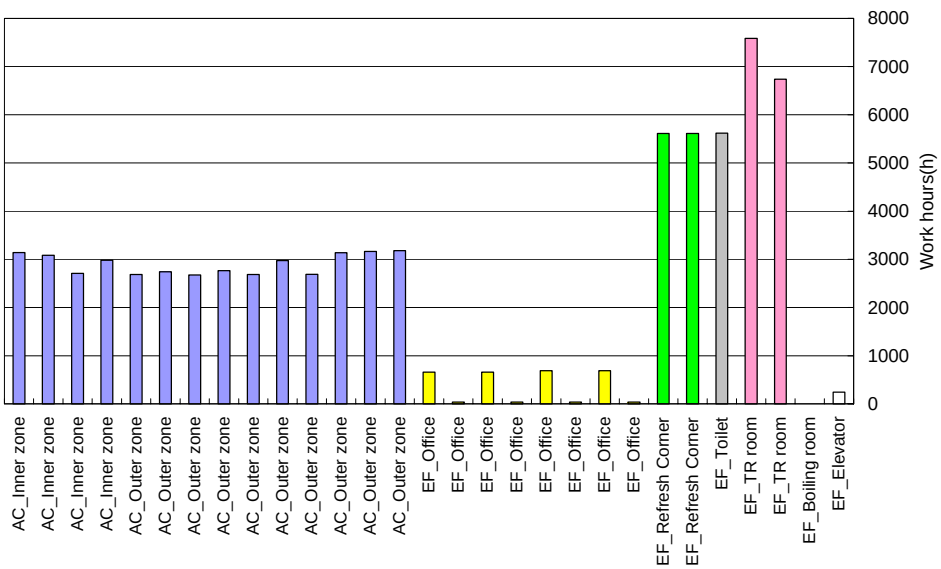

Building Z

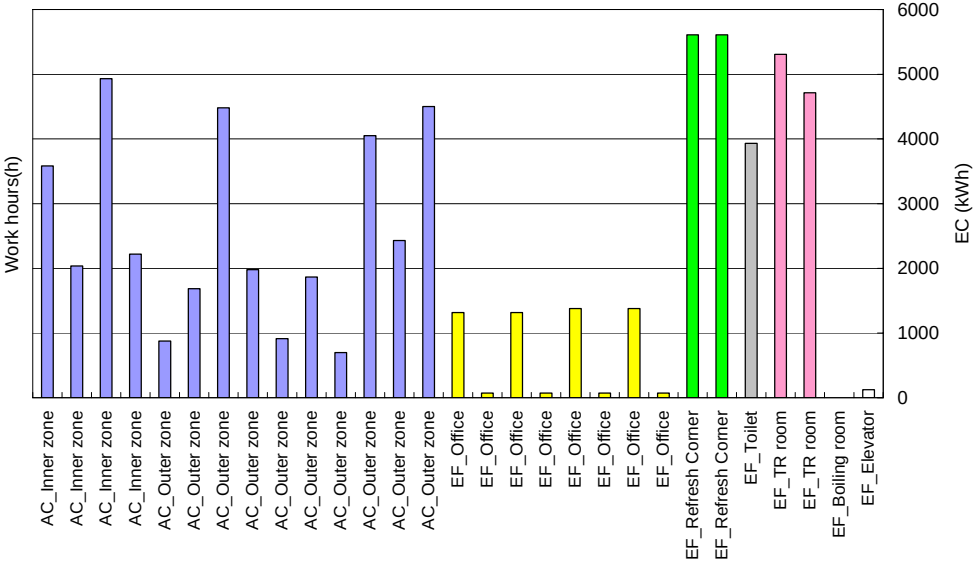
# Air terminals on a standard floor



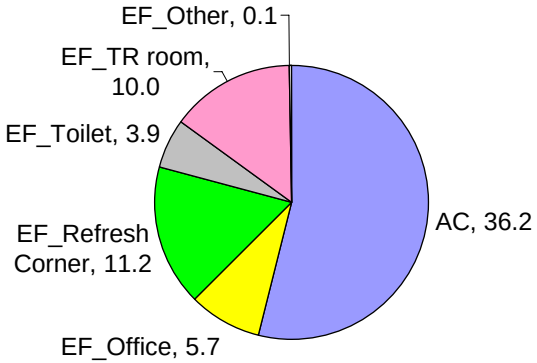



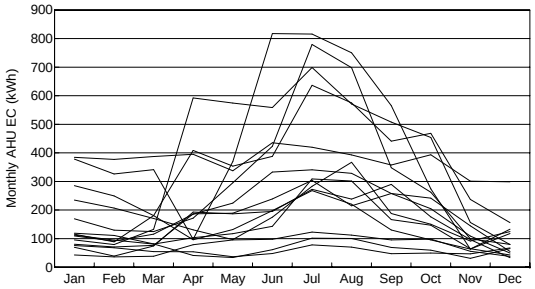

| | Serve area | Rating Power | Notes |
|---|---|---|---|
| AC-01E, AC-03E, AC-04E<br>AC-01W, AC-03W, AC-04W | Office<br>(Outer Zone) | 2.2kW×6 | 2-pipe AHU |
| AC-02E, AC-05E<br>AC-02W, AC-05W | Office<br>(Outer Zone) | 3.7kW×4 | 2-pipe AHU |
| AC-06E, AC-11E<br>AC-06W, AC-11W | Office<br>(Inner Zone) | 3.7kW×4 | 4-pipe AHU |
| FE-01E, FE-02E, FE-03E, FE-04E FE-01W, FE-02W, FE-03W, FE-04W | Office | 2kW×8 | Located at 4 corners |
| FE-05E, FE-05W | Refresh corner | 1kW×2 | |
| FE-06E, FE-06W | TR room | 0.7kW×2 | Do not exist in exceptional floors |
| FE-01C | Toilet | 0.7kW | |
| FE-02C | Boiling room | 0.5kW | |
| FE-03C | warehouse or elevator | 0.5kW | |
| Total | -- | AC: 42.8kW<br>FE: 21.1kW | |

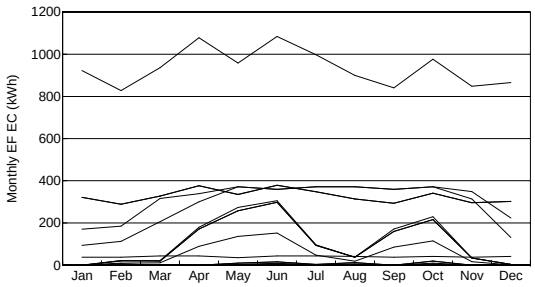


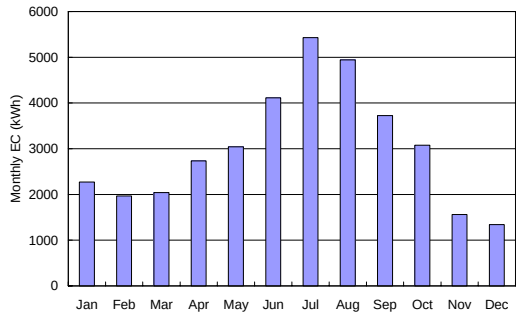



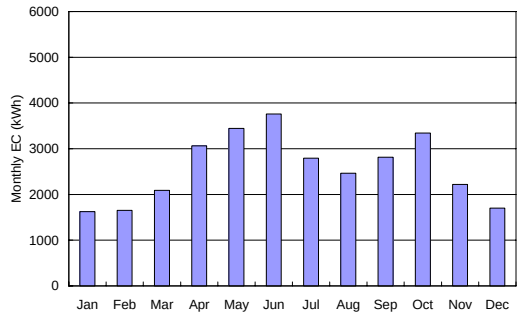

2009 EC of fans at 11th floor of building Z (MWh)
Total: 67.2MWh or 24.6kWh/m2.a



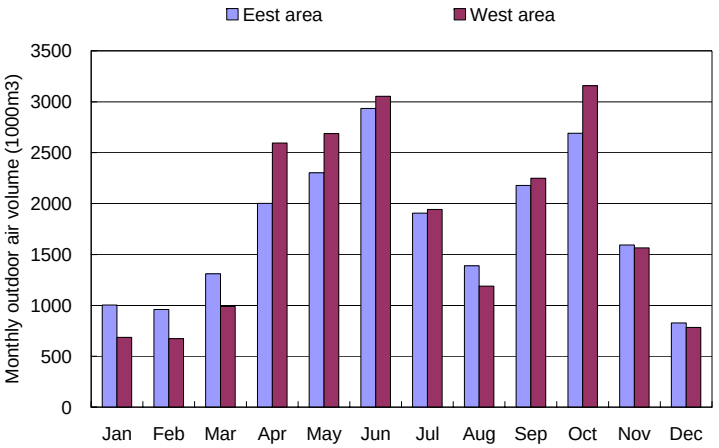



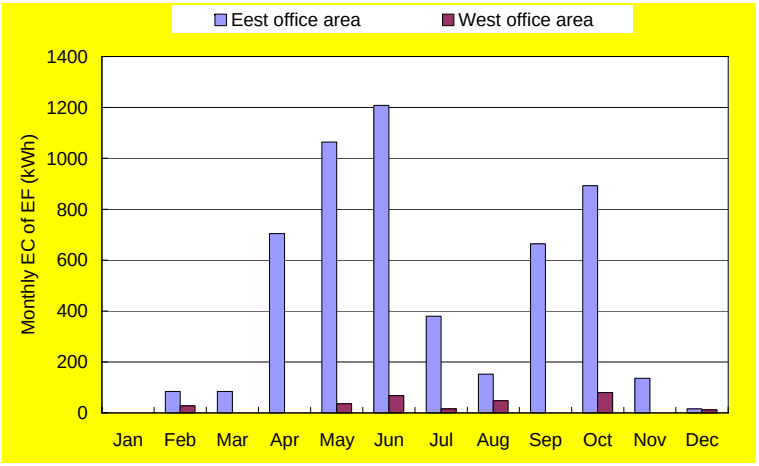



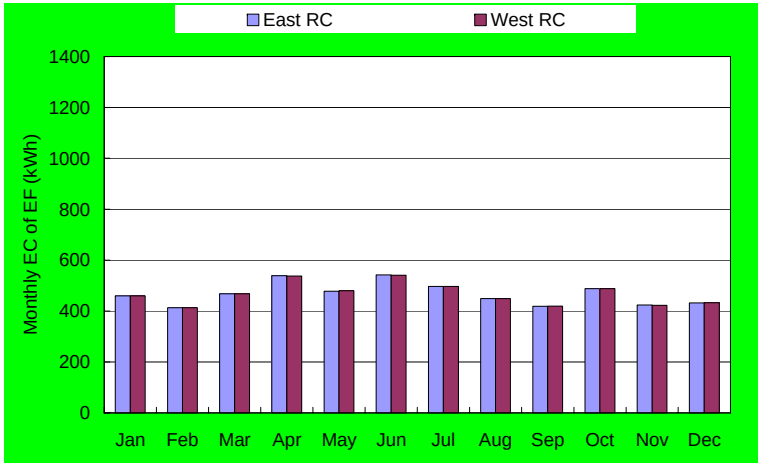



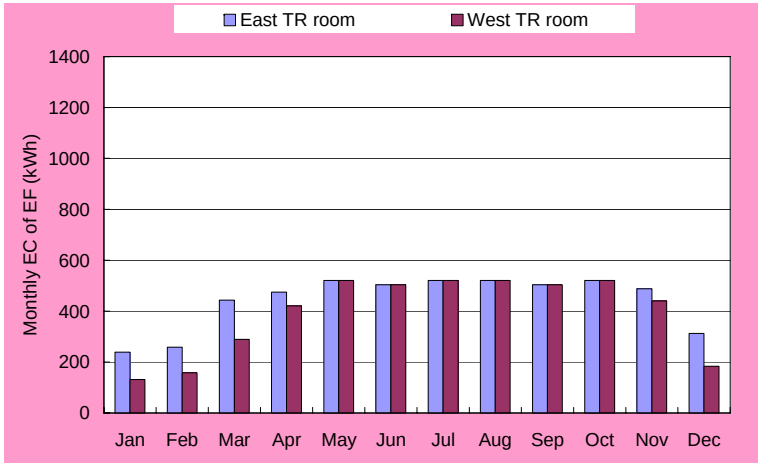

AC

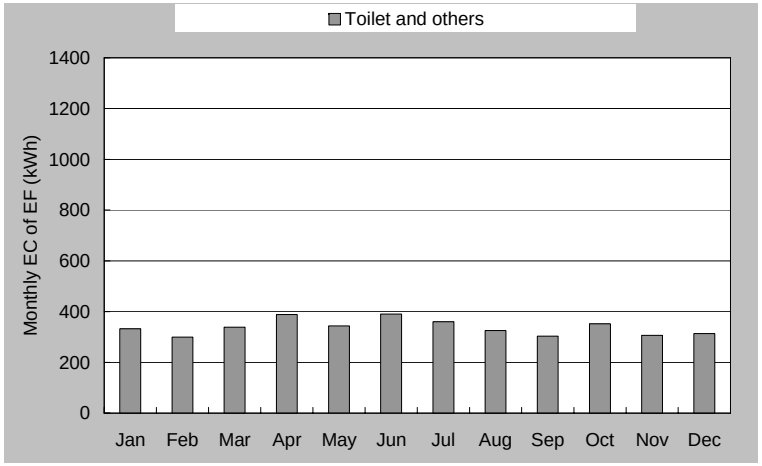
EF


Eest area
West area
Monthly outdoor air volume (1000m3)
3500
3000
2500
2000
1500
1000
500
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec


Eest office area
West office area
Monthly EC of EF (kWh)
1400
1200
1000
800
600
400
200
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

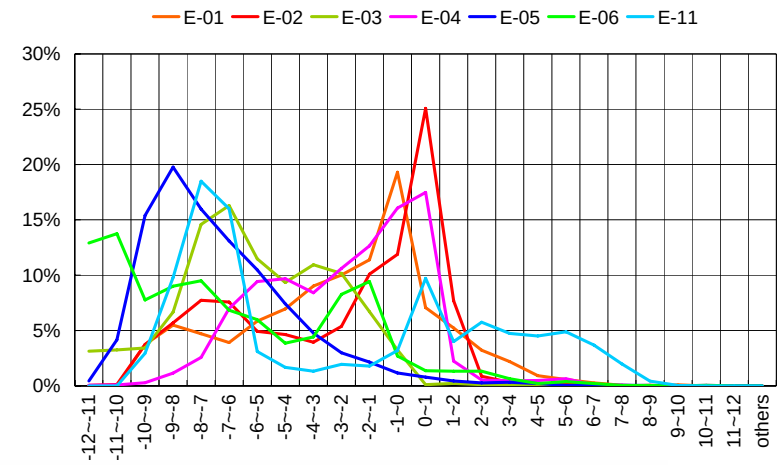

East RC
West RC
Monthly EC of EF (kWh)
1400
1200
1000
800
600
400
200
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

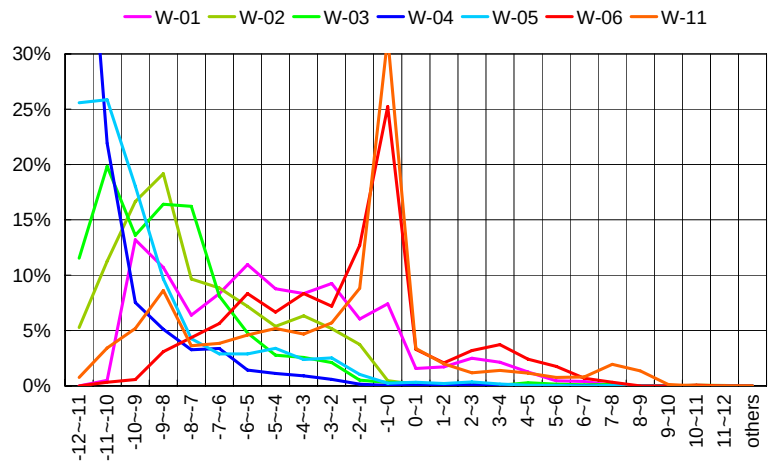

East TR room
West TR room
Monthly EC of EF (kWh)
1400
1200
1000
800
600
400
200
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec


Toilet and others
Monthly EC of EF (kWh)
1400
1200
1000
800
600
400
200
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

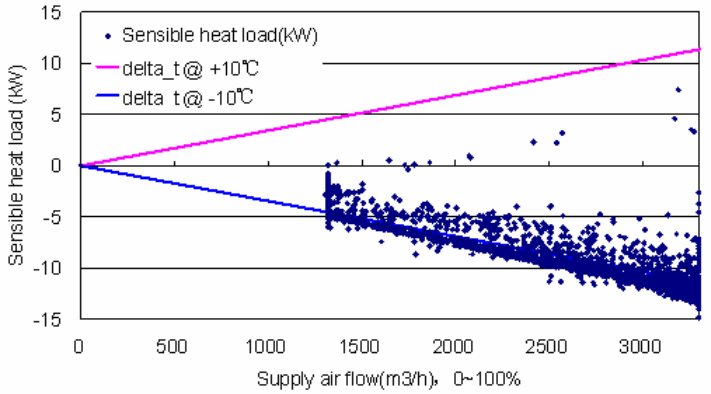
# Proper and improper operation of AHUs

- What's "improper"?
  - Too small temperature difference of supply air and return air
  - Unnecessary cooling and heating consumption
  - Offset of set point
  - Valve opening shaking
  - …
- Why?

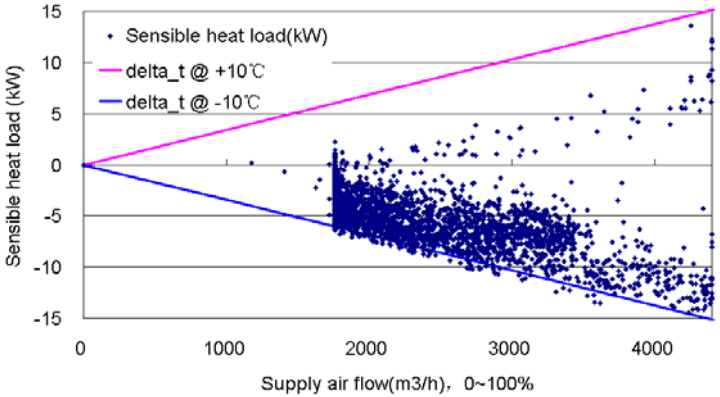


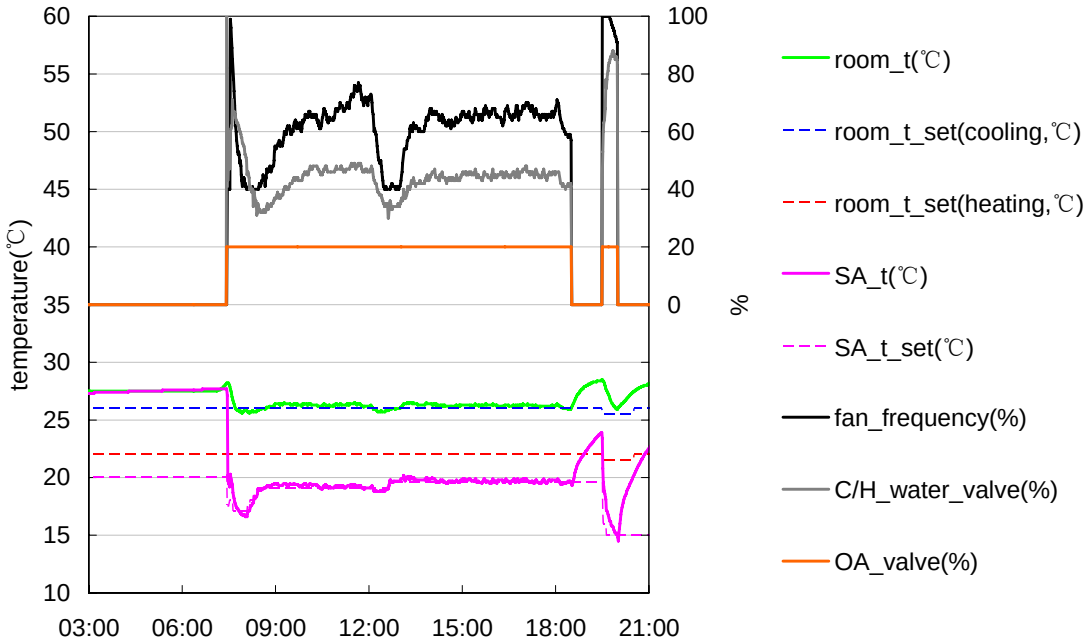



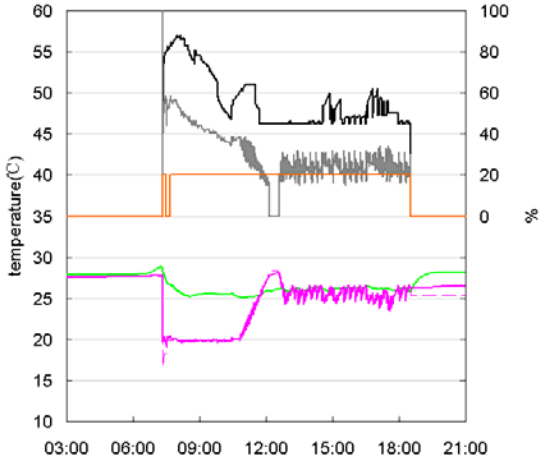

No.04 (2-pipe) AHU load vs air flow



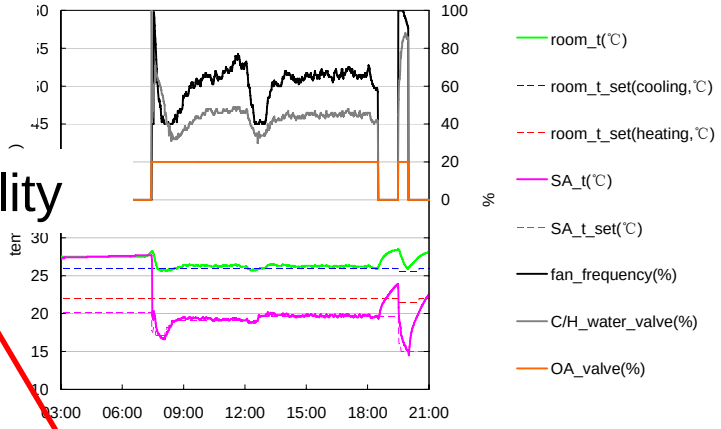

No.05 (2-pipe) AHU load vs air flow






**PID of valve**
**Band width**
**Valve action period**

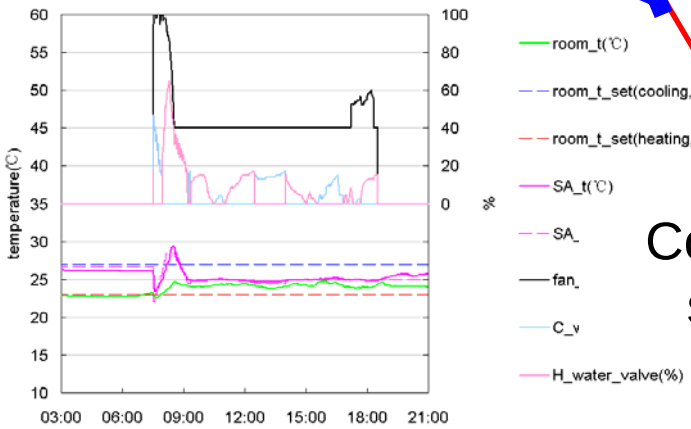



Reliability

Sensitivity

**Band width**
**SA reset period**
**……**

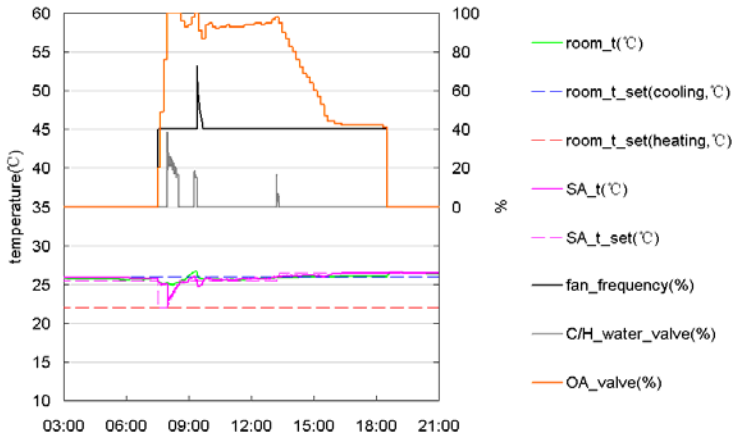
**PID of valve**
**PID of fan Hz**
**……**




Cold/Heat saving

Fan power saving

**Free cooling strategy**
**……**



# Conclusions

- Free cooling needs consideration of the **cost**
- In a typical Japanese office building's VAV system, the following research would be useful for energy efficiency
  - How to **save exhaust air fans' power**?
  - **Optimization** of control parameters

- Thank you!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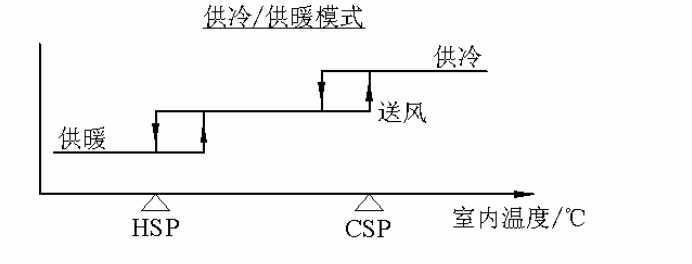
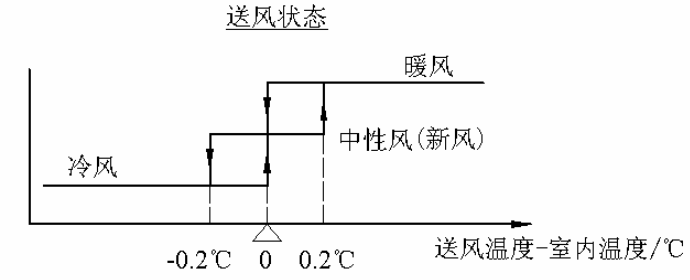
- BERC, THU

# Cascade control strategy (if necessary)




Room mode judgment




AHU supply air mode judgment

## AHU control status

| No. | AHU control status | TDr, FAN INV |
|---|---|---|
| 1 | Cooling lacking | TDr ≥ 2℃ |
| 2 | Cooling changing | 1℃< TDr ≤ 2℃ |
| 3 | Cooling fitting | 0℃< TDr ≤ 1℃ |
| 4 | ZEB | TDr = 0℃, FAN INV = 40% |
| 5 | Heating fitting | -1℃ ≤ TDr < 0℃ |
| 6 | Heating changing | -2℃ ≤ TDr < -1℃ |
| 7 | Heating lacking | TDr < -2℃ |

## Supply air temperature change

| Supply air temperature change | | Supply air mode | | |
|---|---|---|---|---|
| | | Cooling | Neutral | Heating |
| AHU control status | Cooling lacking | -1℃ | -1℃ | -1℃ |
| | Cooling changing | -0.5℃ | remain | -0.5℃ |
| | Cooling fitting | remain | remain | -0.5℃ |
| | ZEB | +0.5℃ | remain | -0.5℃ |
| | Heating fitting | +0.5℃ | remain | remain |
| | Heating changing | +0.5℃ | remain | -0.5℃ |
| | Heating lacking | +1℃ | +1℃ | +1℃ |