A New Approach to Commissioning of the VAV Control System

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Abstract: Commissioning of the HVAC system has been practiced in buildings for the purpose of energy conservation and performance optimization. Commissioning of the HVAC automation system should be paid more attention. In this paper, Objective Control Method (OCM) is proposed to analyze the operational performance of VAV control system. The approach starts with the evaluation of satisfaction of indoor thermal comfort, and then is followed by the performance analysis of different control loops with a graphic chart of relations between different parameters. Finally the operation fault is detected. This approach has been applied and validated in a real VAV control system of a commercial office building in Beijing with one year's on-site measured data. By means of OCM, phenomena of 'hunting' in VAV control system are deeply studied. As a new commissioning approach of VAV control system, OCM is of great feasibility and convenience.

Key words: VAV，commissioning , OCM，hunting

1. INTRODUCTION

Building and/or HVAC commissioning in nowadays sense, however, is understood as the process to realize the real owner's project requirements through building construction stage and continuing to operation and maintenance stage as the life-cycle process in an ideal sense, by defining owner's project requirements on performance, reviewing, inspecting, verifying and testing a total functional performance[1]. Being a type of HVAC system, a VAV system has the great potential on energy saving, it also has a complicated control system and multifarious equipments. Therefore, the performance analysis and diagnose for a VAV system would be a very important part for Building HVAC System Commissioning.

A number of researchers have worked on the diagnose of HVAC system [2][3], but due to the complexity and diversity of different HVAC systems, some methods are not very practical. In the field of VAV system troubleshooting, some researchers mainly focus on the main equipments (AHU, fan, pump, etc.) [4][5], while only a few papers on a complete system diagnosing have been published. For example, Harunori Yoshida (Japan) and Jin Xin-Qiao developed some computerized simulation program to diagnose some typical failure from sensor and monitor in a VAV system [6][7].

VAV system failure mainly includes: improper system design, facilities failure, sensor failure, signal transfer failure and improper control strategy, etc.. Existing diagnose method generally deal with problems like sensor failure with computerized program simulation, and the analysis is based on great amounts of monitored data. While investigation of control strategy and system design in operation stage is insufficient. This paper is try to introduce a new approach to diagnose system design failure, equipment failure, control system failure and signal transmission failure, etc. based on long term commissioning practice, and concludes that Objective Control Method (OCM) is a practical method in realizing a complete diagnosis of a VAV system.

2. OBJECTIVE CONTROL METHOD (OCM)

Commissioning of VAV system is a step by step

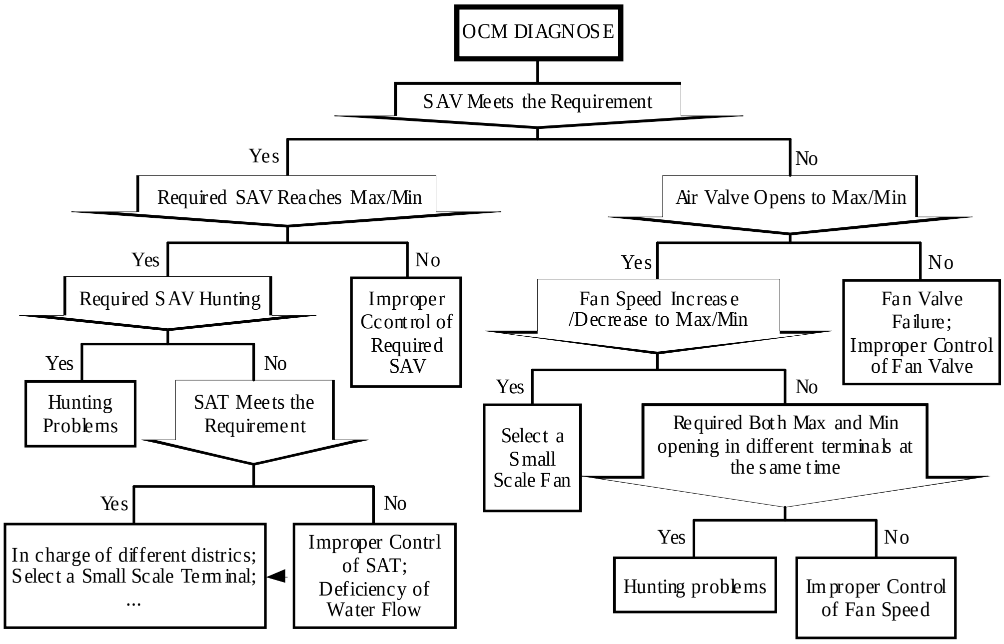

Fig. 1 OCM flow figure of pressure independent VAV system

process, which includes performance evaluation of control system, indoor thermal environment evaluation, and energy consumption analysis, etc. (Fig. 1). The first step is to confirm whether the VAV control system is working under the designed condition. If "yes", then evaluate the indoor comfort starts (since the terminal sensor reaching the design requirement doesn't illustrate a good indoor thermal environment); if "no", then apply OCM to diagnose the VAV control system and find the failure. Finally we analyze the energy consumption and the energy conservation potential.

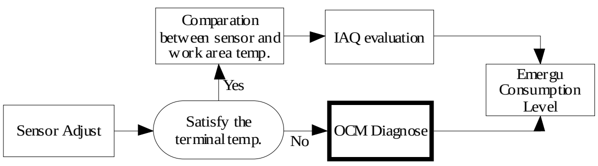

Fig. 2 Commissioning flow chart of VAV system

This paper focuses on setting up the OCM flow chart for diagnosing a VAV control system. The pre-assumption for this method is the data collected from control system test and record is free of error, which means the sensor problem has already been solved. OCM firstly judges whether the performance fulfill the design requirement, then follow the route to the next step according to the analysis result, then it repeated the process for several times until find the reason of the failure.

Take a VAV system with pressure independent terminal for example, the OCM logic flow chart is shown in Fig. 2. Terminal temperature is the original object. If temperature deviation is larger than a fixed value, then it goes to the OCM diagnosis. The first level question is to judge whether the terminal's supply air volume satisfies the requirement. Based on the answer to the first question the secondary level questions are whether required air volume reaches the max (min) or air valve opens to max (min), the potential failure reasons for the former one includes system hunting, a smaller terminal, one terminal responsible for different zones, insufficient water supply for AHU, improper setting of terminal air volume, control problem of air supply, etc. and the reasons for the latter one includes inappropriate selection of fan, excessive resistance in air duct (blocked or failed design), system hunting (the reason of hunting is complicated and will be discussed deeply in the case study), improper control strategy of fan speed, failure of fan valve adjustment etc..

From the OCM logic flow chart, we can see that there are various kinds of object to judge. OCM can help to detect the definite failure and point out the direction of further improvement. For failure facility or air duct blocked problem, it can be repaired immediately; for improper design problem, facilities or terminals should be considered to be replaced; for data transmission problem, the relative facilities should be checked and repaired; for control strategy problems, an improved strategy should be developed;

for water supply deficiency problem, a further commissioning of water system should be carried out; for system hunting or problem of one terminal responsible for different zones, it is hard to be solved in short time, we can only reduce its affect by applying some measures.

3. CASE STUDY

A real case is given to explain how to use OCM flow figure to solve problems.

3.1 INTRODUCTION OF CASE

Beijing Fortune Building (Fig.3) is a slap-up office building, which was built in 1980s. The main building is 80m high with the construction area reaching 54490 m^2. There are 20 stories up ground and 2 stories underground. 3rd ~21st stories are mainly used as office room, designed with pressure independent VAV system. General stories are divided into two large sections and each section includes 3 zones in Fig.4 (I.Z.A/B-interior zone in section A/B; W.P.Z.A-west perimeter zone in section A; N.P.Z.B-north perimeter zone in section B; SE.P.Z.A/B-southeast perimeter zone in section A/B).

3.2 INTRODUCTION OF VAV CONTROL SYSTEM

Pressure independent VAV system is designed, and it includes four parts: terminal controller, integrated management unit, AHU controller and central monitor (Fig.5).

Main functions of each loop are:

(1)Terminal controller: calculate the required supply air volume (SAV) and change the opening of valve by deviation of required and measured SAV;

(2)Integrated management unit: collect each terminal's measured temperature and SAV, and then calculate the fan speed and supply air temperature (SAT). Fan speed is calculated by the total required SAV and then verified by the opening of all the terminal valves; For example, if all the valve openings keep smaller than 80%, the fan speed will decrease; while if at least one valve keeps opening at 100%, the fan speed will increase;

(3)AHU controller: maintain the required fan speed and SAT;

(4)Central monitor: record measured data and contribute to management.

3.3 OCM APPLICATION

Take SE.P.Z.B in intermediate seasons (AHU B12, 2 terminals) for example. Calculate the temperature and SAV deviation of each terminal between set point and measured value(Table 1).

Fig.3 Elevation drawing of Fortune Building

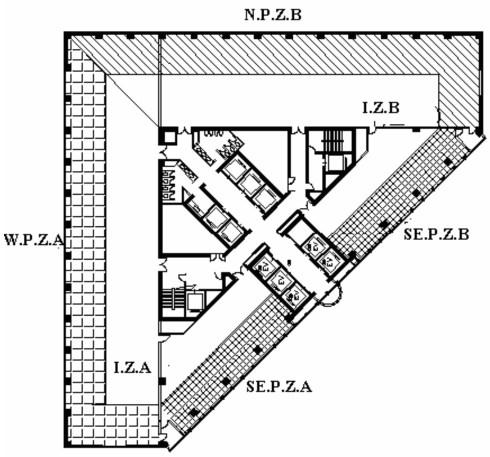

Fig.4 Air-conditioning system zoning

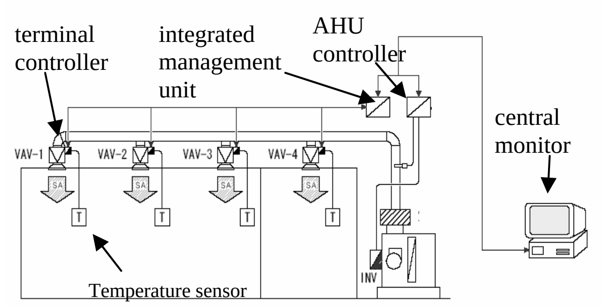

Fig. 5 VAV control system

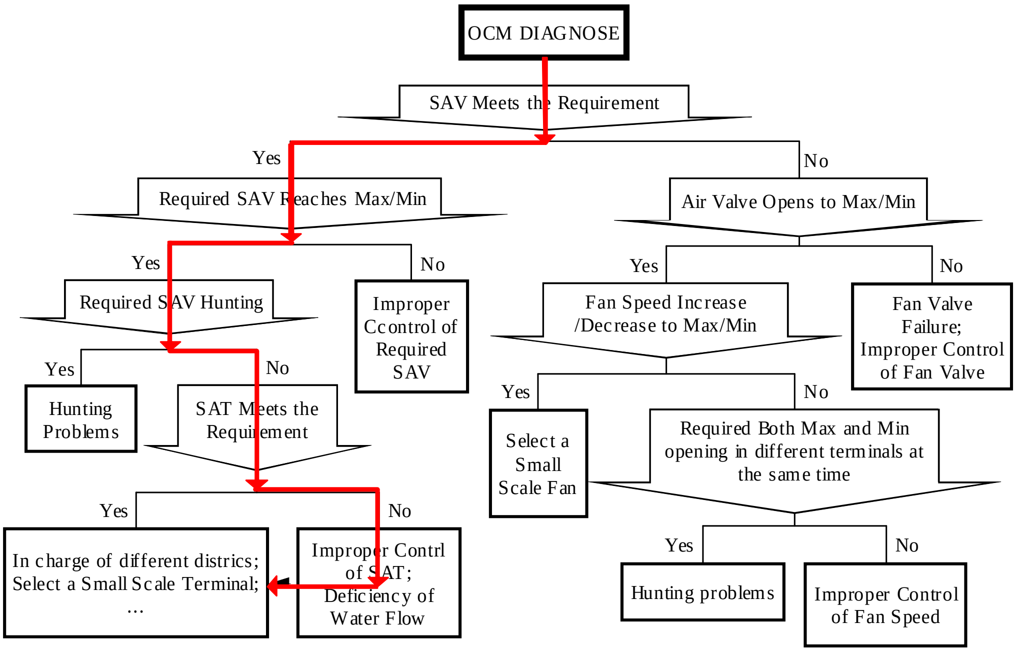

Fig. 1 OCM flow figure of VAV16, transitional season

Tab.1 Terminal performance of B12

1st ,May~31st , May	VAV16	VAV17
Set air temperature (℃)	25.5	25.5
temperature deviation (℃)	1.4	0.1
SAV deviation (×100%)	0.01	0.02

Table 1 shows that VAV16 has a big temperature deviation, and OCM is applied to diagnose the VAV control system.

First step: According to table 1, VAV16's SAV meets the requirement well, and OCM goes to estimate whether "SAV reaches maximum or minimum value".

Second step: According to Fig. 7, required SAV arrived at maximum value during 75% of time, and SAV hunting needs to be analyzed.

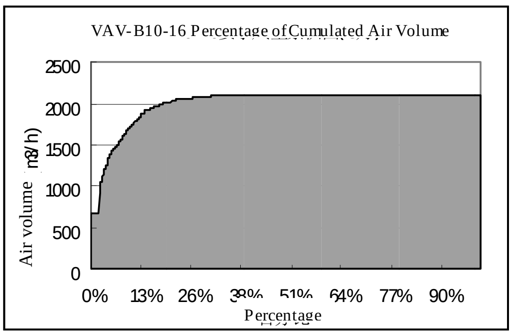

Fig. 2 Accumulative curve of required SAV (Transitional season, VAV16)

Third step: According to Fig.8 when temperature deviation is large, required SAV maintains at maximum value and no hunting appears. OCM goes to analyze SAT.

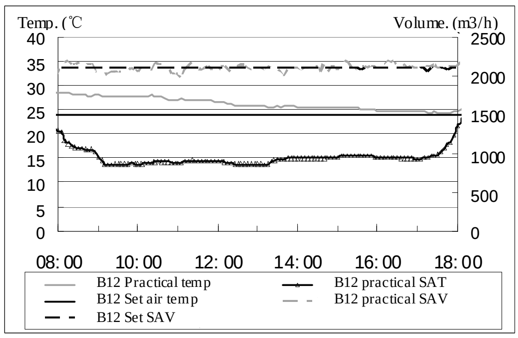

Fig. 3 Curve of indoor parameters（VAV16, May 20th）

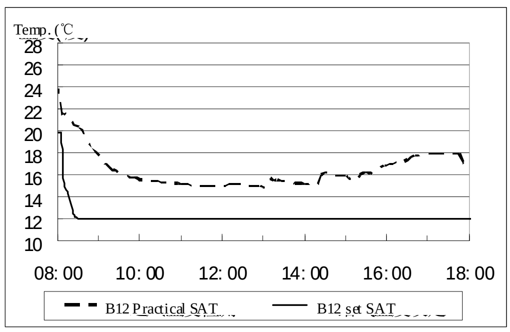

Fig.4 Relationship between practical and set SAT (May, 20th)

Forth step: According to Fig. 9, when set SAT is 12℃, practical SAT is around 15℃, which could not meet the requirement. Therefore, the failure may be result from insufficient water flow rate of AHU.

Fifth step: Analyze other possible failure

As shown in Fig. 10, VAV17's temperature sensor locates in a separated small room when VAV16's in a large-span room. VAV17 is designed to control air temperature in both large-span room and small room. But in practice, small room always has a small load and needs small SAV when large-span room's load is large and large SAV is needed. Because VAV17's SAV is determined by temperature sensor in the small room, practical SAV for the large room is insufficient. Therefore, large SAV and low SAT of VAV16 are required to offset insufficient capacity of VAV17.

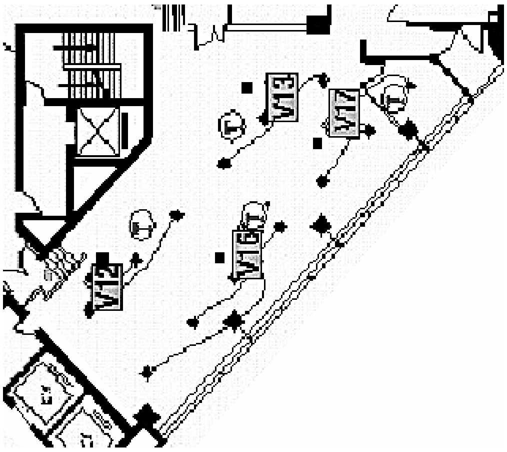

Fig.5 Position of temperature sensor of VAV16 and VAV17 (B12)

Results of Diagnose: 1. Insufficient water flow of AHU; 2. Sensor location is not reasonable.

3.4 Hunting Analysis

Hunting is a prevalent problem in VAV control system, which is also considered in OCM (Fig.2). Take B10 in winter (I.Z.B, 6 terminals) for example.

Table 2 Terminal performance of B10

VAV	12	13	18	19	20	21
Set air temperature (℃)	25	25	25	25	25	25
Deviation of temperature (℃)	0.0	0.0	-0.8	0.5	0.5	0.5
Deviation of volume (×100%)	0.02	0.01	0.04	0.02	0.02	0.02

Table 2 shows that VAV18 has a big deviation of temperature, so enter the OCM diagnose system.

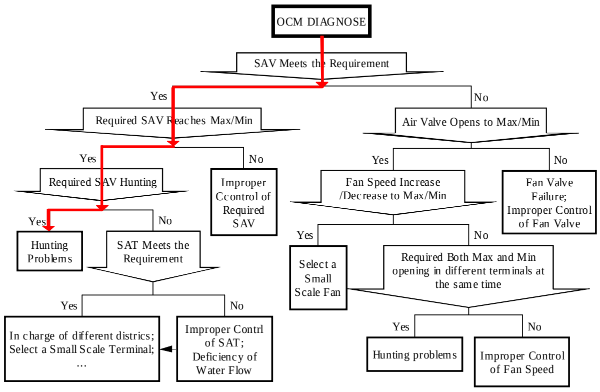

Fig.6 OCM flow figure of VAV18, winter season

First step: According to table 2, deviation of SAV is 4%, and OCM goes to estimate whether SAV reaches maximum or minimum value.

Second step: According to Fig. 12, required SAV arrived at minimun value during 50% of time, and SAV hunting needs to be analyzed.

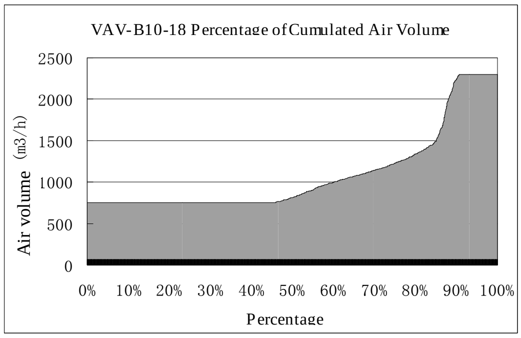

Fig.7 Accumulative curve of required SAV (winter season, VAV18)

Third step: According to Fig. 13, required SAV is hunting at most time.

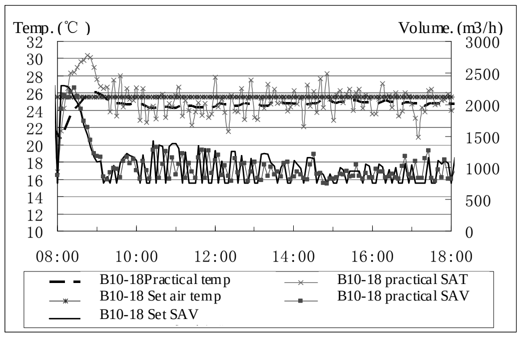

Fig.8 Curve of indoor parameters (VAV18, Jan 26th)

Results of Diagnose: Hunting problem.

As seen in Fig.14, all VAV terminals' set air temperatures are 25℃, and SAV is nearly close to minimum value. On the other hand, SAT varies between 22 and 28 ℃, that means the system alternates between cooling mode and heating mode. Under cooling mode, some terminals' practical temperature are lower than set air temperature and SAV can't be reduced, so SAT needs to be increased until higher than 25℃. Then it turns to heating mode when SAT higher than 25℃. Under heating mode, some terminals' practical temperature are higher than set air temperature so SAT needs to be reduced until lower than 25℃. Then it turns to cooling mode ,when SAT lower than 25℃.

In this case, hunting of SAT appears and it results in hunting of fan speed, water valve, and terminal valve etc..

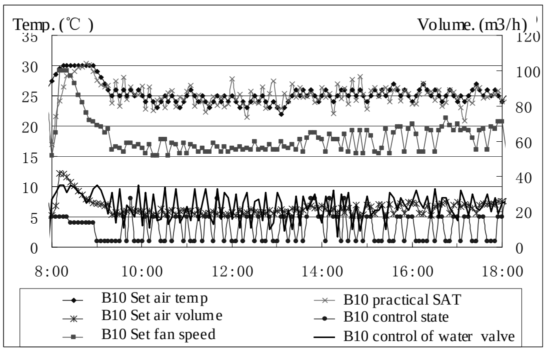

Fig.9 Curve of AHU parameters（B10, Jan 26th）

This case illustrates that hunting problem always appears when cooling and heating requirement existing at the same time for the terminals linked to the same AHU.

There are three situation may result in the problem: 1. small terminal load (always in transitional season or interior zone); 2. Each VAV terminal has a big deviation in set air temperature; 3. Improper zoning.

4. SUMMERRIZE

This paper introduced OCM to analyze the operation performance of VAV control system. OCM will help to figure out the definite reason of a VAV system's failure and point out the direction for further improvement. The author explains how to use OCM logic flow chart in a VAV system with pressure independent terminals through a case study. For other forms of HVAC system, some loops can be omitted, but the main principle is the same. Furthermore, the author analyzes the hunting problem in the case study and summarizes several reasons of it.

OCM is based on the assumption that the data tested and gathered by system monitor are error free (the data in the case study are tested and corrected before analysis). Practically, the troubleshooting of sensor failure relies on actual measurements during the operation stage, sometimes it is possible that the performance test of the sensor and the OCM of the HVAC control system should be carried out simultaneously, which is a more complicated problem and needs further research.

5. ACKNOWLEDGEMENT

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