Case Study of Energy Diagnose and Re-commissioning in a Green Office Building

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Abstract

Building progress consists of master planning, design detail, construction, acceptance and management phases. Due to lack of communication, there are many gaps between the adjacent phases in building progress, such as, the big gap between construction and acceptance phase. The gaps lead to miss part of design intent when buildings were functioned.

Although many prevailing evaluation systems like GOBAS or LEED mean to cover a whole building progress, in reality, they only pay much attention to design phase and generally ignore commissioning phase after construction. It leads an inefficiently facility management of HVAC systems and components. Energy diagnose and re-commissioning by on-site measurement can solve these problems, to improve systems' efficiency and bridge the gap between acceptance and management phase, finally realize a real green building.

In this paper, it presents a case study result of applying this approach in a green office building in Beijing and shows how re-commissioning and energy diagnose contribute significantly to reach a real green building for long-term functioning. That Green Office Building was certified as Golden Level by LEED, and evaluated as Level B by GOBAS. All these evaluation did before construction phase. But the actual power consumption, 74kWh/m^2.a, is twice as the designed consumption, and is only a bit less than other common office building. One month on-site measurement and half a year of data collected after acceptance phase show that some energy-efficient equipment do not run in a proper way. By re-commissioning, most of the systems in the Green Building work well.

Key word

Green building energy diagnose commissioning

1. Purpose

1.1 The evaluation systems of Green Building

The Green Building provides occupants with healthy, comfortable and natural environment and pleasant service, with less energy consumed and pollution at the same time. Evaluation systems are used to analyze green buildings quantitatively. Many developed countries have established kinds of evaluation systems to decide if the building reaches criterions, just as LEED in America, a rating system which created a common standard of measure for green buildings. In August of 2003, GOBAS was proposed by Tsinghua University to evaluate Olympic buildings, and it became the first rating system in China[1].

The evaluation systems can be used for assessment, and also become an basis for design. It accelerates the development of the greening building's construction market in China.

1.2 Commissioning and Energy diagnose

Building progress consists of master planning, design detail, construction, acceptance and management phases. None of them can be neglected, and all of them contribute to the whole life of the green building.

In China, the green building is just in the initial stage. Although many prevailing evaluation systems mean to cover the whole building progress, in reality, they only pay much attention to design phase and generally ignore commissioning phase after construction. Due to lack of communication, there are many gaps between the adjacent phases in building progress, such as, the big gap between construction and acceptance phase. The gaps lead to miss part of design intent when buildings were functioned. It leads an inefficiently facility management of HVAC systems and components.

Energy diagnose and re-commissioning by on-site measurement can solve these problems, especially of green buildings, with complex, new device and system. After construction, energy diagnose and re-commissioning improve systems' efficiency and bridge the gap between acceptance and management phase, finally realize a real green building.

2 Building information and the method of diagnose

2.1 Building information

The building site is in a downtown business district next to MOST and just south of Yuyuantan Park, the second largest green space in Beijing. Most of the building's space is standard office configurations. It has an area of 13223m2. It has a height of 30.3m, with 9-story concrete and masonry structure.

Tab.1 Energy saving measures

Comment	Energy saving measures
building envelope	exposed wall :light colored wall/roof surfaces, good insulation, Sureblock complex wall, integral transfer coefficient U=0.62W/m2·k
	Double-glazed, low-e windows with a high visible transmittance, solar heat gain coefficient SHGC=0.28, visible light transmission coefficient TVIS=0.41. 0.60 m overhang and light redirection devices, added to all windows
	Roof: good insulation(160mm poly-p-phenylene heat preservation) k=0.64W/m2·k
HVAC system	fan coil unite plus fresh air on the first floor, office room and meeting room
	used an under floor air distribution system for exhibition room on the second floor
	Fresh air heat recovery wheel for desiccant dehumidification
	two centrifugal chiller COP=4.4 R134a
Light	Illumination controlled lighting, a direct/indirect task-ambient lighting system with T-4 and T-5 lamps and electronic ballasts for dimming is ecommended. In addition, each occupant should have control of their own efficient task lighting.
Solar energy	PV panels , total power 19kW

According to DOE2 simulation results in design phase, the building electricity is 40kWh/m2.a.

Tab.2 Simulation results in design phase

comment	EU	EU per floor area
	10^4kWh	kWh/m^2
light	22.5	17
Office	9.7	7
Hot water	2.8	2
HVAC	17	13
SUM	52	39

This green building has a good score for less pollution, and some measures to save water, such as lots of water saving equipment and rain collecting system. So in LEED system, it was certified Golden or Silver Level, and in GOBAS system, it was result in Q-L Chart: Level B. All of these evaluation were done in design phase.

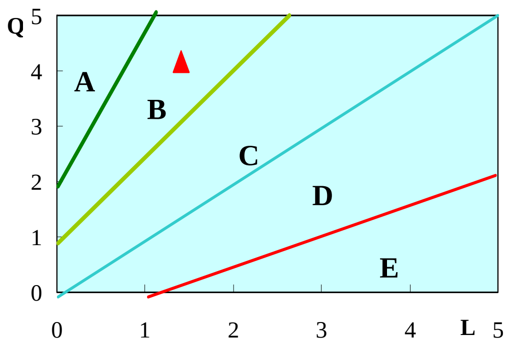


Fig.1 GOBAS evaluation results

Fig.2 LEED evaluation results

2.2 measure method

After construction phase, workers moved into this building quickly, and even did none adjusting and commissioning. Diagnose and re-commissioning was done after operation, and they contains one month on-site diagnose(2004.7～8) and data acquisition （2004.7～12）.

Goals and activity：

1： General – learn real performance of the completed systems

2： Components – diagnosis and make it

3： System – optimized functioning scheme

4： Special interests – energy audit and assessment

Tab.3 Goals and activity

comments	method	time
Electricity use	Annual EU and Operation records daily log	2004
Chiller efficiency	On-site measurement	2004. 7～8
Pump efficiency		
Ice storage operation		
Wheel efficiency		

3. Results

3.1 Electricity Use

The total annual electricity use of 2004 of this building is 980MWh , about 74kWh/m2.a, as following in Tab.4. Figure.3 shows the proportion of each part. According to the data of buildings energy consumption in Beijing[2], the electricity use in common office building is 100～195 Wh/m2.a. This building is more efficiency than common office buildings, but is less efficiency than the design results.

Tab.4 EU-end use of 2004

Comment	EU	EU per floor area
	104kWh	kWh/m^2
Lighting	18.6	14
Office	24.9	19
Elevator	7.8	6

Domestic water pumps	6.8	5
HVAC	36.4	28
SUM	98	74

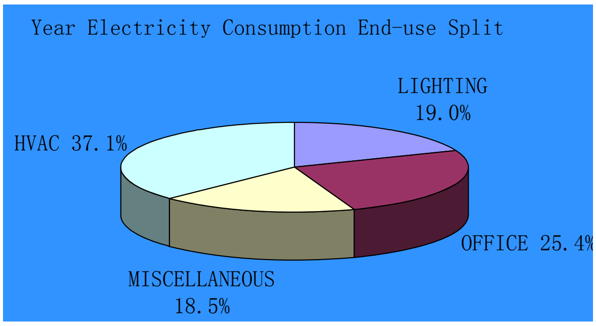


Fig.3 proportion of EU-end use of 2004

Instructions：

1 . Due to workers are twice than the number in design phase, the office EU is16.8 kWh/m2 , much more than design results.

2 . The lighting consumption is 18.6MkW , about 14kWh/m2 ;

3 . The EU of water pumps 和 elevator is 14.6 MkW , about 11kWh/m2 , account for 15% , which was ignored in design phase;

4.The HVAC system accounts consumption is twice than the results of design phase, 24.5kWh/m2. We can see the electricity end-use split by month in Figure.4. In April, May and October, the electricity use is very low, about 6MkW. The electricity use peak occurs in June and August, because during this period HVAC system is operation.

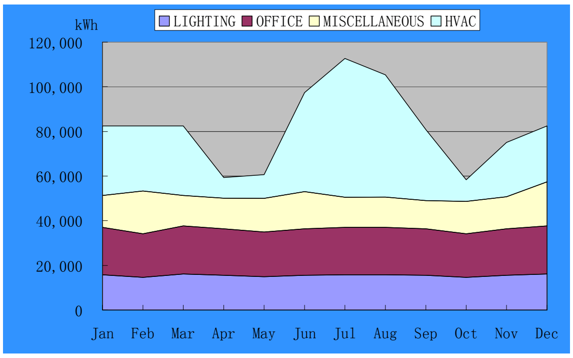


Fig.4 2004 Electricity End-use Split, monthly

3.2 HVAC system

Tab.5 points out each part power and EU of HVAC system, and Fig.5 and Fig.6 gives the proportion. So we can see that HVAC fans power only take a part of 13%, but in reality, they account for 39% of total electricity. The chillers power takes about 57%, and EU only is 6.6*104kWh. So we can see that the EU of fans consumed is even much more than that of chiller. There are many reasons, as following:

1. Due to lack of commissioning, all the fans run all the time during summer time. ;

2 . All the fans were designed to be adjustable according to the cooling load, but in reality, they work at a constant speed.

3. Some people, who pay no attention to energy saving, often leave FCU on after work. Auto-control system only can watch and can to control ,so many FCU work all the time during summer days. That's why fans EU is much more than chillers.

Tab.5 Power and EU of HVAC system

	chiller	pump	AHU	FCU
Power/ kW	139	60	31	15
EU/10^4kWh	6.6	7.7	14.0	8.0

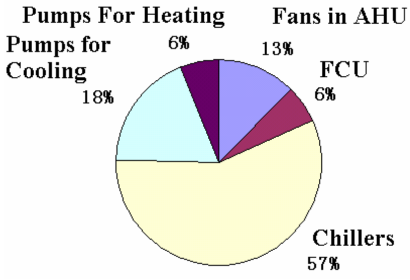


Fig.5 Electricity capacity of HVAC system

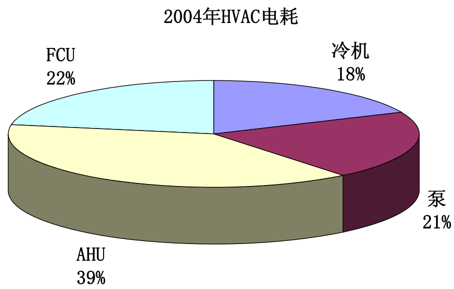


Fig.6 HVAC system electricity use(EU) of 2004

3.3 chiller on-site measurement

There are two chillers running with different cooling mediums, water and glycol (In this article, we call them chiller A and chiller B for short). They are made by Carrier. In summer, the cooling plant can work at 6 different modes (Table 1.4). Although there is an automation system for the whole HVAC system, it doesn't work. The workers change one mode to another based on their experience, usually depended on the weather and the temperature of the chilled water.

Tab.6 Cooling plant operation modes

Mode	Chiller on
Single chiller cooling	Chiller A
Double chiller cooling	Chiller A+Chiller B
Ice storage	Chiller B
Ice melting	
Ice melting + Single chiller cooling	Chiller A
Ice melting + Double chiller cooling	Chiller A+Chiller B

Fig.7 and Fig.8 give COP of two chillers in a typical day. Both of them work in a good condition, just as rated on nameplates. Because the supply water of chiller B is much lower than chiller A, the cop of chiller B fells a little less than chiller B.

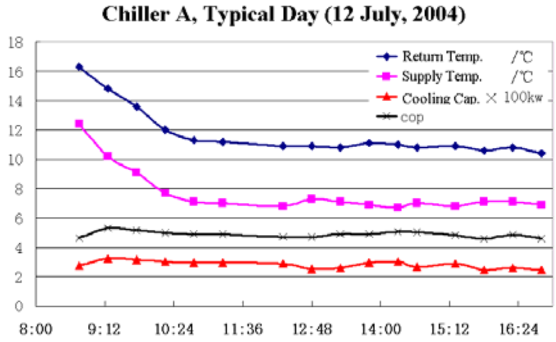


Fig.7 Chiller A work condition on typical day

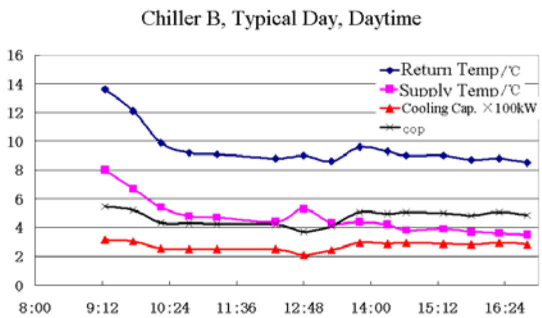


Fig.8 Chiller B work condition on typical day

3.4 Ice storage condition operation

We tried twice to freeze the water into ice (condition1 and condition2), about 17hours (the efficient time is 8hours). The cold water flux in chiller B is less than the flux rated on nameplates (60m3/h), 30.3m3/h in condition (1) and 45.6m3/h in condition (2). It made chiller B work inefficiently.

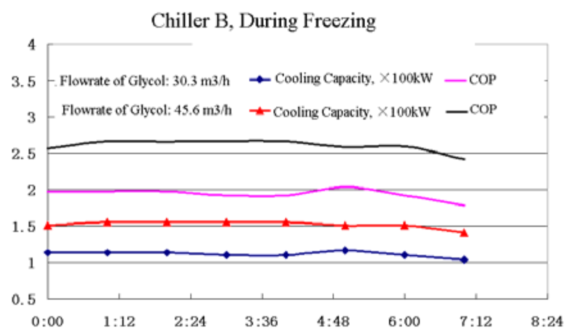


Fig.9 cop and flux in ice storage condition

In condition (1), the cold water flux is 30.3 m3/h. By checking the tube pressure drop, we found that a big drop was made by an electric value, about 0.34MPa. So the pump worked in a inefficient point, and the flux is very small.

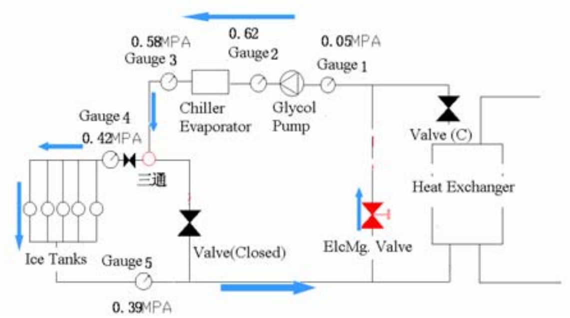


Fig.10 ice storage condition（1）pressure drop

Fig.11 ice storage condition（1）electric valve

After fixed that value, the flux went up to 45.6m3/h, which is still smaller than 60m3/h. We made a great of effort, and finally found that a transform value was suitable for the tube and must be changed.

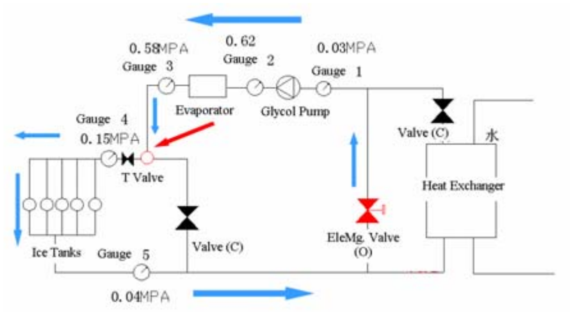


Fig.12 ice storage condition（2）pressure drop

Fig.13 ice storage condition（2）electric valve

3.5 pump measurement

In public buildings , the pumps EU might be bigger than chillers EU, as Tab.5. There are two chilling pumps and two cooling pumps, each two are in parallel connection. We measured the pumps, and results are shown in Tab.6. The efficiency is not very well. Because the pumps are not suitable for this system, it leads to an inefficient pump.

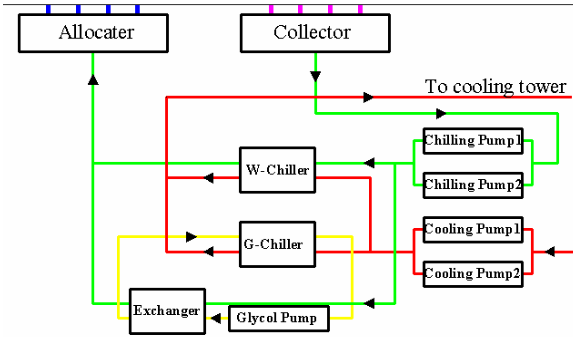


Fig.14 Structure of the cooling plant

Tab.7 Pump efficiency（two chillers on mode）

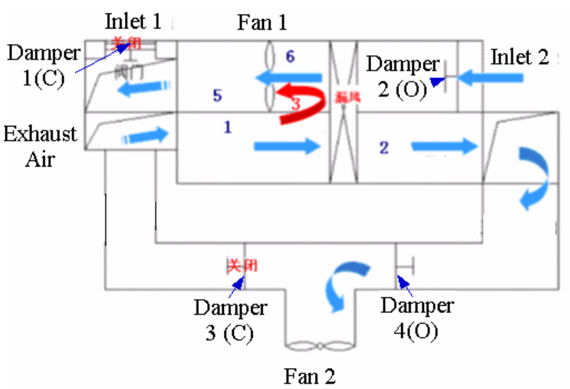
No		Ch. A	Ch. B	Cl. A	Cl. B
flow	m^3/h	61.2	59.4	55	63.4
current	A	11.1	11.2	16.1	16.2
head	m	17	17	17	17
Power output	kW	2.89	2.81	2.6	2.99
power	kW	6.34	6.4	9.2	9.26
Efficiency/%		45.6	43.8	28.2	32.4
Chilling pump=Ch.; Cooling pump=Cl.					

3.6 whole heat recovery wheel

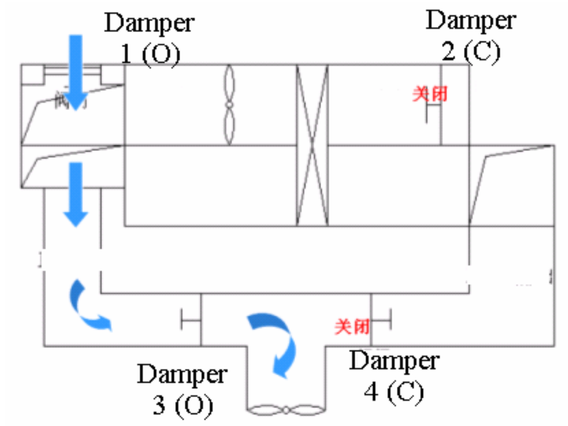
The whole heat recovery wheel is on the ninth floor of the building, it's one of the most important way to save energy. By adjusting four air values, the wheel can work in two operations: summer –winter operation (Fig 14) and intermediate season operation (Fig 15).

In intermediate seasons, the load of fresh air is not large, so the wheel and the fresh air fan can be closed. Fresh air goes into silo through fresh air inlet 1, Exhausted air is discharged to outdoor through tee value (Fig 15). In summer and winter , the load of fresh air can be reduced a lot by the wheel. Fresh air goes into wheel box through e fresh air inlet 2. First, its load is reduced after whole heat transforming with exhausted air; Then, its pressure is increased after fresh air fan; Finally, it goes into silo. Exhausted air goes into wheel box from the silo, and after heat transforming, it will be discharged through the outlet on the roof (Fig 15).

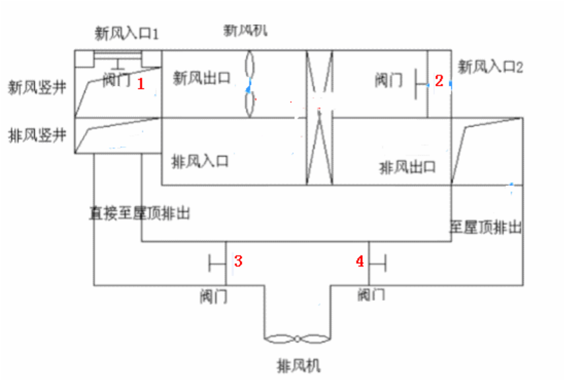
Actually all the values of the wheel was open , so the wheel works incorrectly. Exhausted air go to outside directly by outlet 3, without recovery heat from fresh air. By re-commissioning, the wheel can work well. From exhausted air inlet (1), a part of exhausted air goes to fresh air outlet (6) and mixes with fresh air. The mixed air goes into office room, and the quality of fresh air is not good. The total efficiency is about 59% at this condition.



Tab.15 Air route in summer and winter



Tab.16 Air route in intermediate season



Tab.17 open the value

4: Conclusion

Green Building is a combined system, and should be brought into the course of plan, design, construction and operation. Excellent design project must be used in a correct operation system to realize its ambitions. In china, green buildings are only in the initial stage, related policy, regulation and industrial management isn't completely established. At present times, evaluation systems only pay attention to design stage, which play an important part in creating a good project, calculating correctly how much energy save, pay period and cost benefit. But many evaluation systems don't following construction and operation stages, it leads to an inefficient building. The real energy consumption is much higher than designed and some efficient equipment doesn't work well, especially for HVAC system. According to different climate conditions and users demand, air conditioning system will adjust directly. It's not a stable process and must be adjusted for a whole year before recognized as a green building. The acceptance stage in china now only verifies whether the equipments are installed or not. So many buildings in china don't adjust completely, which reduces the effect of advanced technology and equipment.

We need a course control and quality guarantee system to reach a real green building. The total building commissioning authority or company, which is independent from design institute and construction contractor, works for project owner directly. The total building Commissioning is a systematic methodology that documents the entire building process from the owner's inception and design to construction, and occupancy. It results in successful buildings that operated as expected at delivery, are economical to operate, and met occupant needs for the life of the building. In many papers, total building commissioning is definite as "Commissioning is the process of ensuring that systems are designed, installed, functionally tested, and capable of being operated and maintained according to the owner's operational needs."

The meant task of building commissioning in the operation stage is saving energy, improving satisfaction, reducing the gap between building construction, as following Tab.7.

Tab.8 Commissioning Tasks

	Operation stage
comment	Operation and manage
staff	Management company、Cx-authority、occupant
Task	Finish operation guide line for a whole year, make equipment work at the best piont，establish long-term energy saving system
Measurement Point	air flux、water flow、temperature、data log
report	Operation strategy and energy saving system

Reference

[1] Guideline of Green Olympic Building Assessment System (GOBAS), Tsinghua University, 2004

[2] Yuan Wang. The Energy Database Establish of public building in Beijing: Dep. Building and Environment of Tsinghua University, 2005.

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