



Industrial Technology Research Institute

Project Type: Public Building Renovation
Location: Taiwan

The demand of conditioning electricity has seen a strong increase in recent years in Taiwan, especially during the summer season due to climate change and global warming. The contrast in power consumption is so stark the Bureau of Energy in Taiwan states that the peak electricity load in summer accounts for over 30% of the electricity load of Taiwan Power Company.

Since the HVAC system accounts for 41% of the total electricity consumption in commercial buildings, improving the energy efficiency and performance of the system is therefore the most effective and direct way to manage the country's energy consumption, which is especially important considering Taiwan's energy is mainly dependent of importation from foreign countries.

However, for a long-period of time in Taiwan the design and efficient operation of chilled water hydronic applications of HVAC systems have been neglected. As a result, the Low Delta T Syndrome is a common side effect in most chilled water systems, leading to additional chillers and pumps needed to keep the primary system flow larger than the secondary flow. This means that chillers are operated at lower efficiency due to operation in low cooling load condition. This will not only cause the chillers wasting more energy consumption, but also increasing the energy consumption of the whole HVAC system.

This paper is written as a case study of energy savings for an HVAC system with a magnetic bearing centrifugal chiller. The objective is to reach high efficiency under partial load conditions for the magnetic bearing centrifugal chillers for most of the year. In addition to optimizing system efficiency, the human comfort variable must also be maximized by delivering stable room temperature without oscillations. We optimized the hydronic system by installing differential pressure controllers on the branches of hydronic system, redoing TAB (Testing, Adjusting, and Balancing) for the whole chilled water hydronic system on-site, and controlling the variable frequency pump with optimal energy-saving control, so that the overall HVAC system can run under optimal condition while saving energy.

Key words Differential pressure controller, energy saving for hydronic system in HVAC system, Optimization of variable pump operation, TAB (Testing, Adjusting and Balancing)

The Project

For many years in Taiwan the typical design for HVAC systems for commercial buildings would include fan coil units as terminal units and the control valve for the fan coil unit is an ON-OFF-controlled two-way valve in variable flow system.

There are many potential technical issues that can be raised regarding traditional ON-OFF-controlled variable flow systems; most often related if the TAB was performed on the HVAC system on site. The inadequate TAB on site is a key reason why most existing chilled water system suffer from Low Delta T Syndrome - over-flow of the chilled water flow rate in part load condition - even if the system is in design condition.

In part load condition, the two-way control valve is subjected to excessive pressure difference, which causes the problem of over-flow to be more serious. When the increase of differential pressure is applied on the control valve, the actuators cannot close-off the control valves, leading to noise generation and ultimately discomfort. Moreover, the energy cost of the whole HVAC system is increasing as the variable speed pumps in the variable flow system cannot reduce frequency according to the cooling load reduction due to improper operation of control valves in the hydronic system [1].

The Hydronic Challenge

In this particular case study, the chilled water plant supplies chilled water to two buildings; building A and building B. Building A is a five-story building with one basement and Building B is a three-story building with one basement. They are both combined-use buildings (office and research laboratory). The 500RT centrifugal chiller and the 400RT magnetic bearing centrifugal chiller are mutually assisted to provide chiller water to cooling capacity of Building A and Building B. The chilled water supplied by the chiller

plant provides 12 hours of air conditioning in most areas to meet working-hours requirements. However, it needs to provide 24-hour chilled water to the laboratory facilities as they require uninterrupted air conditioning. Each floor is controlled by an ON-OFF electrical two-way control valve, while a 24-hour demand is directly bypassed in front of this valve. The air-conditioning system is constantly providing chilled water to the requirement of cooling capacity every day.

The chillers staging is controlled according to the requirement of cooling load year-round. In the spring, autumn and winter the chilled water is supplied by the 400RT magnetic bearing centrifugal chiller to supply the chilled water to air conditioning load demand on-site in part load condition. In the peak load condition in summer, the 400RT magnetic bearing centrifugal chiller couldn't satisfy the cooling load demand, so it is necessary to switch on another 500RT centrifugal chiller and turn off the 400RT chiller to provide enough cooling capacity in peak cooling load condition.

The hydronic system is a Primary/Secondary chilled water system, and the chilled water pump in the primary side is operated for constant flow control, and the secondary side is divided into three zone pumps. There is variable speed control for the chilled water zone pumps according to the cooling load variation. The Schematic diagram for Hydronic system in existing building can be referred in Figure 1.

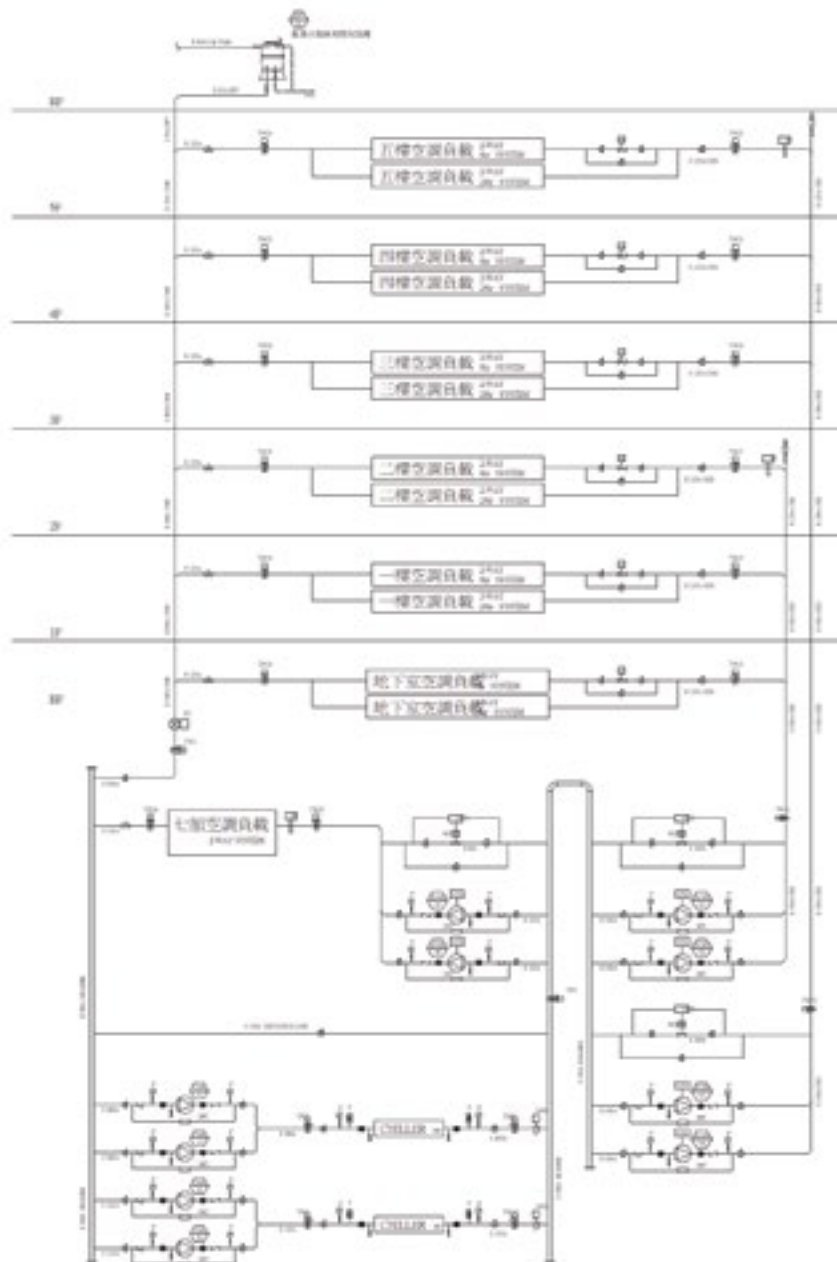


Figure 1: Schematic diagram for Hydronic system in existing building

The Solution

With the government's policy of energy saving and carbon dioxide reduction in recent years, the equipment of air conditioning system in the ITRI (Industrial Technology Research Institute) had been replaced in recent years. From the early plan for replacement of the magnetic bearing centrifugal chiller to improve the chiller's operation efficiency, to install variable frequency control to the chilled water pumps, and replace the old fan coil unit with new ones, etc. But the optimization of the hydronic system control is not necessarily related to the highly-efficient equipment, but whether it could be operated in an energy-efficient way. The proposal from IMI Hydronic Engineering was on how to optimize the hydronic system to run the full air conditioning system in the required energy-efficient condition.

The strategy of optimization of the hydronic system for the air conditioning system is listed as follows:

1. Install differential pressure controllers on the branches of the hydronic system and redoing TAB (Testing, Adjusting, and Balancing) for the whole chilled water hydronic system on-site
2. Adjust the differential pressure of each differential pressure controllers on branches
3. Optimized the setting of the operating frequency of variable zone pump

In order to optimize the whole hydronic system, the TAB executing must be implemented on-site, the Dp controllers on the branches can make the room temperature control more stable, as Dp controllers absorb locally any differential pressure variation, to achieve the purpose of room temperature comfort control and energy saving.

The proposed retrofitting of hydronic system is to install Dp controllers across branches, as illustrated in Figure 2. This Dp controllers can be used to stabilize the differential pressure across this branch with several terminal units, provided the required design flow through the operating terminal units during full load and part load conditions, to provide indoor climate comfort [2].

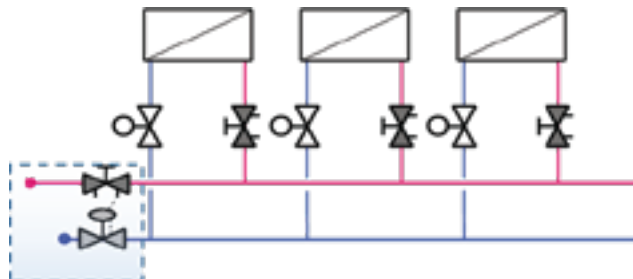


Figure 2: Retrofitting by installed differential pressure controller across branch in hydronic system.

As the chilled water flow could be precisely controlled at any working conditions, the hydronic system could maintain the temperature difference between supply and return chilled water temperature as high as possible without chilled water over-flow. The variable-flow chilled water plants could be operated in a higher efficiency condition, as the variable frequency chilled water pumps and chillers could be reduced the energy consumption during part load conditions.

Measurement and verification of the performance for differential pressure controller on-site

Before installing the Dp controller in hydronic system, hydronic calculations were required. Using the HySelect software the required Dp across the branches according to the pressure drop of piping, valves, and coil pressure drops of the installed terminal units could be determined. Then IMI hydronic Engineering measured and adjusted the setting of differential pressure on the Dp controller while doing TAB process on-site. The installation of Dp controller on-site is shown in Figure 3 below.



Figure 3: Installation of Dp controller on-site

The performance of Dp controller is verified by the following testing procedures on-site.

1. Record the setting of differential pressure value of each Dp controller on-site
2. Remote control the different operating conditions of two-way control valve of fan coil unit in the branch to simulate the cooling load variation, to record variation of the differential pressure value of Dp controller on-site
3. In the meantime, monitor the room temperature variation during testing, to examine if the indoor climate comfort is satisfied while operating the hydronic system in optimized condition.

In the above procedure, the test conditions for the different operating conditions of two-way control valve of fan coil units in the branch to simulate the cooling load variation is listed below.

Condition 1: The number of operating fan coil unit in the branch is 5 units.

Condition 2: The number of operating fan coil unit in the branch is 10 units.

Condition 3: The number of operating fan coil unit in the branch is 25 units.

Condition 4: The number of operating fan coil unit in the branch is 49 units.

It can be seen in Figure 4 that the Dp controller can effectively stabilize the differential pressure across the branch during different testing conditions, provided the required chilled water flow through the operating terminal units during any part load conditions and design condition, to provide the indoor climate comfort.

The Building Management System (BMS) is continuing to monitor and record the status of differential pressure variation and frequency variation of variable chilled water zone pumps. When the variation of different pressure and frequency of variable chilled water zone pump are out of the normal operating range of setting value, the BMS will automatically record and send out a warning for alarm function.

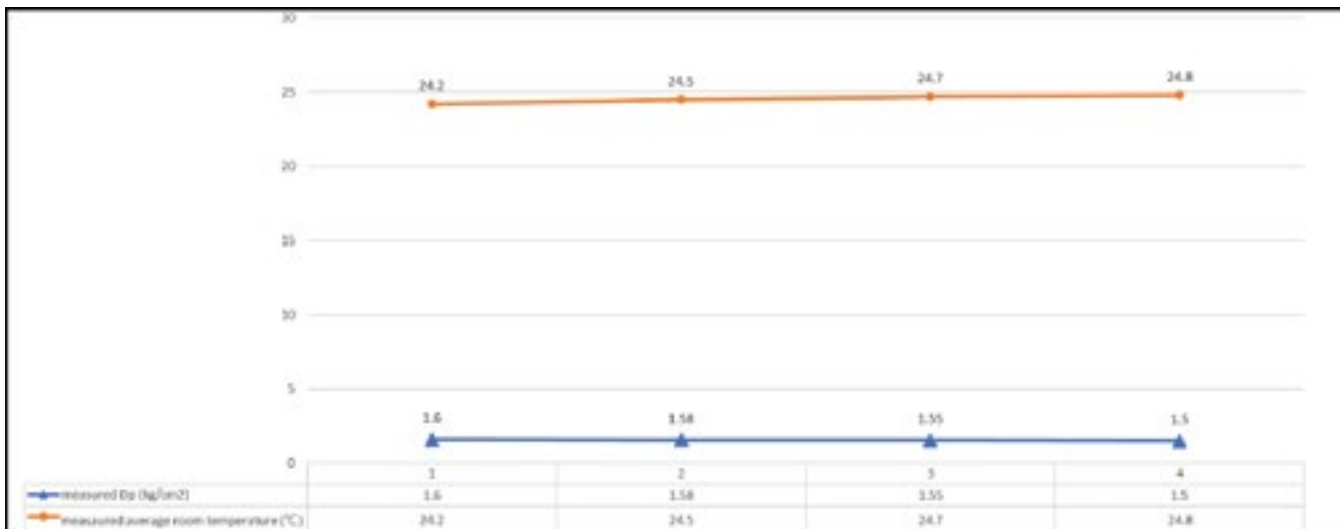


Figure 4: Measurement & Verification for performance of Dp controller on-site

Energy Analysis

Figure 5 is a comparison of the monthly energy consumption of the 400RT high-efficiency magnetic bearing centrifugal chiller before and after retrofitting. It can be found that this magnetic bearing centrifugal chiller can be operated at excellent high-efficiency performance, because the hydronic system was optimized with Dp controllers across branches after retrofitting. The monthly energy consumption of this chiller can be saved at least 20%, and even up to about 60% in winter.

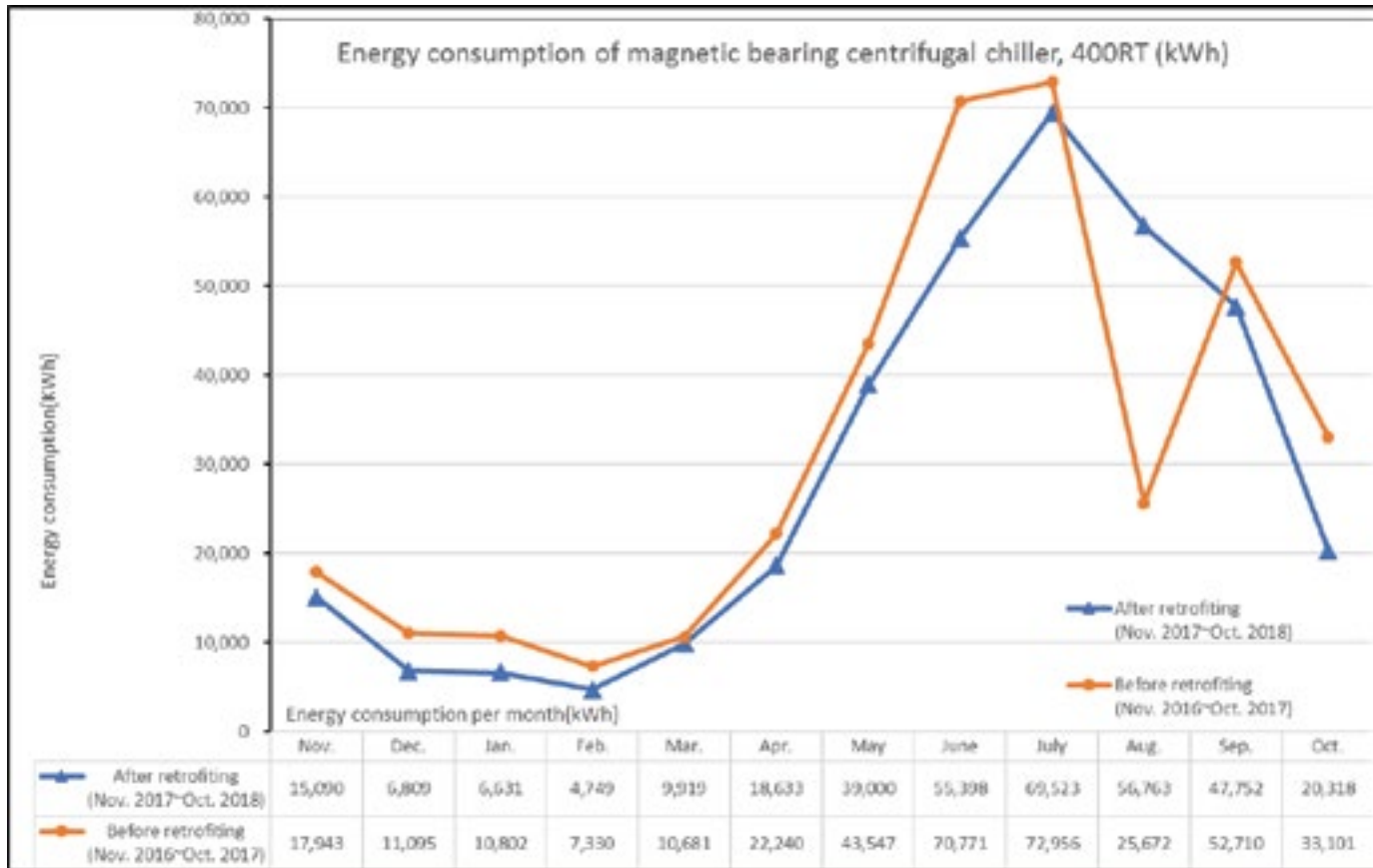


Figure 5: The comparison of monthly energy consumption of 400RT high- efficiency magnetic bearing centrifugal chiller before and after retrofitting.

It is interesting to note on Figure 5 that the monthly energy consumption of this chiller is higher after retrofitting in August. The energy consumption of this chiller after retrofitting is 56,763kWh higher than of 25,672 kWh before retrofitting in August.

After comparing the monthly energy consumption of the 500RT centrifugal chiller in Figure 6 it was possible to determine the reason for that as following:

Before retrofitting, in the peak load condition for summer, like in August, the 400RT magnetic bearing centrifugal chiller couldn't satisfy cooling load demand, so it was necessary to switch on the 500RT centrifugal chiller, and turn off this 400RT chiller to provide enough cooling capacity in peak cooling loadcondition. Therefore, the energy consumption of the 400RT chiller was lower pre-retrofitting because the number of its operating hours were lower as it was substituted by the 500RT centrifugal chiller.

However, after retrofitting with optimized hydronic system with Dp controller, the chilled water flow can be precisely controlled and the 400RT magnetic bearing centrifugal chiller could deliver enough cooling capacity for the peak cooling load in August on its own.

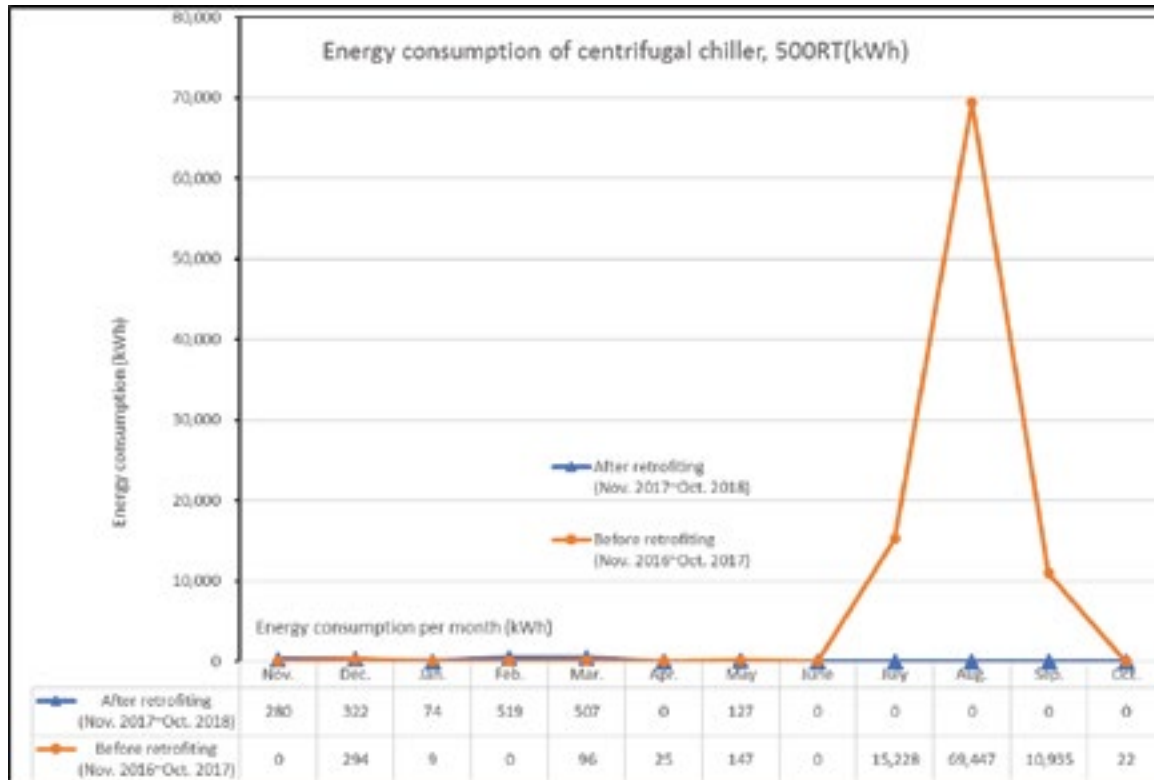


Figure 6: The comparison of monthly energy consumption of 500RT centrifugal chiller before and after retrofitting.

The reader can refer to Figure 7 for the monthly energy consumption of the total chillers (sum of 500RT chiller and 400RT chiller) before and after the retrofitting. In this case, the reduction in energy consumption of total chillers after retrofitting is clear.

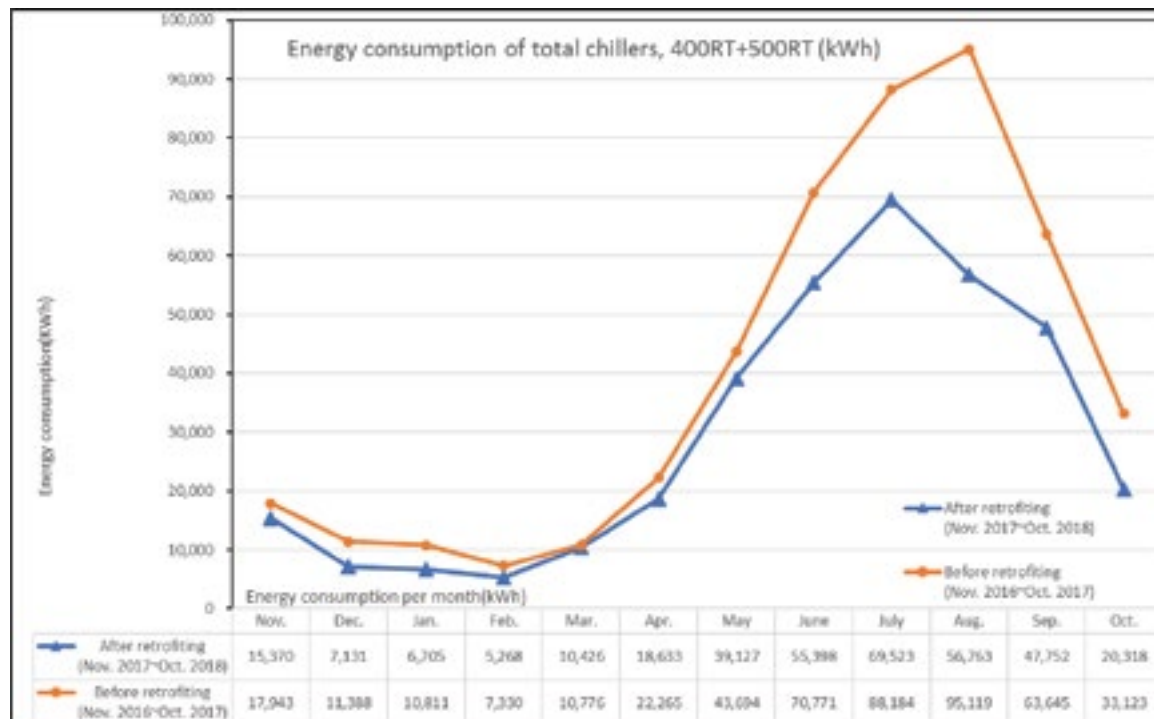


Figure 7: The comparison of monthly energy consumption of total chillers (sum of 500RT chiller and 400RT chiller) before and after retrofitting.

In addition, the energy consumption of variable chilled water zone pumps could be reduced after retrofitting with optimized hydronic system with Dp controller, as shown in Figure 8. There is a very significant energy saving effect for variable chilled water zone pumps. **The annual average energy savings can be as high as 42%, and even up to 60% in some seasons.**

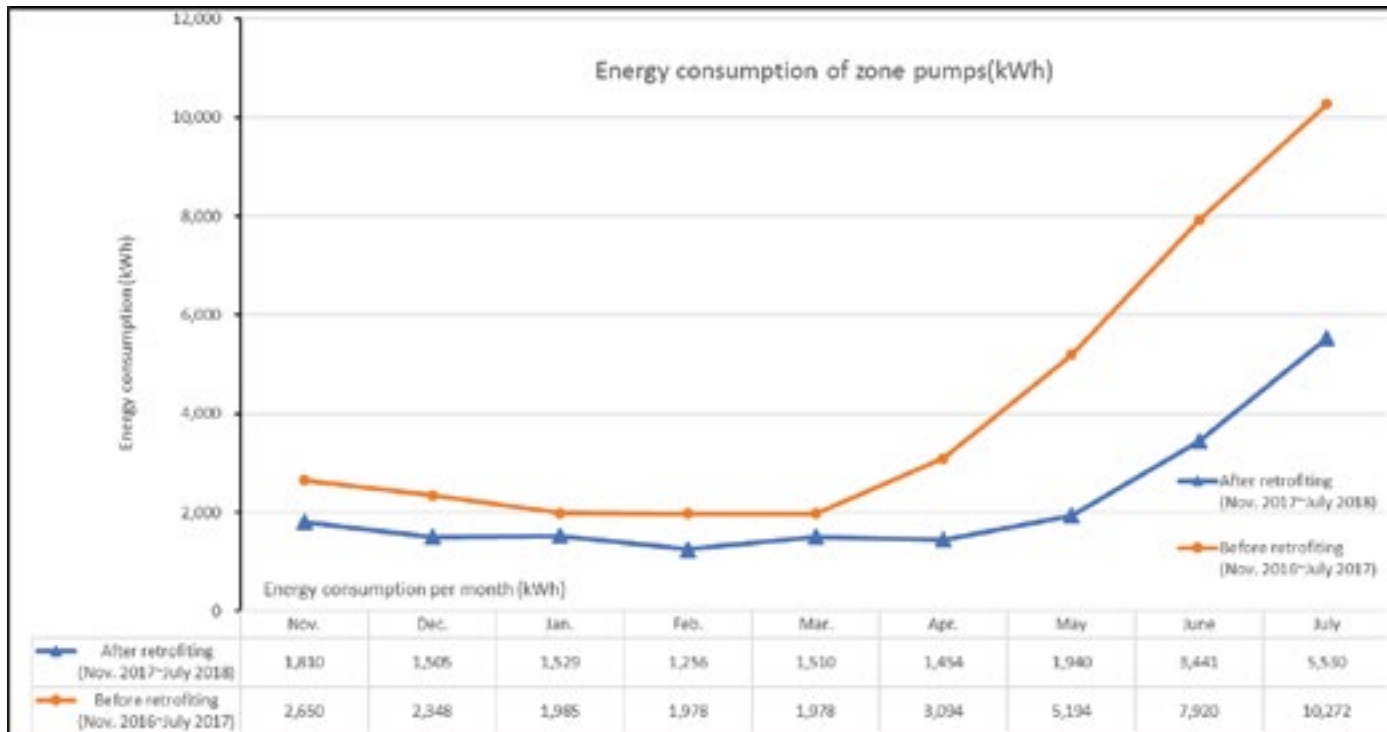


Figure 8: The comparison of monthly power consumption of variable zone pumps before and after retrofitting.

The analysis of energy consumption of the whole HVAC system is shown in Table 1, from Nov. 2017 to July 2018. The total energy consumption before retrofitting is 805,220 kWh (767,801 kWh + 37,419 kWh), and the total energy consumption after retrofitting is 671,054 kWh (651,079 kWh + 19,975 kWh). The energy saving is about 130,000 kWh, and the annual average energy saving is more than 15%, which is higher than the original target setting of 10%. It is estimated that the payback period is within three years.

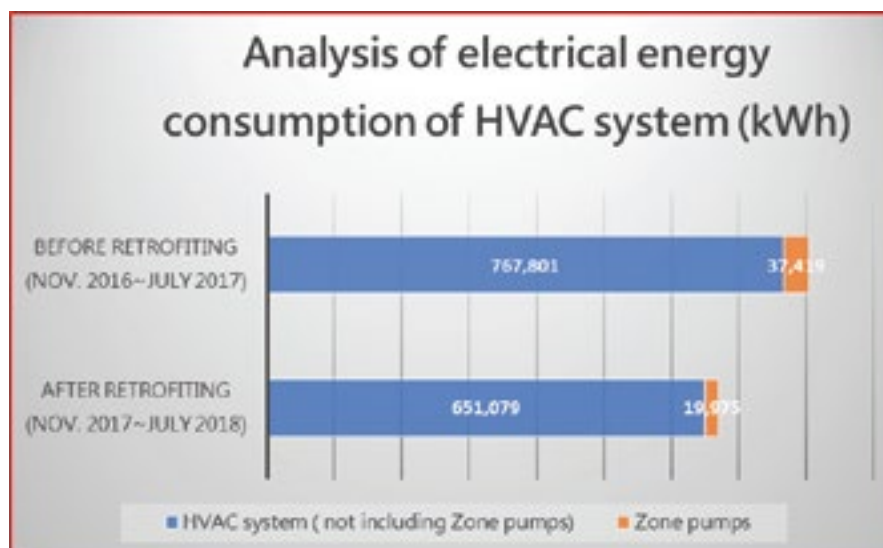


Table 1: The comparison of power consumption of whole HVAC system before and after retrofitting

Conclusion

In this case study, though the chilled water is already provided by high-efficiency magnetic bearing centrifugal chiller, we could gain more additional energy saving by optimizing the hydronic system through the Dp controller on the branches, redoing TAB for the whole chilled water hydronic system on-site and controlling the variable frequency pump with optimal energy-saving control.

After this improvement, the performance of whole hydronic system optimization is very impressive, not only having outstanding energy saving benefit for the whole HVAC system, but also providing indoor climate comfort.

REFERENCES

1. Jean-Christophe Carette, Proceedings of Convention "Towards Smarter and greener buildings", Sharm-El-Sheikh, December 2007.
2. R. Petitjean, 1997, Total Hydronic Balancing, Tour & Andersson, pp. 270-273.