# THE METHODS TO OPTIMIZE POWER USAGE FOR CHILLER SYSTEM OF TPS UTILITY

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*Abstract*

The recently completed Taiwan Photon Source (TPS) is one of the brightest synchrotron X-ray sources in the world. It will offer 500 mA beam current at 3 GeV for all kinds of different subject experiments and novel scientific ideas. This facility will be the most inspiring trigger to scientific researches in the twenty-first century in Taiwan. In order to make sure this giant machine operate properly, the utility system plays a very important role. Not only for the giant machine, the utility system also takes responsibility for providing a cozy environment for all staff. Furthermore, the requirements of air condition in some critical areas are very strict even to +/- 0.1℃ temperature accuracy. All of it cost a large amount of energy to satisfy everyone's demand. According to the annual budget report of NSRRC, the total charge of electricity and water was more than 80 million N.T. dollars per year before TPS project initiated, and increased by more than 200% after TPS inauguration. Since the government budget is limited, the whole utility system must be operated under more economic ways to use energy more efficiently.

## INTRODUCTION

Since April 1993, the first beam stored in the Taiwan Light Source (TLS) storage ring, many scientific researches and experiments had been conducted in the first synchrotron light source of Taiwan. In the last two decades, a lot of remarkable results of academic research had been done by this third-generation synchrotron, and the total number of beamlines had also increased from 3 to 26 during this period. Due to the saturation of beamline usage, the TPS project was initiated in 2004, and operated officially in 2015. In other words, the TLS and the TPS will be operated at the same time in the following years. Comparing the TPS with the TLS, the former has relatively large size and beam energy, which implies the cost of keeping both going will increase substantially. According to the annual budget report of NSRRC, total cost of electricity and water bills, especially electricity, increased obviously from 2011 to 2014 due to the number of contract power capacity had been raised (Refer to Figure 1). The contract power capacity for TLS and TPS now are 5.5 MW and 7.5 MW separately. For the rising cost and the limited budget, it is necessary to develop energy saving processes for utility group [1].

Besides the main supporting systems of the light source and beamlines, about 1/3 of power usage was consumed at air condition systems including water cooling systems which provides a comfortable environment and higher experimental quality. To avoid affecting these advantages while achieving energy saving at the same time, lots of ideas and procedures are tentative and approved in recent years. According to the theses proposed before, a run-around heat recovery process and connecting TLS and TPS chilled water system were verified [2]. The former process is applied in heat-exchange coils in air handling unit. It saves nearly 30% of energy in cool and heat exchangers and takes about 3% power consumption of whole system to operate the circulating pump. Despite of the additional cost and space for the heat-exchanging coils, it is still a worthy investment.

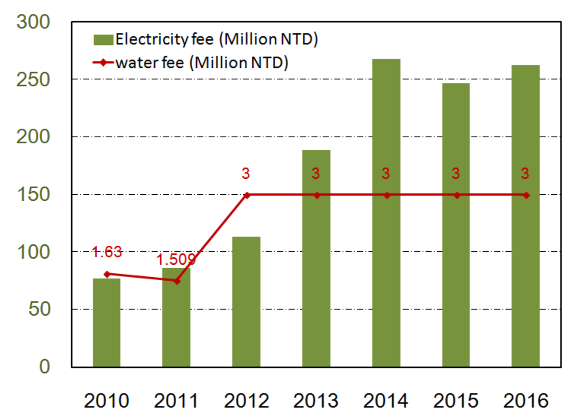


Figure 1: Annual budget in electricity and water between 2010 and 2016 of NSRRC.

The other energy saving procedure is the piping connection of chilled water system between TLS and TPS. It not only increases the COP (coefficient of performance) of chillers, but also provides the redundancy while one of the chilled water system fails. In this article, the operational improvement of cooling towers and chillers is achieved. We replaced an ordinary fan with an energy saving fan while eliminating the old one. A wiser algorithm was deployed to local controllers to reduce the shock from human resource shortage.

## THE ENERGY-SAVING PROCESSES FOR CHILLED WATER SYSTEM

The experience in using programmable automation controllers (PAC) is helpful to utility system in NSRRC. More than one hundred PACs are applied to handle water and air conditioning systems. These advanced controllers are organized into a flexible-customized supervisor and controller system [3]. Combining with the existing supervisory control and data acquisition (SCADA) system,




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these local controllers could act more wisely and response faster. All of the efforts are prepared for the trend of Industrial 4.0, and expect to realize the ideas of smart factory. Measurement to figure out the state of the controlled equipments is the first priority. Cooling tower exchanges the energy from heat load to air, and is the first layer of the chilled water system. The cooling tower is driven by a varied frequency drive, and operates in low frequency with less heat load. The drive is controlled by a PAC under PID control mode. The control variable is the wet ball temperature, and the dependent variable is the frequency of the VFD which changes with the set point. The set point in this case is the temperature of supply cooling water, which is set between 24°C to 27°C. There are three cooling towers in TLS and eight in TPS. Each of them operates alternately and the number of enabled cooling towers depends on the total heat load. In our measurement, it is found the total power consumption of cooling towers in lower frequency with more enabled number will probably be less than fewer enabled machines in higher frequency. Therefore, the enabled timing is set to trigger while the average operation frequency reaches 40 Hz. It keeps the cooling towers operate in low frequency while heat load is less. Besides, we set two possible variables to cope with the fluctuation of atmosphere temperature. One is the temperature of supply cooling water, which is set to 20 or 24°C during cold days, the other variable is the wet ball temperature plus 3°C. The former setting is suitable for low temperature weather, and the later is for high temperature between June and October. In real case, total energy consumption of three drives at low frequency (such as 20 Hz) is about 30 kW, while two drives at high frequency (such as 55 Hz) is more than 65 kW. When more cooling towers are enabled, the ventilation space will be larger and the efficiency of heat exchange increases naturally. The only cost is the problem caused by wear and tear will happen more frequently.

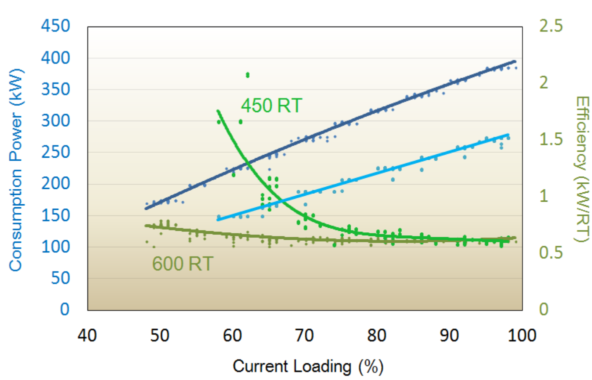


Figure 2: Performance of chillers used in TLS.

In addition to modifying the operation mode of cooling towers, the performance of chiller system is also a critical index due to its large power. There are four chillers used in TLS, which are two 450 RT and two 600 RT in capacity respectively. The performance in different size of chiller capacity is illustrated in Figure 2. Two blue straight lines represent the relation between the power consumption and current loading percentage. The bright blue line is for 450 RT chiller while the dark one is for 600 RT. It is not surprising the power consumptions of both lines are directly proportional to current loading percentage. However, if we take the removal of heat load into consideration, the difference will be clear in low current loading. The efficiency below 75% loading current of 450 RT chiller is getting worse than 600 RT chiller. As a result, the operation arrangement of these four chillers could be properly planed and programmed in controllers. One larger chiller will replace two small chillers while heat load is increasing.

The temperature of cooling water also affects the performance of chillers. The performance of chiller will decrease about 1% if the temperature of cooling water rise 1°C. The problem is, in order to supply colder cooling water, more pumps and cooling towers must be enabled if necessary. How to balance both side consumption is still our next mission.

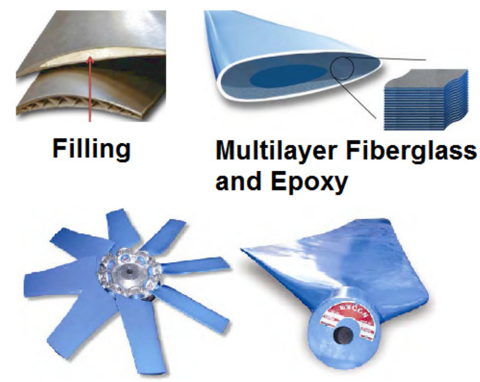


Figure 3: Structure difference in traditional fan and energy-saving fan.

In addition to the measurements of existing equipments, some of the new commercial productions are tried out in our factory. A set of energy-saving fan is installed in TLS. Unlike traditional aluminium alloy fan or FRP (Fiberglass Reinforced Plastics) fan, the energy-saving fan is made from multilayer fibreglass cloth and epoxy. This complex material is lighter and stronger than ordinary aluminium or FRP fan. Besides, the blade shape is more aerodynamic comparing to retired fan (Figure 3). The performance of the energy-saving fan is record once after installation. The discharge area of cooling tower is 8.96 $m^2$, after subtracting hub area remains 8.79 $m^2$ transverse area. The exhaust wind velocity is measured at four quarter arc in five equal segments of radius. The wind velocity profile is shown as Figure 4. Wind velocity distribution of energy-saving fan is more uniform than ordinary fan, which means the former has more equivalent wind path than later. We have measured under the same average wind velocity and quantity, the energy consumption of energy-saving fan at 60 Hz is about 28 kW, and the ordinary aluminium fan is 38 kW. It reduces nearly 25% of power usage at full speed without any reduction of performance. However, it is also found the benefit of energy-saving fan will gradually decrease along with the diminishment of operation frequency. The power consumption will be the same under 10 Hz frequency. Hence, the lowest operation frequency of cooling towers is set to 15 Hz and this frequency is also the turn-off frequency in controller's programming.

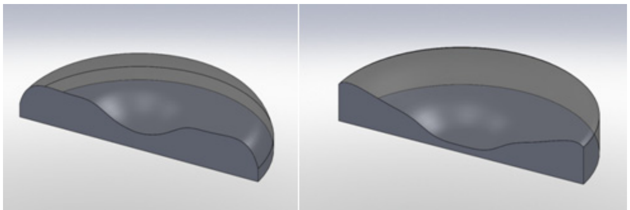

Figure 4: Wind velocity profiles of energy-saving fan and ordinary fan.

"Industrial 4.0" is a widely discussed issue in industry and manufacturer in recent years. It essentially contains cyber-physical system, internet of things, big data and cloud [4]. Thanks to advances in distributed controllers, more and more complicated algorithm and real time function are applied in local controllers. This progress makes a smart factory possible. A cRIO-9074 made by National Instrument handles the controlling of TLS chillers system (show as Figure 5). All real-time controlling and data acquisition programs are deployed in this robotic controller. The iteration of experiment and programming must be continued to reduce any risk of machine shutdown and operate more precisely.

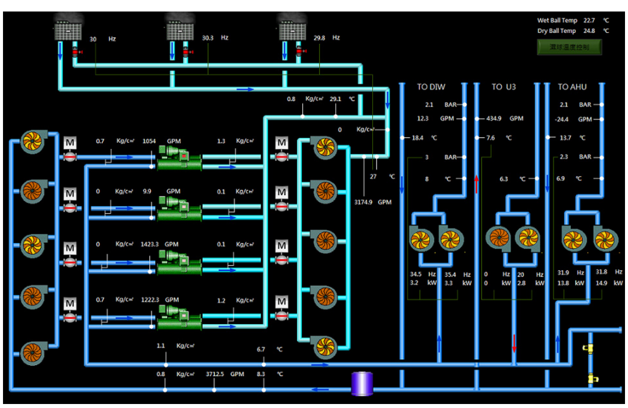


Figure 5: Chiller system of TLS.

## CONCLUSION

In this article, we describe the energy saving processes for utility system in NSRRC. Due to the limited budget, every possible method and theory must be tested and then programmed into local controllers. We have measured the performance of main equipments in a chiller system, such as cooling towers and chillers. An alternative operating process of cooling towers is defined after several measurements. There are two controlling modes for cooling towers, one is wet-ball temperature control, and the other is supply water temperature control. The performances of chillers are measured too. After knowing well the characteristics of equipments, the information will be turn into a program deploying to the controller. Besides, we have installed a set of energy-saving fan which efficiency is about 25% better than ordinary fan. All of the efforts will make a smart and efficient factory possible.

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