

## POWER SAVING STATUS AT NSRRC

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### Abstract

National Synchrotron Radiation Research Center (NSRRC), Taiwan currently operates two synchrotrons, the Taiwan Light Source (TLS) and Taiwan Photon Source (TPS). The former one has been operated for more than 22 years, while the latter is in commissioning phase. We target of the beam current of TPS on 500 mA. Thus, the power consumption increases higher than ever. Currently, the contract power capacities of the Taiwan Light Source (TLS) and the Taiwan Power Company (TPC) with the Taiwan Power Company (TPC) are 5.5MW and 7.5MW, respectively. The ultimate power consumption of the TPS is estimated about 12.5MW. To cope with increasing power requirement, we have conducted several power saving schemes for years. This paper presents our latest power saving schemes, which include installation of solar photovoltaics (PV) and power saving fan for the cooling tower, adjustment of air exchange based on the outdoor air enthalpy, replacement of old air handling unit (AHU), and power factor improvement.

### INTRODUCTION

NSRRC has been conducted several major projects, such as installation of superconducting rf cavities and magnets, construction of extension buildings in the TLS for years. Besides, the TPS project has been in commission process. Those projects have been greatly increasing the electrical power consumption. Currently, the contract power capacities of the TLS and the TPS with the TPC are 5.5MW and 7.5MW, respectively.

As the construction and commission of TPS had been completed, the power consumption has clearly increased since 2014. Fig. 1 shows TPS monthly power consumption from 2014 to 2016.

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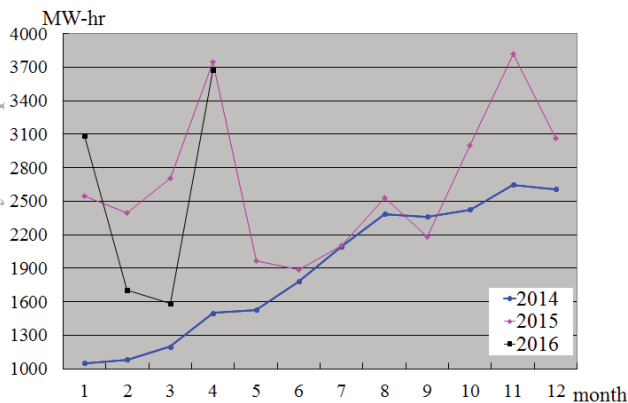


Figure 1: TPS monthly power consumption from 2014 to 2016.

On the other hand, as the price of petroleum fluctuates, the power bill was also affected. During 2008

to 2013, the power bill of per kW-hr was increased about 35%, 40%, and 10% in 2008, June 2012, and Oct. 2013, respectively. It also reduced about 4% in Oct. 2015. Fig. 2 shows monthly average power bill per kW-hr of TLS from 2012 to 2016.

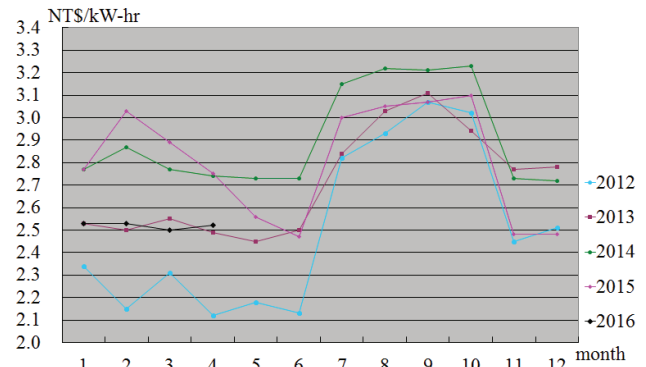


Figure 2: Monthly average power bill per kW-hr in NSRRC from 2012 to 2016.

To cope with fast growth of the power consumption and power bill, NSRRC has been conducting a series of power saving schemes since 2006 [1]. Those power saving schemes include optimization of chiller operation, power consumption control, improvement of temperature and humidity control, electrical power factor improvement, lighting system improvement, and application of heat pumps. We keep conducting those schemes and create some new ones, including installation of solar PV and power saving fan for the cooling tower, modified run-around coil AHU, change of power bill calculation mode, and promotion of power saving. Some major schemes are described as follows.

### INSTALLATION OF SOLAR PV

It is important not only to save energy but also to develop technologies of renewable energy. Solar energy is one of the crucial renewable energy. Theoretically, solar energy has immense potential. It is found that the amount of solar radiation intercepted by earth is more than three orders of magnitude higher than annual global energy use. The annual potential of solar energy was 1,575 to 49,837 exajoules (EJ) [2]. NSRRC had just proposed a three-stage project of the installation of solar PV. This plan had been approved by the board of trustees on March 1<sup>st</sup> 2016.

The areas of three stages are respectively marked in green, blue and red colors in Fig. 3. The areas of the first stage include the Instrumentation Building (Stage IA), the Administration Building (Stage IB), and the Activity

Center (Stage IC). The areas of the second stage include the TLS Building and the Research Building. The area of the third stage is located on the old Guest House. All the solar panels will be installed on the roof of buildings.

We had proposed the procurement of an open bid for the first stage of the project. The measure of area and estimated power generated in areas A, B, and C are listed in Table 1. The budget of the bid is about one million US dollar. The bid is scheduled to be opened in May 2016 and the whole construction and installation will be completed in the end of 2016.

According to the Formula for Calculating Feed-In Tariffs of Renewable Energy Electric Power of the Ministry of Economic Affairs (MOE) in Taiwan, we may contract with TPC to sell our generated power to TPC. We also aim to contract with TPC in the end of 2016.

Table 1: Estimated Generated Power in the First Stage

Area	Square Measure	Estimated Power
A	907 m <sup>2</sup>	119 kWp
B	1,258 m <sup>2</sup>	136 kWp
C	1,987 m <sup>2</sup>	258 kWp
Total	4,152 m <sup>2</sup>	513 kWp



Figure 3: Areas of three stage of the installation of solar PVs.

### REPLACEMENT FOR AGING EQUIPMENT

As TLS operated for over two decades, many equipment of utility system has lost initial performance and consumed higher power than ever. We have replaced those aging equipment with power-saving one. Old chillers, AHUs, pumps and fans have been replaced every year.

For example, we had replaced old 1 AHU by so called run-around coil loop AHUs. The old traditional AHU contains a cooling and a heating finned-tube coils for heat exchange. There are extra pre-cooling and pre-heating finned-tube coils in the run-around coil loop AHU. In our experiments, 33 % chilled water and 63 % hot water were saved, respectively. We have replaced three old AHUs with the run-around typed ones so far. Compared to the

traditional AHU, the run-around typed one saves about 36.5 kW.

We also replaced a set of fans of the cooling tower located on the roof of the 2<sup>nd</sup> Utility Building in 2015. The old one has been operated for 13 years. The blades became rusty and its performance decayed. The old blades are made of aluminum, and the new ones are made of Fiber Reinforced Polymer (FRP). Others specifications are listed in Table 2.

Table 2: Specifications of the Old and New Fans

	Old	New
Blade material	Aluminum	FRP
Number of blades	4	6
Fan diameter (mm)	3,320	3,320
Discharge area (m <sup>2</sup> )	8.96	8.96
Hub area (m <sup>2</sup> )	0.17	0.17

We respectively collected 25 air velocity data on the flow exit area of the old and new fans to evaluate the average flowrate. We also collected the power input of both cases. When the cooling tower was operated by the old fan, it consumed 38.65 kW and its flowrate was 318,497 m<sup>3</sup>/h. On the case by the new one, it consumed 28.66 kW and flowrate was 324,035 m<sup>3</sup>/h. Therefore, the new fan saved 25.85% power and increased 1.7% flowrate.

### ADJUSTMENT OF AIR EXCHANGE BASED ON OUTDOOR AIR ENTHALPY

We modified our conventional control system of AHU R3 by control outdoor air based on the atmosphere enthalpy to save power consumption. Fig. 4 demonstrates the control system of the AHU R3.

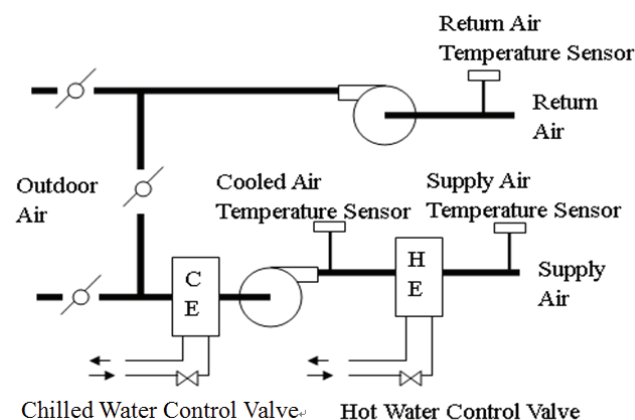


Figure 4: Control system of the AHU R3.

As shown in the figure, return air from the air conditioned area is mixed with outdoor air then flows through a chilled water heat exchanger, which is respectively controlled by a control valve to control the mixed air temperature to 13 °C. As flowing through the chilled water heat exchanger, the relative humidity of the air near saturation. Cooled air then flows through a hot

water heat exchanger to control air temperature to 17-20 °C. The relative humidity of the supplied air is controlled within 50%.

As Taiwan locates in the subtropical zone, outdoor air is usually higher than 20 °C and the relative humidity is higher than 60%. We normally control 10% outdoor air to mix with return air to keep the air fresh. We changed the air exchange last Oct. as the outdoor air temperature was about 13 °C. Fig. 5 shows the chilled water flowrates of 100% and 10% air exchange, respectively. As shown in the figure, the chilled water flowrates of 100% and 10% air exchange was 2.5 and 6 GPM, respectively. The scheme save about 60% chilled water flowrate and 5.3 kW.

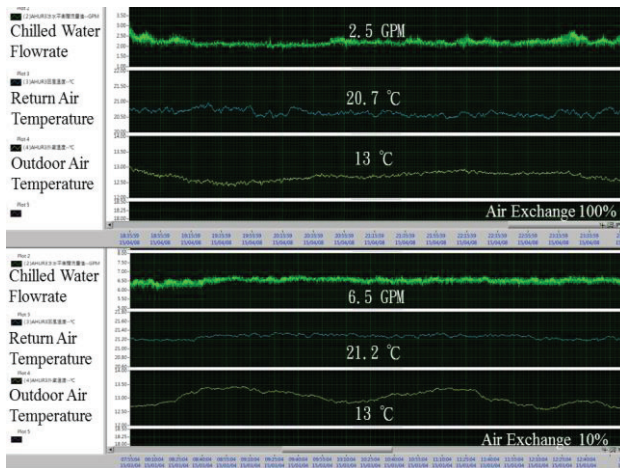


Figure 5: Chilled water flowrates of 100% and 10% air exchange.

### POWER COMSUMPTION CONTROL

Setting “Contract power capacity” is a crucial charge power bill policy of TPC. Contract power capacity is also the index of basic power bill cost. Setting an optimized contract power capacity can not only save power bill, but also provide accurate data for TPC for operation. There are rules of extra charge for power costumers once their power consumption is over the contract capacity. Thus, power customers are suggested to control their power consumption less than the contract power capacity.

Although the electrical power consumption has been largely increased for years at NSRRC, we still keep the contract capacity of TLS on 5.5 MW since 2006. Fig. 6 shows monthly peak power consumption in NSRRC from 2011 to 2016. Because of hot weather and power consumption of TPS construction added, the peak power consumptions of 2011 to 2013 were over contract capacity. Especially in July 2011, the peak power consumption was as high as 6,000 kW. Due to rf system of TPS test, the peak power consumption in Jan 2012 also reached to 6,000 kW. As the construction of TPS is completed, the peak power consumption had been reduced since 2014. All of the monthly peak power consumption were controlled under 5,500 kW in 2015 and

2016. It also demonstrates our effort on the power saving.

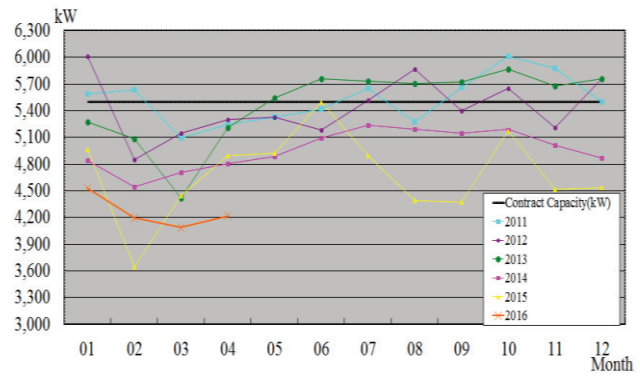


Figure 6: Monthly peak power consumption in NSRRC from 2011 to 2016.

### ELECTRICAL POWER FACTOR IMPROVEMENT

We have kept improving in the electrical power factor since 2004. We applied power factor correction capacitor bank to improve the power factor as well as reduce power losses ( $I^2R$ ).

The yearly average power factor was improved from 95.08% in 2004 to 100.00 in 2010. The TPC rewards power customers with discount of power bill for their efforts on good power factor control. The saved power bill was also increased from NT 1,200,298 dollars in 2004 to NT 2,846,689 dollars in 2015.

### CONCLUSION

The power saving result of those abovementioned power saving schemes is notable. Because of the TPS construction, the growth rates of power consumption of 2010 and 2011 are 3.48% and 7.26%, respectively. After efforts of our power saving works, the growth rates of power consumption of 2012, 2013, 2014 and 2015 dropped to -4.5%, -2.5%, -0.42% and -8.18%, respectively. Moreover, we had launched the solar PV project to create renewable energy. We aim to complete the first stage of this project in the end of 2016.

### ACKNOWLEDGEMENT

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