# THE STRATEGY BETWEEN OPTIMAL CONTROL AND ENERGY SAVING ABOUT UTILITY SYSTEM OPERATION

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*Abstract*

Previously, the Taiwan Light Source (TLS) at NSRRC had proven that the good beam line quality depends on the utility system stability. Subsequently, several studies including the temperature control of cooling water and air conditioning were in progress for improving the system stability. Due to the importance of energy saving issue, the heavy power consumption of utility system was also discussed and intended to reduce extensively. The paper addresses some experience between optimal control and energy saving about operation of utility system in TLS. This provides a strategy between stability control and power reduction, including the flow balance, inverter usage, facility operation, control philosophy and so on.

## INTRODUCTION

The TLS had been conducting a series of beam quality studies on utility effects such as the cooling water, air conditioning and electric power [1]. Furthermore, the related thermal paths had mostly been verified and the main effects could be controlled to meet our requirements [2][3]. However, the facility with high power consumption must be evaluated and decreased as the issues of the energy saving and carbon reducing are addressed significantly.

In accelerator facility, most thermal waste of devices is exhausted by using de-ionized water or air conditioning, as shown in Figure 1. All thermal waste is eventually purged into the atmosphere via the cooling tower water. Most high power consumption facility comes from the cooling water and air-conditioning system, including chillers, boilers, pumps, fans, etc. The total utility system consumes near half power of overall accelerator facility. Therefore, the utility system not only is requested to provide stable quality, but also is chosen carefully with a satisfactory energy-efficient ratio (EER) and coefficient of performance (COP).

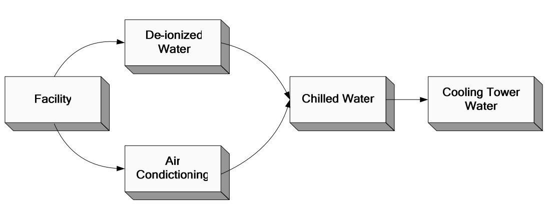


Figure 1 Thermal Propagation of Accelerator Facility

In general, the utility system always has more capacity to meet the variable thermal loading caused by the variations of season, day-and-night or facility addition. Therefore, the effective capacity management is discussed and coordinated. The paper presents a series of strategy and experience to compromise stable control and energy saving optimally.

## FACILITY EFFICIENCY UPGRADE AND OPTIMAL CONTROL

For optimal control and energy saving issue, the efficiency of the facility must be upgraded first. The paper proposes some facility upgrade, including pumps with inverters, chillers, heat pumps and cooling towers.

### *Pumps with Inverters*

Traditionally, the water pumps are always operated with full speed. For loading variations, the facility uses a bypass design to proceed a tuneable and balance mechanism. The alternative is to use state-of-the-art inverters, which apply control logic to decrease the rotor speed so as to diminish the power consumption. According to the pump affinity laws, the volume flow is proportional to pump speed and the total power consumption of the pumps is the pump speed to the cubic power. As the volume flow throughout the subsystem is variable, the inverter is introduced to shift the pump characteristic curve and operation point from 1 to 2, as shown in Figure 2. The pump can provide a stable pressure within ±0.1 kg/cm$^2$ and enough flow for the all subsystem. In addiction, the inverter may start pumps on or turn pumps off with slow rotation to suppressed transient electric current and protect mechanical parts.

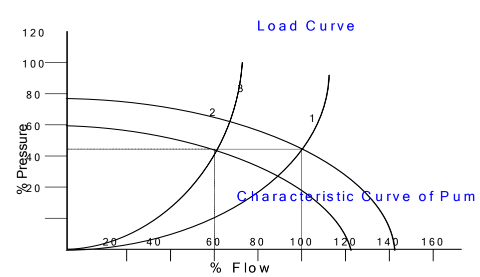


Figure 2 Characteristic Curve of a Pump with an Inverter

Furthermore, using two synchronous inverters with a distributed loading even provide an opportunity to perform pump maintenance or interruption without affecting the accelerator operation. The two synchronous inverters still consume less power than one full speed pump, as shown in Figure 3. Therefore, the inverters can

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give many advantages of on-line redundancy, mechanical maintenance, and energy saving.

However, the electric circuit of the inverter typically generates electric harmonics. The effective isolation transformers and filters must be installed.

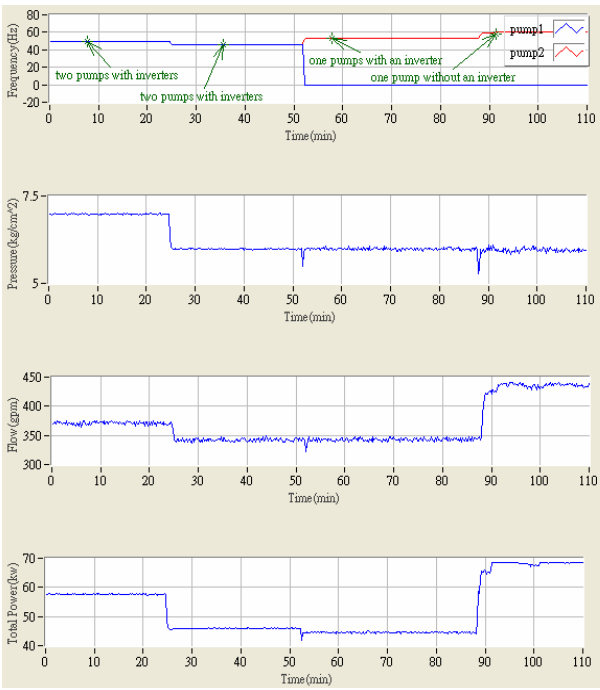


Figure 3 History of the Pump Status

## Chillers

The chillers are the largest power consumption component of utility facility. Because the chillers have many mechanical parts, the efficiency will decrease year after year. The maintenance is very important to keep the efficiency with rated values. In our experience, the chiller with above 10 years commission can be recover more 10~15% efficiency, including the upgrade of shell-tubes, packing, oil, filter, mechanical shaft seal etc.

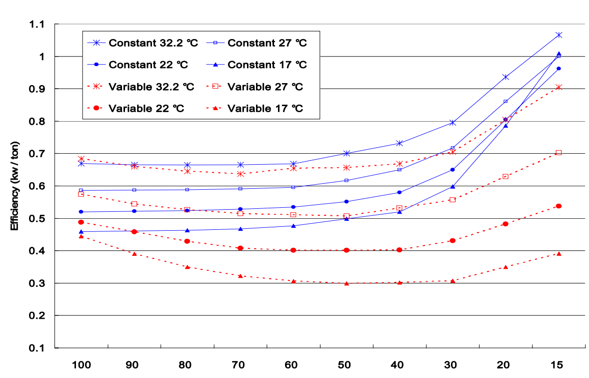


Figure 4 Chiller Efficiency

In the future, the installed chillers with inverters will consume less power, as red lines shown in Figure 4 and permit to operate with the lowest 20% loading. These may match variable loading without any surge and easily achieve stable temperature control without switching-on-off chillers. In addition, the legends with different temperature also show that the cooling tower water with lower temperature increases the chiller efficiency and the power consumption may be decreased significantly.

## Heat Pumps

In order to obtain optimal temperature and humidity control, the hot water is usually provided by boilers. Boilers may be designed to burn coal, wood, fuel oil, nature gas, or to operate with electric resistance heater. However, the cost compared with the efficiency is not economic because of the increasing fuel cost year after year. A heat pump which extracts heat from a source and transfers it to a sink at a higher temperature is presented. In engineering, the heat pump is generally employed for beneficial heating purposes, rather than removing heat for cooling only. Dual-mode heat pumps alternately provide heating or cooling.

As shown in Table 1, the heat pump has good COP. A typical COP for a commercial heat pump is between 3 ~ 4 units transferred per unit of electric energy supplied. The table also shows that the heat pump has optimal cost effect as the units multiplied by fuel cost. However, the compressors of heat pumps often operate only on-off-stage control, which may induce an unstable temperature. A employed buffer tank may minimize the effect.

Table 1 the Comparison of Heating Cost

| type | demand | ÷ | heat value*COP | = | unit | × | price/unit | = | price | % |
|---|---|---|---|---|---|---|---|---|---|---|
| Electric Heater | 12000kcal | | 860*0.9 =774kcal/° | | 15.5° | | 2.6NT$/° | | 40.3 | 100% |
| liquefied Nature Gas | 12000kcal | | 12000*0.75 =9000kcal/kg | | 1.34 kg | | 30NT$/kg | | 40.2 | 99.80% |
| Diesel Oil | 12000kcal | | 8816*0.75 = 6612kcal/liter | | 1.82 liter | | 17NT$/liter | | 31 | 77% |
| Nature Gas | 12000kcal | | 8942*0.75 = 6707kcal/° | | 1.79° | | 14NT$/° | | 25 | 62% |
| Heat Pump | 12000kcal | | 860*3.5 = 3010kcal/° | | 3.98° | | 2.6NT$/° | | 10.3 | 26% |

## Cooling Towers

Cooling towers are heat removal devices used to exhaust heat to the atmosphere, including latent and apparent heat exchanges. They may either use the evaporation of water to remove heat and cool the working fluid to near the wet-bulb air temperature or rely solely on air to cool the working fluid to near the dry-bulb air temperature. The former is the main mechanism of heat exchange and the wet-bulb temperature affects the total performance significantly. In general, the cooling tower design needs a minimal 3℃ approach temperature which equal to outlet water temperature subtracted wet-bulb temperature. Once the approach temperature is less than 3 ℃, the cooling tower cannot work efficiently. The wet-bulb temperature may be relied on to decide the lowest water temperature for chiller condensers. The fans control based on the water temperature can decrease the fan speed to avoid extra power consumption.

## THE STRATEGY FOR OPERATION

In addiction, the strategy for operation may save energy, including the system piping design, flow balance, temperature setpoint and energy management.

### *Decouple System*

Traditionally, the chilled water has primary and secondary constant flow, which provides a stable temperature control. This system design needs three-way control valves to balance the local flow and maintain the constant total flow. The unavoidable bypass flow result in high operation cost, which must be solved to coordinate secondary huge variable flow with inverters. The system design has the primary constant flow and the secondary variable flow, known as a decoupled system. This adopted design may provide stable temperature control and adequate energy saving. In addiction, the most efficient energy saving design is variable primary flow (VPF), which has the primary variable flow and no secondary pumps. However, the system with larger variation cannot meet the high precision requirement of the temperature and humidity control. The compromised decouple system is better for energy saving and optimal control.

### *Flow Balance*

Flow balance is an important issue among the piping. The precise flow balance can ensure the draindown system fills. Supply pumps with inverters may maintain enough pressure and flow. The local water loop with two-way regulators keeps the exact water flow to avoid flow waste and reduce power consumption of pumps. In addition, the flow balance can manage the energy usage. For examples, the parallel chillers with different performance can be matched by regulation. The chillers with better performance may occupy a larger percentage loading to save energy and have no influence on temperature control.

### *Setpoint and Differential Effect about Temperature*

Temperature setpoint is another important issue for energy saving. In NSRRC, the cooling temperature setpoint of facility is set at 25℃, including air-side and water-side cooing. If the air-side setpoint may be increased 1℃, the 3% power consumption can be saved. In water-side aspect, the direct cooling can be proceeded by cooling tower if the return de-ionized water is above 32℃. In Taiwan, located a tropical zone, the average wet bulb temperature is below 29 ℃. The cooling tower water often keeps water temperature with below 32 ℃, which may cool de-ionized water directly. Therefore, this may decrease chiller loading to save much more energy.

Besides, the system may operate in a condition of larger differential temperature and smaller flow, if the cooled device can tolerant. These can increase temperature approach between cooling and cooled facility to promote heat exchange efficiency and decrease pump power consumption. However, the compromise must be considered carefully to avoid worse temperature control.

### *Energy Management and Control System*

Previously, the control system provided enough status monitor for operation and maintenance. For energy management, the control system must involve energy surveillance and the adopted control logic must be evaluated with an optimal operating condition. The historical status of the thermal loading, power demand and facility performance may be archived, which is relied on to promote overall system operation.

## CONCLUSION

This paper presents the strategy between optimal control and energy saving about utility system, including methods of “facility efficiency upgrade and optimal control” and “strategy for operation”. In facility aspects, the presented inverters and heat pumps, and the promoted chillers and cooling towers may save large energy. In operation aspects, piping design, flow balance and temperature setpoint also provide an energy saving opportunity. Finally, the energy management and control system will continue to be implemented to obtain optimal utility operation.

## ACKNOWLEDGEMENT

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## REFERENCE

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