ANALYSIS OF A REMOTE BUILDING ENERGY AUDITING SYSTEM USING INTERNET

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ABSTRACT

In order to facilitate on-line energy auditing of building energy consumption, a remote control system using internet has been installed. This control system enables diagnostics on the HVAC system so that energy conservation measures can be performed with successful result.

Measured data indicated that the chiller plant runs at 0.71kW/RT or about 18% higher power consumption than average units. Further on-line measurement receives that the chiller always runs with Inlet Guided Vane partially opened, results in unfavorable loading conditions.

1. INTRODUCTION

Following the grand opening of the Kenting Aquarium recently, it has become one of the most popular sight-seeing spots in southern Taiwan. The local weather is typically hot and humid, with ambient temperature of 32°C and relative humidity of 85% to 90% during the summer, imposing very heavy cooling load to the building. The HVAC system includes three units of 500 RT centrifugal chillers and a 400 RT screw chiller for ice-storage during the night. Brine with 25% to 30% ethylene glycol was used as secondary refrigerant for ice making and melting, and coupled with plate heat exchangers to separate the primary and the secondary loop. The secondary loop, or the distributed chilled water system was served by three inverter-driven zone pumps to save energy under partial load conditions. Fig. 1 shows the schematic diagram of the system. A “common pipe” as denoted as point C in the figure enables the system to keep constant flow in the primary loop, when the flow rate changes in the secondary loop due to varying load conditions.

A field survey was conducted during the earlier stage of the project to check the performance of the existing DDC (Direct Digital Control) system at the jobsite. All sensors, including temperatures and flow rates, were carefully calibrated with K-type thermocouples and ultra-sonic flow meters, until temperature deviation was kept within 0.5°C, and chilled water flow rate within 1%.

2. SYSTEM SIMULATION

In order to provide a baseline record for the annual power consumption of the building, analysis has been performed using the DOE 2.1 program. The program calculates hourly cooling load, annual power consumption of the HVAC system, and with economic assessment. The local weather data together with building geometric and material data were inputted, yielding a typical hourly cooling load diagram for four seasons as shown in Fig. 2. During the field survey, it was found that although the aquarium has been designed with ice-storage system, the load-shifting effect is insignificant. The original design was based on a partial-storage concept, but with fairly low ice-storage capacity. More ice-storage capacity would have introduced more initial investment, but could end up with faster payback when power tariff differences between on-peak and off-peak hours are significantly large. In Taiwan, this difference is 7 vs. 1 for three-tiered extreme cases, with an extra 25% discount for ice-storage end-users resulting in tremendous operational cost savings. Local power tariff differs significantly between on-peak and off-peak hours. In two-tiered structure, the difference is 4.5 vs. 1, and 7 vs. 1 when it is three-tiered. This is actually the major driving force to accumulate over 200 ice-storage cases under commercial operation in Taiwan within a decade. The demand charge is reduced also with smaller chiller capacity and power transformers. It has been calculated that the optimal design percentage for ice-storage is around 30% to 40% of total cooling capacity based on current tariff and installation cost in Taiwan.
Fig. 1: The schematic diagram of the air-conditioning system in the aquarium site
Fig. 2: The typical hourly cooling load diagram for four seasons of the aquarium site

Fig. 3: The pie chart of annual energy consumption for the existing system

Fig. 4: The pie chart of annual energy consumption for ice-storage system
The DOE program is again used to simulate for the aquarium with 40% ice-storage capacity and compared with the existing system. Figs. 3 and 4 show pie charts of annual energy consumption for each system. The demand charges and annual operation cost has been assessed after breaking down the on-peak and off-peak hours with different power tariff, resulting in a cost savings of 20.1%. This provides an important concept in improving this system economic performance by enlarging the ice-storage capacity during the next phase of extension project.

3. DESIGNING NEW REMOTE ENERGY AUDITING SYSTEM WITH INTERNET

The existing DDC is a typical proprietary system with closed structure. Operational data was logged in through a BCU (Building Control Unit) then transferred to the control center. The BCU allows data storing for 2 days, and is able to communicate with ethernet. Through PTP (Point-to-Point) dialing, it is accessible remotely with a personal computer or through LAN (Local Area Network). After data was transferred from the BCU, it can then be transformed into historical logging data at the remote control center.

If the computer in the DDC can be upgraded into an FTP server, then the user end can directly ping the data end through TCP/IP protocol to construct a bi-directional data transferring process. However, in normal cases, firewalls were installed in local DDC systems to prevent hacking. Therefore, the remote end cannot get access from outside through LAN to the DDC and data has to be provided unidirectionally from DDC outward. To tackle this problem, an Energy Auditing Center, or EAC, was established in the National Sun Yat-Sen University which served as a buffer allowing bi-directional data transfer. The end-users could then ping the EAC for historical data while leaving the DDC side intact.

Fig. 5 indicated this communication structure. A Linux FTP server has been established at the EAC inside the university to receive data transferred through Ethernet from DDC, which is around 100 km away, automatically on a pre-scheduled period. Then any other remote side, for example, another branch office, can easily get access to the EAC through ISP or LAN to download data and responded accordingly to arrange for a timely maintenance plan if necessary.

![Diagram of communication structure of Energy Auditing Center in NSYSU](image-url)
4. SYSTEM DIAGNOSTICS AND EXPERIMENTAL INVESTIGATION

After the EAC has been established successfully, operational data were transferred automatically and regularly as scheduled. These data include chiller compressor on/off status, inlet guided vane position, power consumption, and supply/return chilled water temperatures. Fig. 6 indicated that on June 20 and 21, or a typical summer condition, three 500 RT centrifugal chillers were operated simultaneously. But all with a low part-load ratio condition since the inlet guided vane was on a low position between 40% and 60%. This is an important symptom showing that, it would have been better to operate two 500 RT chillers, each with 90% output, and the third one idle. The power consumption data validated this point of view, as it showed a value of 0.71 kW/RT. This is about 8% higher than specified.

Suggestion was made to the Aquarium to enlarge ice storage capacity for future extension project. The chillers would then run on a much higher load fraction, preferably 80% to 90% most of the time, yielding a lower power consumption of around 0.65kw/RT. During nighttime off-peak hours, the larger ice storage tanks can now take full advantage of the excessive chiller capacity to generate ice, with a very low operation cost. This in turn, would help chillers which will run on the next day during on-peak hours to compensate for the minimum cooling requirement only since the ice-melting mode can now share a larger portion of the cooling load. Chillers can now operate on a rotary sequence, leaving one as a spare, with all others running with higher load ratio, and thus with better energy efficiency. This redundancy would greatly improve the reliability of the life support system of the aquarium, which depends heavily on strict temperature control anytime.

Another point is about the inverter-driven zone pumps. As shown in Fig. 7, most of the pumps run on very low load conditions also, or around 33 Hz in most cases. Although the merit of using inverter-driven pumps is that they can save energy in lower operating speed, however, the multiple-chiller concept as mentioned above can also apply in here, so that one or two pumps can serve as spare units adding reliability to the system. This will make a better maintenance plan as well, since most pumps now run on higher load conditions and on a rotary sequence with more even service hours among each.

![Fig. 6: The operational data recorded on a typical summer day at the NSYS University through Ethernet – Power consumption of chillers (kW) and IGV % vs. time](image)
This remote energy auditing system revealed much more valuable information than before for system diagnostics and thoughts for strategies to improve system efficiency.

5. CONCLUSIONS

In this research, a remote energy auditing system using internet for data transferring has been developed. This powerful information technology enables two sites, which is around 100 km apart in this case, to share real time on-line operation data, so that system performance diagnostics can proceed instantly. The feedback information or energy conservation strategies can respond through internet allowing a timely improvement of system performances. The whole procedure has been demonstrated successfully in this paper. During second phase of the study, expert system would be developed as a build-in software in the energy auditing center. The response would be more versatile and effective, since the energy conservation strategies could cover a much broader range but not relying on operators’ personal opinions.

ABBREVIATION

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>RT</td>
<td>Refrigeration Ton</td>
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<tr>
<td>DDC</td>
<td>Direct Digital Control</td>
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<td>DOE</td>
<td>Department of Energy</td>
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<td>BCU</td>
<td>Building Control Unit</td>
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<td>PTP</td>
<td>Point-to-Point</td>
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<td>LAN</td>
<td>Local Area Network</td>
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<td>TCP/IP</td>
<td>Transmission Control Protocol/Internet Protocol</td>
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<td>EAC</td>
<td>Energy Auditing Center</td>
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<td>FTP</td>
<td>File Transfer Protocol</td>
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<td>ISP</td>
<td>Internet Service Provider</td>
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<td>Hz</td>
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<td>IGV</td>
<td>Inlet Guided Vane</td>
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REFERENCES