ETM010

Peak Demand Control by using thermal energy storage with CHS Solution for Large office building

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Abstract

The application of thermal energy storage for office buildings does not directly reduce electrical energy consumption of air conditioning system but it is to make the electrical load profile of the building is nearly flat curve, which as a whole has helped reduce the need to increase the supply of electric power. The thermal energy storage system stores the cooling energy in the night time where the electrical demand is low (Off-Peak period) and cooling energy is used during the day time where the electrical demand is high (On-Peak. period).Thus the demand charge cost for building is reduced both for TOD (Time of Day) and TOU (Time of Use) rate. In this study, a solution of CHS (Clathrate Hydrate. Slurry) containing TBAB (Tatra-n-Butyl-Ammonium Bromide) and water is used, the heat capacity in the temperature range 5.5 – 12.2°C equal to 2.17 times of water and the density and viscosity of aqueous solution is nearby equal to water. The cooling storage capacity of this study was 1,009 tons of refrigeration. When the load profiles are given in 3 profiles, each for of 4 months, the control of the operation of discharge cooling storage were also 3 cases as 1) the rate of cooling discharge is constant at 143 RT for 7 hours during 9:00. am - 16:00 pm 2) the rate of cooling discharge is constant 167 RT for 6 hours during 9:00 am - 15:00 pm, and 3) a constant release rate at 200 RT. for 5 hours during 9: 00 am - 14:00 pm., All three cases, the cooling energy of 1,000 RT.h was used. Then the electrical demand of 181, 212 and 254 kW were reduced respectively. Thus the total electricity cost saving was 814316 Bahts /year, and the investment cost was 13 million Bahts. Thus the cooling storage system in this study was not worth investing in. However, this thermal storage concept helps to prolong the new installation of electrical power plant for the country.

***Keywords*:** Air Conditioning System, Thermal Energy Storage, Peak Demand

1. Introduction

It is said that air conditioning occupies approximately 40-60% of all energy consumption in office buildings. From this aspect, improving air conditioning systems has been encouraged for energy conservation. The Clathrate Hydrate Slurry (CHS), a new latent heat storage medium capable of replacing water and ice and its application to latent thermal energy storage technology, and has succeed in the world's first energy-saving thermal energy storage in air conditioning system. *H. Ogoshi* and S.Takao [1] used CHS as a cooling medium with high thermal density in the air-conditioning system and thus reducing the flow rate and pumping energy. One method to control the peak demand of the building is to use the thermal storage which stores the cooling energy during the night time where the electrical demand is low (Off-Peak period) and cooling energy is then used during the day time where the electrical demand is high (On-Peak period). Thus the electrical load profile of the building is nearly flat curve, which as a whole has reduced the need to increase the supply of electrical power for the country.

2. Clathrate Hydrate Slurry[2]

When an aqueous solution of tetra-n-butyl ammonium bromide (TBAB:CAS No.1643-19-2) is cooled, fine hydrate particles of about 40 μm in average size are formed in the solution, producing a turbid fluid containing hydrate particles or CHS (Fig. 1). The CHS restores to its former aqueous solution state when warmed up. The hydrate has long-term stability and shows no change in thermal properties after repeated generation and decomposition of aqueous solution and hydrate. The CHS has its forming temperature in the same range (5-9°C) as that of the chilled water in air conditioning system.

a) No Hydrate Particles b) With Hydrate Particles

Fig.1 Aqueous solution

Due to sensible heat of aqueous solution, the specific energy decreases at a constant rate of 4.07 kJ/kg.K as the temperature decreases, until the hydrate is formed. Once the hydrate starts being formed, as the temperature decreases, the amount of hydrate increases, the latent heat amount increases and thus the specific energy rapidly decreases at a constant rate of 25.26 kJ/kg.K as the temperature decreases as shown in Fig.2 .From the figure, the zero specific energy was set at the temperature of 12 ºC. From the temperature range between 6 to 8 ºC, the equivalent specific heat of the aqueous solution with hydrate particles is 25.26 kJ/kg.K which is approximately 6 times of the specific heat of water which is 4.187 kJ/kg.K

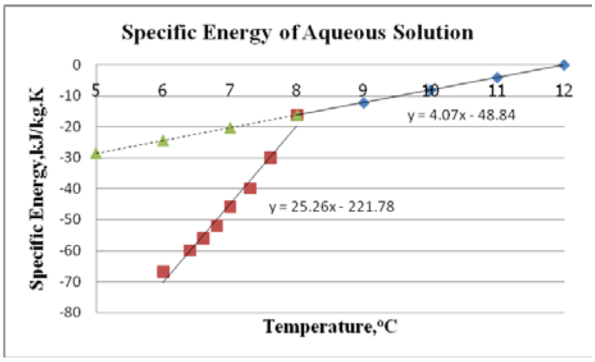

Fig.2 Specific Energy of Aqueous Solution 14%wt

3. Building data

The office building has 20 stories and the air conditioning floor area is 30,675 m^2. The working days excluded holidays are Monday through Friday and the working time is during 6:00 am to 16:00 pm .The chilled water system consists of 3 large chillers and one small chiller with their capacity of 500 RT and 250 RT respectively. The performance of chilled water system excluded air handling units was 1.36 kW/RT .The CHS system consists of chiller with 250 RT, charging and discharging pumps, heat exchanger, and CHS storage tank of 10 units. The size of storage tank was 2.9x4.92x2.62 m^3.The total mass of aqueous solution was 316,890 kg and the cooling stored energy was 1000 RT.h or 12.66 GJ

The electrical charge rates [3]for large commercial building using 12-24 kV for TOU type (time of use) are as follow: for On Peak the electrical demand and energy rates are 132.93 B/kW and 3.6796 B/kWh respectively, and for OFF Peak the electrical demand and energy rates are 0 B/kW and 2.1760 B/kWh. The ON Peak is defined as Monday through Friday between 9:00am-10:00 pm and Off Peak is defined as Monday through Friday between 10:00 pm-9:00 am Saturday ,Sunday and Holidays between 0:00 am-12:00 pm.

The electrical demand load profile for the building is shown in the fig.3

4. CHS operation

The CHS system was charge during the night time for 7 hours from 10 pm to 5 am. by using 250 RT chiller. The water was circulated by the charging pump through chiller and plate heat exchanger in the chilled water loop while the aqueous solution was circulated by solution pump through the plate heat exchanger and CHS storage tanks in the aqueous solution loop. The schematic diagram for charging mode was shown in fig.4.When the aqueous solution temperature

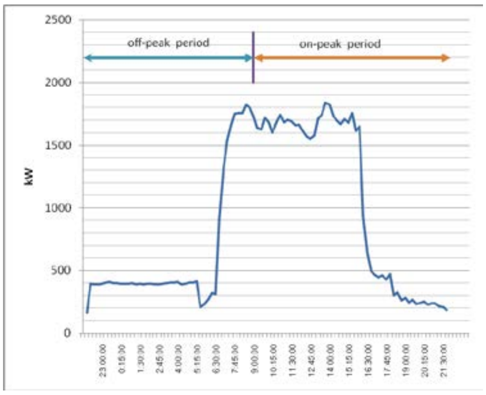

Fig.3 The electrical demand load profile

reached 45 ºF (7.2ºC), the CHS storage tanks were fully charged with cooling capacity was 1000 RTh.

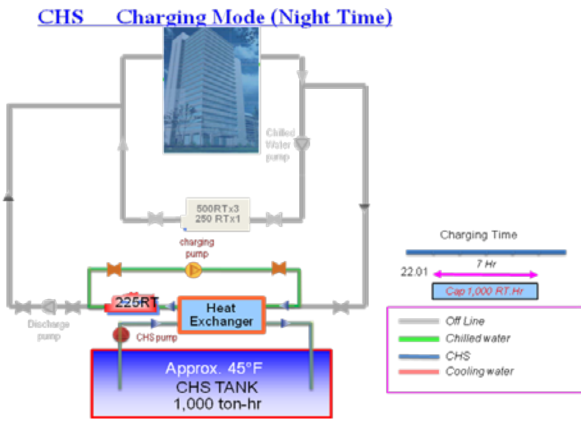

Fig.4 CHS Charging mode operation

The CHS system was discharge during the day time in order to control the peak demand of the building. The aqueous solution was circulated by solution pump through the plate heat exchanger at the temperature of 45 ºF and return to the CHS storage tanks at the temperature of 57 ºF in the aqueous solution loop while the return water from building at temperature of 58ºF was circulated by discharging pump through plate heat exchanger and supply to the building at the temperature of 48 ºF in the chilled water loop as shown in fig.5. The maximum discharge capacity was 250 RT. The chilled water produced by the CHS storage tanks combined with the chilled water produced by the exiting chillers in order to support the building cooling load.

The stored energy of the aqueous solution in the storage tanks could be calculated from equation (1) and equation (2)

For $8^oC \le T < 14^oC$

$$Q = mC_p(T - T_0) = 4.07m(T - 14) \qquad (1)$$

For $6^oC \le T < 8^oC$

$$Q = 4.07m(8 - 14) + 25.26m(T - 8) \qquad (2)$$

Where

m – mass of aqueous solution, kg

T- temperature of aqueous solution, °C

C_P-specific heat, kJ/kg.K

Q-stored energy, kJ

The charging and discharging energy varied with the time of day was shown in fig.6

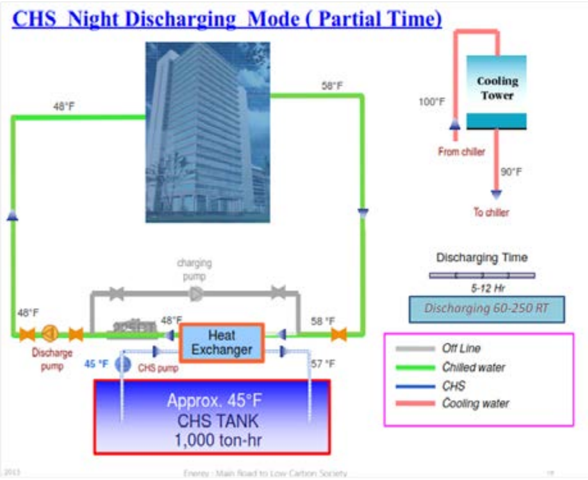

Fig.5 CHS discharge mode

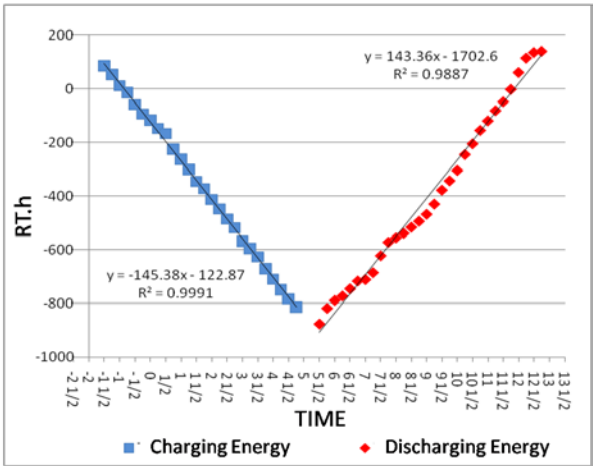

Fig.6 Charging and Discharging energy plot against time

5. Peak demand control

5.1 Existing peak demand control

The cooling stored energy was 1000 RTh and the maximum discharging capacity was 200 RT, thus the maximum operating time was 5 hours. If the electrical power demand of the building occurred during 5 hours period, then the cooling load could be reduced 200 RT corresponding to decrease in electrical power demand of 254 kW since the efficiency of the chiller plant with CHS discharging system was 1.27 kW/TR when secondary pump was not included. But for charging system, the efficiency was 1.29 kW/TR when the solution pump was included.

The existing of the building operation with manual control was shown in fig.7. From the figure, the CHS system was started from 6 to 13 hours with a constant rate of 143 TR (electrical power 181 kW). Unfortunately after there was no energy left in the storage tanks, another peak demand occurred at 13.30 hours. Thus, the actual peak demand was reduced only 105 kW instead of 181 kW. However, there was a electrical cost saving of 53,184 Baht in chilled water operation in March, 2014. The cost saving due to the demand charge and energy charge was 13,958 and 39,226 Baht respectively.

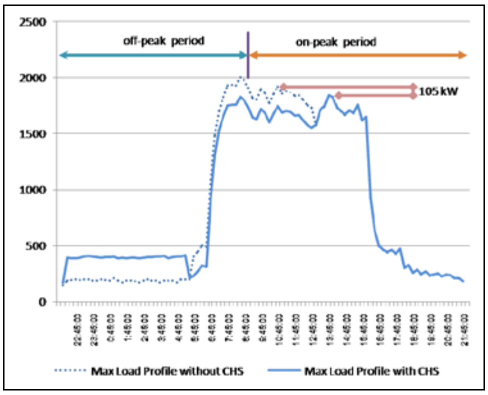

Fig.7 Building power load profile with CHS system

5.2 Future peak demand control

The cooling energy of the storage tanks was 1000 RTh that could be discharged during the day time. The simple way to control the peak demand by manual operation was to start the CHS system with constant discharge cooling rate at the same time of ON Peak at 9.00 hours and matched with building power load profile. From the study of building power load profile the operation of CHS system were classified in to three patterns. Each pattern covered 4 months .Pattern 1, Pattern 2, and Pattern 3 were operated at constant rate of 200 RT(254kW) for 5 hours, 167 RT (212kW) for 6 hours, and 143 RT(181 kW) for 7 hours respectively. The Electrical saving cost was shown in table 1. From table, the Off Peak energy consumption for charging mode was larger than the On Peak energy consumption for discharging mode due to lower chilled water temperature at charging mode and additional solution pump. The total saving was 764,960 B/yr.

Table 1. Electrical saving cost

List	CHS Operating Time		
	7 hours	6 hours	5 hours
Electrical Demand Reduction,kW	181	212	254
Demand Saving,B/mo	24117	28137	33764
On Peak energy,kWh	26670	26670	26670
Off Peak Energy,kWh	27090	27090	27090
Energy Saving,B/mo	39187	39187	39187
Total Saving,B/yr	814316		

5.3 Financial analysis

The demonstration project using CHS system for this study had the investment cost of 13 MB. The saving cost, and maintenance cost were, 814,316 B/yr , and 49,859 B/yr . If the discount rate, inflation rate and project life were 7%, 2%, and 15 years respectively, the net present value (NPV), interest rate of return (IRR) and payback period (PB) were -5.01 MB, 0.44 %, >20 years. Thus, this project is not worth investing in for financial point of view at present time.

6. Conclusion

The aqueous solution of TBAB with 14%by weight was used as the latent heat storage medium with the capacity of 1000 RTh. The CHS system was charged during the night time where the electrical demand is low (Off peak period) and discharged during the daytime where the electrical demand is high (ON peak period) which as a whole has helped reduce the need to install the new electrical power supply of the country. The three patterns of control for discharging of a constant cooling energy were assigned to match with the power load profile of the building. This manual operating control reduced the electrical peak demand of maximum of 254 kw and electrical cost of 814,316 B/yr. The financial analysis showed that the use of CHS thermal storage was not worth investing in. However this thermal storage concept helps to prolong the new installation of electrical power plant for the country.

7. References

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