Single Well System for Supply and Return Water used in BHDG Office Building

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Keywords

Single well system (SWS), cooling/heating source, shallow geothermal, triple-supply (heating, cooling and domestic hot water)

ABSTRACT

Beijing Haidian District Government (BHDG) office building has a total space heating area of 4,5661m^2. The single well system (SWS) of supply and return water is installed for the building to provide heating, cooling and domestic hot water (triple-supply) by collecting the shallow ground geothermal energy [Xu & Rubach, 2003]. The heating system has a Coefficient of Performance of COP = 2.81, and a renewable energy resource use ratio of η = 64.40%. During the heating seasons, there is no C_2O, SO_2 and NO_x, and particles emitted into the air by this systems. SWS technology has been widely spread in China. Up to April, 2006, there are 272 projects, 3.26×10^6 m^2 of floor space in China utilizing SWS technology to provide the triple-supply for all kinds of buildings including schools, factories, shopping centers, hospitals, office buildings, hotels, resident houses, swimming pools etc.

Figure 1. Beijing Haidian District Government Office Building.

Introduction

BHDG office building located at Wanliu Zone of Beijing northwest, has 13 floors (floor height 3.3m) of construction area 45,661 m^2 above ground and three floors of construction area 12,832 m^2 under ground, a total space heating area of 58,493 m^2. Since 2003, the SWS of supply and return water technology has been used for the building to provide the space heating & cooling as well as domestic hot water. This is done by collecting the shallow ground geothermal energy for the all office rooms, keeping the room temperature at about 27°C during the summer season, about 20°C during the winter season and the hot water temperature about 50°C all year.

During the heating and cooling seasons, there is no C_2O, SO_2 and NO_x, and particles emitted into the air by the systems.

Installation Description

BHDG office building has a total heating and cooling area of 58,493 m^2 with a heating design load: Q_R = 6477 kW, a cooling design load: Q_l = 4845 kW, and a domestic hot water requirement capacity of 12 t/h. Figure 2 shows the system mechanical room.

Figure 2. Building Mechanical Room.

There are eight sets of triple-supply hot pump unit: HT760 and one set of the unit: HT380 installed in the building mechanical room. The shallow ground geothermal energy are collected by nine single wells with the depth of 82 to 86 m, with a space of 10 m between the wells. The terminal systems have fresh air units under ground and both fan-coil units and fresh air units above ground.

The System Performance

Coefficient of Performance in the System

We calculated the coefficient of performance (COP) in the heating system by following method:

① System supply heat capacity per hour:

We have 126 days in every heating season. The temperature difference between the supply water and return water in the terminal unit is, on the average of 126 days, $\Delta t = 2.28°C$. Water flow capacity in the system is, on the average of 126 days, G = 790 m^3/h. Water density in the system at ≤45°C is $\rho = 990.25$ kg/m^3, water specific heat c= 4.1868 kJ/kg.°C=1.163×10^{-3} kWh/kg.°C. System supply heat capacity on average per hour:

$$Q_{pj} = c\times\rho\times G\times\Delta t \quad (1)$$
$$=1.163\times\times10^{-3}\times990.25\times790\times2.28=2074.4 \text{ kWh/h}$$

② System supplying heat capacity in (d=) 126 days

$$Q_r = d\times h\times Q_{pj} \quad (2)$$
$$=126\times24\times2074.4=627.30\times10^4 \text{ kWh}$$

③ Domestic hot water capacity in 126 days:

The hot water supply amount on average in 126 days is (G =) 38.9 ton/day. The temperature of hot water is 45°C and the tap water temperature is 8°C. The heat energy amount used per ton water:

$$Q_{s1} = c\times ton\times\Delta t$$
$$=1.163\times10^{-3}\times1000\times(45-8)= 43.03 \text{ kWh/ton}$$

The total heat energy supply quantity in 126 days:

$$Q_s = Q_{s1}\times d\times G$$
$$= 43.03\times126\times38.90 = 21.09\times10^4 \text{ kWh} \quad (3)$$

④ Total heating capacity in126 days:

$$Q = Q_r + Q_s \quad (4)$$
$$= (627.30+21.09)\times10^4$$
$$= 648.39\times10^4 \text{ kWh}$$

⑤ Total electricity consumed in 126 days:

From Nov.13, 2003 to March 17, 2004 (126 days), the total electricity consumed,

$$N = 231.22\times10^4 \text{ kWh}$$

⑥ Coefficient of Performance in the System:

$$COP = Q/N \quad \textbf{(5)}$$
$$= 648.39/231.22$$
$$= 2.81$$

⑦ Renewable energy resource use ratio:

The Renewable energy resource use ratio in BHDG office building in a heating season (for heating, fresh air, hot water) is:

$$\eta =(1-1/COP)\times100\% = 64.40\% \quad (6)$$

Energy Consumed Calculation

In the heating season of total 126 days (including weekends and holidays of 42 days); the total electricity consumed, $N = 231.22\times10^4$ kWh, including space heating, fresh air and domestic hot water supply.

① The electricity consumed for domestic hot water:

The heat energy amount used per ton water (see above ③):

$$Q_{s1} = 1.163\times10^{-3}\times1000\times(45-8)$$
$$= 43.03 \text{ kWh/ton} \quad (7)$$

The electricity energy used per ton water:

$$N^{`}_{s1} = Q_{s1}\div COP = 43.03/2.81$$
$$= 15.31 \text{ kWh /ton (COP = 2.81)} \quad (8)$$

The total heat energy supply quantity in 126 days (G = 38.9 t/d):

$$Q_s= Q_{s1}\times d\times G \quad (9)$$
$$= 43.03\times126\times38.90 = 21.09\times10^4 \text{ kWh}$$

The total electricity energy consumed for hot water supply in 126 days:

$$N_w = d\times G\times N^{`}_{s1} \quad (10)$$
$$= 126\times38.90\times15.31=7.50\times10^4 \text{ kWh}$$

② The electricity energy used for fresh air supply:

We have 45 units for fresh air supply in the building, where 31 units for the 13 floors above ground with a fresh air supply capacity of (p_a=) 2,071 kW, working six hours a day in 126 days; where 14 units under ground having a fresh air supply capacity of (p_u=) 1,545 kW, working 24 hours a day in 126 days.

The heat energy consumed for the fresh air supply under ground in 126 days:

$$Q_u = \phi\times p_u\times h\times d \quad (11)$$
$$= 0.726\times1545\times24\times126 = 339.19\times10^4 \text{ kWh}$$

Where the average heating load coefficient ϕ=0.726.

The electricity consumed for fresh air supply under ground:

$$N_u = Q_u/COP \quad (12)$$
$$= 339.19\times10^4/2.81=120.71\times10^4 \text{ kWh}$$

The electricity consumed per m^2 for fresh air supply under ground (A_u=12,832 m^2) in the heating season:

$$N_{su} = N_u /A_u \quad (13)$$
$$=120.71\times10^4 /12832 = 94.07 \text{ kWh/m}^2\cdot\text{season}$$

The heat energy consumed for the fresh air supply above ground in 84 days:

$$Q_a = \phi\times p_a\times h\times d \quad (14)$$
$$= 0.726\times2071\times6\times84 = 75.78\times10^4 \text{ kWh}$$

The electricity consumed for fresh air supply above ground in 84 days:

$$N'_a = Q_a/COP \quad (15)$$
$$= 75.78\times10^4/2.81 = 26.97\times10^4 \text{ kWh}$$

The fresh air load is about 50% of heating supply load above ground, so namely:

$$N'_{ax} = N'_a \times 0.5 = 26.97\times10^4\times0.5 = 13.48\times10^4 \text{ kWh} \quad (16)$$

The practical electricity consumed for fresh air supply above ground in 84 days:

$$N_a = N'_a - N'_{ax} = (26.97-13.48)\times10^4 = 13.49\times10^4 \text{ kWh} \quad (17)$$

The electricity consumed per m^2 for fresh air supply above ground (A_a= 45661 m^2) in the heating season:

$$N_{sa} = N_a / A_a = 13.49\times10^4 / 45661 = 2.95 \text{ kWh/m}^2\cdot\text{season} \quad (18)$$

The total electricity consumed for fresh air supply in the heating season:

$$N_f = N_u + N_a = (120.71+13.49)\times10^4 = 134.2\times10^4 \text{ kWh} \quad (19)$$

③ The total electricity consumed for heating season:

$$N_h = N - N_f - N_w = (231.22-134.19-7.50)\times10^4 = 89.53\times10^4 \text{ kWh} \quad (20)$$

The electricity consumed per m^2 in the heating season:

$$N_q = N_h / A_a = 89.53\times10^4/4566\ 1 = 19.61 \text{ kWh/m}^2\cdot\text{season} \quad (21)$$

Table 1. BHDG Office Building and SWS operation results (US$1.0 = RBM￥8.1 Yuan).

<table>
<tr><td colspan="2" rowspan="3">Project Name BHDG Building</td><td rowspan="2">Construction type/property</td><td colspan="2">Construction area</td><td>Heating area</td><td>Design total load</td><td>Domestic hot water</td><td>Fresh air load</td><td colspan="2">Total electricity consumed</td></tr>
<tr><td colspan="2">(m²)</td><td>(m²)</td><td>(kW)</td><td>(t/day)</td><td>(kW)</td><td colspan="2">(kWh)</td></tr>
<tr><td>Office/ energy saved</td><td colspan="2">58493</td><td>58493</td><td>6477</td><td>38.90</td><td>3616</td><td colspan="2">231.22×10⁴</td></tr>
<tr><td colspan="3">Total electricity consume composing (kWh)</td><td colspan="3">Electricity cost (RMB 10⁴ Yuan)</td><td rowspan="2">Heating electricity consumed (kWh /m²·season)</td><td rowspan="2">Heating cost (Yuan /m²·season)</td><td colspan="3">Peak & vale electricity price (Yuan/kWh)</td></tr>
<tr><td>Heating</td><td>Fresh air</td><td>Hot water</td><td>Heating</td><td>Fresh air</td><td>Hot water</td><td>Par price</td><td>Peak price</td><td>Vale price</td></tr>
<tr><td>92.61 ×10⁴</td><td>131.11 ×10⁴</td><td>7.50×10⁴</td><td>48.44</td><td>68.57</td><td>3.92</td><td>19.61</td><td>10.61</td><td>0.67</td><td>0.67</td><td>0.23</td></tr>
<tr><td colspan="4">Heating season electricity consume (kWh /m²·season)</td><td colspan="3">Heating cost (Yuan/m²·season)</td><td colspan="2">Only equal electricity used for heating area (m²)</td><td colspan="2">SWS installation cost (Yuan/m²)</td></tr>
<tr><td colspan="4">39.53 (US $4.88) (Incl. heating, fresh air, hot water)</td><td colspan="3">20.68 (US $2.53) (Incl. heating, fresh air, hot water)</td><td colspan="2">20800</td><td colspan="2">80 (US $9.88)</td></tr>
</table>

The System Operation Data and Economic Results

The building data and system operation calculation results are shown as following Table 1:

From Table 1, we can obtain the electricity consumed of 39.53 kWh/m^2.season on average in heating season (126 days); the average electricity cost of ￥20.68 (US $2.53)/$m^2$.season, when using both peak and vale electricity.

If only using the equal electricity energy without collecting the shallow ground geothermal energy, we could only provide the heating area of 20,800 m^2 (<58,493 m^2 in our case).

Our single well system has an average installation cost about ￥80Yuan ($10)/$m^2$. The larger construction area can obtain the system installation less cost.

Environment Benefit

Table 2 shows the environment benefit obtained from SWS installation in BHDG Building.

Table 2. Environment benefit obtained from SWS installation in the Building (58493m²).

Project	Function	Electricity consumed 10^4 kWh /season	Standard coal t/season	Smoke 10^4m^3/ season	Particles t/season	SO_2 t/ season	NO_X t/ season	CO_2 t/ season	Renewable energy resource use	Machine room (cooling+ heating) m^2	Design capacity (cooling+ heating) kW	Design capacity/m^2 W/m^2	Cooling tower Water consumed t/season
SWS	Heating, cooling, hot water	231.22	590 (Plant}	0	0	0	0	0	64.4%	480+0	1785+0	30.5	0
Electric boiler	Heating, hot water	662.99	1658 (Plant)	0	0	0	0	0	0	480+450	0+5000	85.5	28180
Coal boiler	Heating, hot water	18.1	2163	2924	93	51	37.4	5498	0	480+ 400*	2050+60	36.1	28180
Oil boiler	Heating, hot water	13.2	1289	1757	0.13	5.9	10.5	4096	0	480+ 280*	2050+45	35.8	28180
Gas boiler	Heating, hot water	13.2	152× 10^4 m^3	1814	0	0	11.1	2807	0	480+ 280*	2050+45	35.8	28180

Notes: * The safety distance which machine room of Coal, Oil, Gas boilers must keep from the building.

From Table 2, we can see that if using SWS technology to provide heating, cooling and domestic hot water, we are able to obtain the excellent environment benefits without any pollution into the air, SWS technology much better than the Coal, Oil, Gas boilers.

Conclusion

Beijing Haidian District Government (BHDG) Office Building is a building of 13 floors of 45,661m^2 above ground and three floors of 12,832m^2 under ground, a total heating and cooling area of 58,493m^2. Since winter season in 2003, the building has used the Single Well System of supply and return water technology to provide winter heating, summer cooling and all year's domestic hot water by collecting the shallow ground geothermal energy.

During the heating season including heating, fresh air and hot water supply, the coefficient of performance is COP = 2.81; the renewable energy resource use ratio is 64.40%. The system is without any C_2O, SO_2, NO_x and particles emitted into the environment. The completed SWS project has been operated perfectly which has been providing a good model role in both Beijing and China. Up to April, 2006, there are 227 projects, 2.95×10^6 m^2 in Beijing zone and 272 projects, 3.26×10^6 m^2 in China utilizing SWS technology to realize the triple supply.

Reference

1. Xu Shengheng and Ladislaus Rybach, Utilization of Shallow Resources of Direct Use. Geothermal Resources Council, 2003 Annual Meeting, p.115-118.