Technology of Heating Accumulating with High Voltage and High Power Furnace Instead of Coal

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Abstract. This paper discussed a kind of heating storage technology with high voltage and high power furnace. This technique used solid heat storage media, which changed electric power of 10 kV voltage level into thermal energy, to supply heat to the residents. In north of China, it could partly solve the pollution problem of traditional heating system. If the electric power was from the wind energy, solar energy or the valley electric power, the value and effect were much greater. This paper discussed the status, problems and efficiency of this technology and gave some practical and significant suggestion.

1. Introduction
The social, economic and environmental problems caused by the traditional coal heating system were becoming more and more seriously in north of China. The coal was consumed largely, the heating cost of the residents could not be ignored and the environment pollution was more obviously. All this questions stimulated many researchers to solve or promote the situations. Today, the supply of electric energy was more and more sufficiently, which may come from wind, solar energy and many other clean sources. So it was a feasible method that using electric energy to replace coal to supply heating to the residents. Now it had been used in some enterprises, companies, residential quarters and some departments. Part of traditional coal-fired boilers were replaced, the pollution was decreased. The article was gonging to discuss this problem, analyze the technology, efficiency and social questions, in order to provide some benefit suggestions and advices.

2. Electric Energy Heating Technology
In China, the heating systems with electric energy could be classified intensive type and distributed type according to their scales. The intensive type included common boiler, heat accumulating boiler and heat pump. The distributed type[1] included electric room heater, electrothermal film and electric heating floor and so on. In this case, the common boiler possessed higher cost because it could not store heating. The heat accumulating boiler has the characteristic of higher equipment investment but lower operating cost because it could use the valley electric energy in those areas of the peak and valley electric prices differently. Now, the technology was of mature technique and steady heating output. When the boiler operated longer time the cost becomes relatively lower. So it was the best choice of the electric heating device. (See Table 1)

| Items                  | Coal heating | Electric heating | Heat accumulating with electric |
|------------------------|--------------|------------------|---------------------------------|
| Heating as (㎡)        | 72           | 95               | 95                              |

Table 1. Comparison among three common heating ways[2]
### 3. Electric Energy Heat Accumulating System

The electric energy heat accumulating system was a new technique invented. It changed electric energy of high voltage and high power into heating with a solid material. It introduced separating water and electric technology, high voltage controlling technology, heat accumulating and preservation technology to transform electric energy from wind energy, solar energy or valley power energy into heat energy and reserve it into some solid media. When it was needed, the stored heating would be changed into hot water, hot wind or steam to be used in residents heating system. In some special cases, the heat energy also could be fed back to the power grid in order to release electric supply stress.

#### 3.1. Structure

The high voltage high power electric energy storage furnace could be used to fulfill functions as the former. Its structure was shown as Fig.1.

![Figure 1. Plane graph of high voltage high power electric energy storage furnace](image)

It included several parts. They were high voltage heating part, high temperature heat storage part, heat interchange part, heat output controller, air blower, heat keeping level, low temperature air circulation way, high temperature air circulation way, high voltage power controller, and so on.

The high voltage heating part[4] could directly transform the 10kV or higher voltage level electric energy into thermal energy without the transformer. The heating materials may be heating silks, heating slices or heating tubes. The high temperature heat storage part was some high density-high specific heat capacity heating accumulating material, which was of keeping temperature, fireproof, insulated. It could endure 800℃ temperature. The heat interchange part changed the heat energy stored by the accumulating material into hot water. The method was that the heat energy was transformed through high temperature air flow in the closed way between the accumulating body and the heat exchanger. The blowers drove the hot air flowing in the closed way. The revolution could be adjusted according to the heat supply demands. The air velocity could be changed by the hot water temperature. The high voltage power controller included time controller that controlled the start of the high voltage power switch and temperature controller that controlled the temperature of the heat accumulating body.

The high voltage high power electric[5] energy storage furnace was kind of new heat resources. It saved valley electric and discard wind energy into some solid heat stored materials. It didn’t need
transformers and could directly work under the 10kV or 66kV voltage level. The input power of one unit could be reach 100 MW and the heat accumulating capacity could be reach 800 MWh. At the same time, the equipment could consume the discard wind energy, supplied the heat 24 hours without interruption in large or great large areas, so it could replace the traditional heating system partly or completely. It not only reduced the consuming of unrenewable energy but also cut down the generation of the waste.

3.2. Principle
The equipment of this paper was working at the valley time of the power grid. It connected the high voltage switches with the auto-control system. When the switch was closed, the high voltage power grid could supply electric to the heat accumulating body continuously, then the electric energy was changed to heat energy here. The temperature of heat accumulating body was raised up by the absorbing of the heating. When the temperature reached a upper limit, the switch was open and at the same time the grid would stop providing electric energy to the body. At last, the heat energy stored in the heat accumulating body would be changed to the other type of heat energy and export through the output controller and heat exchanger. Because the heat transmission between the body and the exchanger was fulfilled by the hot air circle flowing and heat the hot water in the heating system, many technique questions that used the high voltage power grid to supply heating directly were all solved.

4. Efficiency Analysis

4.1. The Cost Analysis
In northern China, the discard wind power was commonly generated in winter while the heating supply period was also at that time. So, the cost of coal heating system and the discard wind power heating system could be compared.

Unit price of coal heating system could be calculated by 860 Kcal times transfer efficiency of electric boiler and price of coal, then divided by low order calorific value of coal and transfer efficiency of coal-fired boiler. The transfer efficiency of electric boiler was generally 95%, the price of coal was 600 Y/ton, the low order calorific value of coal was 5000Kcal/ton. The transfer efficiency of coal-fired boiler was 70%. At last the Unit price of coal heating system was about 0.14 ¥. If the price of the discard wind power was 0.14 ¥ per kWh, the cost of these two types was considerable.

The cost of the electric boiler was related with the unit power consumption and its heat efficiency. The unit power consumption of converting electric to hot water, steam or supply heating were as follow:
Supply heating: 1GJ = 277.8 kWh, hot water: 1Ton hot water of 50℃ = 46.7 kWh, steam: 1ton saturated steam of 170℃ = 760 kWh.

\[
\text{Cost} = \text{Unit power consumption} \times \text{Heat efficiency} \times \text{Power price}
\]

In according to the current residential architecture of energy conservation design standard of Liaoning Province, Rule DB21/T1476-2006, the design heating load index of the architecture of saving 65% energy was 32.8W/㎡. In southern areas of Yingkou and Huludao City, the index was 25.7W/㎡.

The heat consumption of the residential architecture was related with design heating load, supply heating time per day and the supply heating period. It could be calculated by the formula as below.

\[
Q_h = Q_q \times T \times (1 + F) \times Z \times K
\]

Where \(Q_h\), average heating consumption (kW/㎡); \(Q_q\), design heating load index(kW/㎡); \(F\), loss of the pipe networks and equipments, getting 10%; \(T\), supply heating time per day (h); \(Z\), supply heating period (day); \(K\), weighted average heating load correction factor, getting 0.5. (See Table 2)

| Table 2. The heating consumption of some cities in Liaoning Province during the heating period[6] |
|--------------------------------------------------|
| Cities                | Supply Heating consumption \(Q_h\) |


4.2. The Investment Analysis

Equipment investment was calculated by this formula:

\[ C_e = Q_q \times T / T_c \times (1 + F) \times D \quad (¥/m^3) \]

(3)

Where \( T_c \), time of discard wind power supply (h); \( D \), unit price of devices (electric boiler was 850 ¥/kW) (See Table 3)

| Time of wind power supply | Investment of equipments (¥/m³) |
|--------------------------|--------------------------------|
| 7 hours                  | 30W/m³ 40W/m³ 50W/m³ 60W/m³ |
| 15 hours                 | 30W/m³ 40W/m³ 50W/m³ 60W/m³ |

The investment cost was:

\[ C_o = Q_q \times T \times (1 + F) \times Z \times K \times P \quad (¥/m^3) \]

(4)

Where \( P \) is electric price (¥/kWh).

For example, a house in Shenyang city, its heat load index was 40 W/m³, its discard wind power unit price was 0.14 ¥/kWh, the supply heating period was 152 days, so its operation cost was

\[ C_o = Q_q \times T \times (1 + F) \times Z \times K \times P = 0.04 \times 24 \times 1.1 \times 152 \times 0.5 \times 0.14 = 11.24 ¥/m^2 \]

The other costs were depreciation and maintenance of equipment, the pipe maintenance and personal management and so on. In those, the designed life of the electric heating furnace was 20 years. Its heating stored body could have 40% residual value. The pipes maintenance fee between the stove house and resident house was about 1.5 ¥/m² according to the experience. The repair charge of the stove was about 1~2 ¥/m². The personal management fee was salary times number times heating area per month. For example, the people of management were often 3 people when the area smaller than 100,000 m², 6 people when larger than 100,000 m². The average per month was 3500 each person. The personal management fee was 3500 × 3 × 6 / 100000/m² = 0.63 ¥/m².

4.3. Investment Payback Period

The investment payback period could be calculated use this formula:

\[ T_p = \frac{Q_q \times T / T_c \times (1 + F) \times D \times j}{(heatingfee - a - s - g - r - j / 20)} \quad (year) \]

(6)
Where \( j \), depreciation of equipment; \( a \), operational cost; \( s \), maintenance of equipment; \( g \), pipe maintenance; \( r \), personal management fee.

For example, a certain dwelling district in Shenyang city, the heating area was 100,000 m², resident heating fee was 28 ¥/m², heating load index was 40W/m², heat exchange station management people were 3. The investment payback period was

\[
T_p = \frac{0.04 \times 24 / 7 \times 1.1 \times 850 \times 0.6}{(28 - 11.24 - 1.5 - 1 - 0.63 - 3.6)} = 7.7 \text{ (year)}
\]

5. Instance Analysis

This essay take the [9] Longyuan supply heating project with area 200,000 m² in Faku Town using discard wind power as an example. The indexes of this project were as below.

The general heating index of Faku Town was about 72W/m². The designed heating index of saving energy 65% architecture was 32.8W/m² according to the Liaoning province building energy conservation design rules. The index of this project adopted 50W/m² by measuring and calculating.

The total heating load was[10]:

\[
Q_L = Q_q \times Ao \times (1 + F) = 50 \times 200,000 \times (1 + 10\%) = 11MW
\]

Where, \( Ao \), central heating area, getting 200,000 m².

The heat consumption of the whole year of this project was:

\[
Q = Q_q / q \times Q_q \times T \times (1 + F) \times Z \times Ao
\]

\[
= 0.015 / 0.0328 \times 0.05 \times 24 \times (1 + 10\%) \times 161 \times 200000
= 19,437,805 \text{kWh}
\]

According to the meteorological condition of Faku Town, during the supply heating period, the average outdoor temperature was -6.2 ℃, the average outdoor relative humidity was 58%, the temperature difference between indoor and outdoor was 22.2 ℃. So the \( q = 32.8 \text{W/m²} \); \( Q_h = 15 \text{W/m²} \) according to the DB21/T1476-2006 Rules of Liaoning province.

Because the total heating load was 11MW, the heating mode was designed 7 hours accumulating and 24 hours releasing. It adopted 4 high voltage high power electric stored heating furnaces. The total stored heating power was 40MW and the largest stored capacity was 280,000kWh, the output heating power was 12 MW, it could satisfy the supply demand.

The furnaces could be adapted voltage scale was 10kV~66kV. Its output method was hot water of under 85 ℃ temperature with ordinary pressure. Its design power was calculated as follow:

\[
P_e = Q_q \times T / T_c \times (1 + F + F_c) \times Ao = 0.05 \times 24 / 7 \times 1.15 \times 2 \times 10^5 = 37.71MW
\]

Where \( P_e \), power of the furnace(MW); \( T_c \), heat loss of the furnace, getting 5%.

The project could select wind power enterprise or grid company to complete a nearby electric transmission lines to introduce the furnaces. Once the project was fulfilled, it could utilize the discard wind power 20,000MWh, reduce coal consumption 7,000 Tons, decrease the carbon emission 16,000 tons. Its benefits were the sale proceeds of the discard wind power, selling electric proceeds and supply heating proceeds.

Case one. The transmission lines were built or remade by the wind power enterprise and the fee was about ￥5,000,000.

The profit of the wind power enterprise was income of selling electric (20,000MWh*0.5214 ¥/kWh= ￥10,428,000)plus allowance (20,000MWh * (0.45-0.14) = ￥6,200,000), plus additional tax added...
value tax*6%= ¥ 55,900), plus financial cost( ¥ 5,000,000*7%= ¥ 350,000). The value was ¥ 3,822,100 and the payback period was 1.3 years.
The profit of the heating supply enterprise was income of selling heating energy (¥ 32*200,000 m² = ¥ 6,400,000) plus electric purchase fee(20,000MWh * 0.14= ¥ 2,800,000), plus management fee( ¥ 150,000 per year), plus pipes maintenance fee (¥ 300,000), plus equipment maintenance fee( ¥ 200,000), plus depreciation cost( ¥ 960,000 for 20 years). The value was ¥ 1,990,000 and the payback period was 8.5 years.
Case two, The transmission lines were built or remade by the grid company. The profit of the wind power enterprise was ¥ 4,170,000 and the profit of the heating supply enterprise was ¥ 1,990,000. The payback period was not changed.
6. Conclusion
According to the initial economic analysis, when the heating supply enterprise bought the valley electricity, the price was under 0.45 ¥/kWh or the discard wind power was 200MW, the operational indicator of each side was satisfactory.
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