Research on Current Status and Prospects of LNG Cryogenic Energy Utilization

DONG Shier, WANG Jinfeng, YANG Hong
School of Civil Engineering and Architecture, Southwest Petroleum University, Chengdu, 610500
ds_xyz@sina.com

Abstract: The application of liquefied natural gas in our country kept fast growth year by year, while the use of cold energy of LNG has the vital significance to save energy, lower energy consumption and reduce pollutants discharge. Cold energy of LNG not only has feature of the high density but also of extensiveness of temperature distribution. This article unifies lots of domestic and foreign material to start with the purpose and significance of cold energy of LNG summarizes the current usability and features of cold energy of LNG. According to the thermodynamics, this article forwards the concept and computational method of evaluation the cold energy of LNG, summarizes the methods and strategies of comprehensive utilization of cold energy of LNG, and also from four aspects of using precautions of cold energy of LNG including the temperature limits, dosage limits factory location, and security restrictions. Finally, the prospects using of cold energy of LNG in our country were analyzed and predicted.

Keywords: LNG, Cold energy analysis, Energy saving, Comprehensive utilization, Prospect

1 Introduction

Being not sufficient in energy and environmental problems had become increasingly serious cases; the human is trying to explore new energy sources to replace original energy. LNG, as a clean and efficient energy, with its imports of energy consuming countries, will help diversify energy supply, energy security. Thus the trade of LNG is becoming a new hot spot for global energy markets. According to the China Petroleum and Chemical Industry Association figures show that: In 2005, China's exportation of LNG is 483t, while 677,500 tons in 2006, an increase of up to 1,400 times. According to this trend, China will import LNG 42 million tons by 2015. LNG as urban household fuel and industrial chemicals associated with the gasification process, which contains the cold energy has not been fully utilized, lead to cold energy a large number of pass. Under the high energy prices and demand, the premise of cold energy economics of recycling projects can not be ignored. To fully grasp this opportunity, we need to learn the experiences and lessons from abroad, to realize own values, innovate the intellectual property rights of a self-optimize by using LNG cold energy technologies and integrated LNG receiving terminal in a reasonable arrangements for LNG cold energy recovery facilities. Full realization of the LNG cold energy cascade time and the rational use of space, the establishment of LNG cold energy suppliers, and user ,which can develop mutually beneficial and win-win system between them, receive more effective social-economic benefits in reducing the cost of LNG use and develop downstream gas users played a good role. This scale of development can promote the healthy development of the LNG industry to meet the needs of energy-saving society in China to the development goals, thus the analysis of LNG cold energy utilization is of great practical economic and technical significance.

2 Availability Analysis of LNG Cold Energy

2.1 The analysis of LNG cold energy availability
The main component of natural gas is methane, and the critical temperature of 190.58K, at room temperature conditions, pressure alone can not meet its liquefaction process conditions. The temperature of LNG storage in cold gas system is usually 112K, while the pressure is about 0.1Mpa, in the standard
conditions, the density of methane is 1/600 times the volume energy density of gasoline 72%, such conditions are conducive to its storage and transport, because of their superiority in all aspects of human use of the accelerating pace of LNG. LNG per unit mass required under the power consumption is about the energy utility equipment 850kwh / t. In the gasification process of LNG will be a huge release of cold energy, per unit mass of about 830kJ/kg, that 231kw.h / t [6].

In the process of LNG output from the gas storage system, which go through two distinct thermodynamic processes: gasification temperature and pressure (see Figure 1).

According to two different orders before and after, the process of gasification of LNG in the heating process can be divided into two: High-pressure. Gasification temperature (high-pressure gasification process) and low gasification temperature (low pressure gasification process). Suppose first LNG with low pressure pump and then pressurized to a specific gasification process, this process can be called a high-pressure gasification process; but assumed first by gasification of LNG cold can the temperature and then heated to certain value, so doing work on the LNG to gas pressure low after the transmission of natural gas.

Different gasification processes, different power requirements on the pressure (pressure equipment energy consumption) and the gasification conditions have a great degree of cold can release the different effects, so these two factors during the heating process in the gasification need to be measured.

Gasification of LNG delivery pressure is generally 8.0 ~ 9.5Mpa in our country. When the pressure is 9.5Mpa, the relationship between cold energy of LNG and the temperature distribution can be shown in Figure2.

2.2 Cold energy utilization in the World
LNG cold energy can be divided into two major categories of time and space utilization. World LNG cold energy of the main application areas is shown in Table 1.

<table>
<thead>
<tr>
<th>Applications and Products</th>
<th>use</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deep frozen</td>
<td>Low-temperature cold storage</td>
<td>Food preservation and so on</td>
</tr>
<tr>
<td>Air separation</td>
<td>liquid nitrogen</td>
<td>Centralized cooling system, etc</td>
</tr>
<tr>
<td>Liquid CO₂</td>
<td>liquid argon</td>
<td>Welding and so on</td>
</tr>
<tr>
<td></td>
<td>liquid oxygen</td>
<td>Ozone and so on</td>
</tr>
<tr>
<td>Cryogenic grinding</td>
<td>Rubber powder</td>
<td>Industrial production and so on</td>
</tr>
<tr>
<td>Cold energy power generation [2]</td>
<td>Power Generation</td>
<td>As power and lighting and so on</td>
</tr>
</tbody>
</table>

Figure 1 Low power requirements and generation of low-temperature relationship

Figure 2 Distribution of LNG cold energy (P = 9.5MPa, super fluid)
Desalination

Desalinated water

Industrial and civilian

2.3 The reality of the recent cold energy utilization in our country \[6,7\]

During the process of learning experience and technology abroad, we use LNG cold energy in our country mainly in the following ways:

1. Invest large-scale air separation equipment, mainly produce liquid oxygen, argon, nitrogen, while a small amount of liquid nitrogen as the cold medium during liquid carbon dioxide and low temperature for the production of crushed powder and other works. After gasification, the nitrogen can be used as the raw material for the production of ammonia; some oxygen is also used as raw material for large-scale coal gasification plant, through various processes of synthesis, gas can be further re-processed, as IGCC (gas-steam combined cycle power generation) and ammonia based fuel. Cold air separation facilities can, which invested by the CNOOC and established in Fujian, figures that it is the first demonstration of signs of LNG cold energy utilization.

2. In considering the safety of LNG production based on the time and space to do cascade LNG rational use of hot and cold can make the switch after the first LNG station again and the human environment-friendly refrigerant heat transfer, human and environment-friendly refrigerant can be used as synthesis gas purification process and cold storage of the refrigerant.

LNG as the primary energy, from the current use of strategies, whether it is cold energy power generation, air separation unit, the system of carbon dioxide or a freezer, can not blindly say that is better way. Taken in various ways at different temperature levels under the use of cold energy of LNG, and now the main programs are isolated using cold energy of LNG, did not make full use of LNG cold energy.

3 LNG cold energy utilization of the principle \[5\]

LNG cold energy utilization is mainly through the media with the surrounding environment and the temperature difference between the pressure differences, change of state through the LNG refrigerant with the outside world to reach equilibrium, the process of recycling the release of LNG cold energy. During the evaluation process of LNG cold energy, the use of the exergy concept is relatively reasonable, considering the interaction between the external environments, the media can be effectively out of the inspection system, the relationship between energy and the environment make evaluations. The meaning of the so-called inspection system can be understood as the medium in equilibrium with the outside world, the outside world have made a particular system, the largest of its power. Small range of flow system, assume that: (1) changes in flow system are the reversible process; (2) the heat flow CAMOT cycle heat input from the outside world; (3) recycling exhaust heat is to low and stable flow system is Q. The balance system work W is W1 and W2, according to the energy balance equation (1) Find the definition of cold can type:

\[
\Delta A = -W = \Delta H - T_0 \Delta S = \Delta(H - T_0 S)
\]

Where: \( A \)—exergy (kj); \( T_0 \) —outside temperature (k)

The expression is the state parameter entropy \( S \) and enthalpy \( H \) of the function, if the state is known, then that is a defined state parameters, while equation (2) can be said as the cold energy change:

\[
\Delta A = \int_{S_1}^{S_2} dA = \int_{Q_1}^{Q_2} \left(1 - \frac{T_0}{T}\right) dQ
\]

Cold energy of LNG include pressure exergy and temperature exergy, pressure exergy \( A_p \) indicates LNG from the temperature \( T_0 \), the total pressure \( P \) to reach equilibrium with the outside work done, the formula (3), said:

\[
A_p = R T_0 \log \left( \frac{P}{P_0} \right)
\]
where: $A_p$— pressure exergy (kJ); $R$— gas constant; $T_0$— Outside temperature (K); $P_0$— outside Total pressure (Pa).

Temperature exergy of the LNG at a temperature $T$, when the total pressure is $P_0$ change to equilibrium with the outside world, the outside world get the power can be used can be formula (4) that the temperature exergy of LNG:

$$A_t = \int_0^t \frac{(t_0 - t)}{T} \, dt$$

where: $A_t$— Temperature exergy (kJ/kg); $T$— Temperature (K).

Suppose $P_0$ with the vapor pressure changes, temperature changes, the change process can be shown in Figure 3, can be seen from the figure 3, with the pressure $P_0$ of the rise in temperature but decreases, when the pressure $P_0$ is 7.0MPa, the maximum temperature up to 273K system can be obtained from the temperature of LNG is about 290kJ/kg.

LNG as the chemical raw materials and long-distance transmission of gas, require the gas pressure is relatively high (2.0 ~ 10.0MPa), the process temperature exergy is lower, but the pressure exergy is reasonable to use. When the LNG supply power plant near its base, the requirements of its relatively low vapor pressure (0.5 ~ 1.0MPa), during this process the temperature exergy can not be ignored.

4 The Utilization of Cold Energy of LNG

4.1 LNG cold energy utilization methods and strategies

According to temperature, time and space utilization, economic investment, minimal loss of LNG cold energy utilization principle, and user characteristics of cold energy analysis to determine the state at different temperatures, the effective use of technology and investment minimum, at last ,establish the comprehensive utilization of LNG cold energy customers received the best information theory and control of automated heat exchanger network. The rational use of the four temperature zones: deep cold, middle cold, secondary middle cold and simple cold.

4.2 LNG cold energy utilization Notes

4.2.1 Security Restrictions

LNG has flammability, making full use of LNG cold energy should be taken to avoid LNG flammable or oxidizing substances directly to the heat exchange, which may form explosive gas leakage of LNG. People should first consider the refrigerant to meet the above conditions, the system complexity and economic optimization.

For the storage temperature and the purity of LNG, which have to give full consideration to the bearing capacity of gas storage equipment, and resistance to corrosion, etc., so that maximum safety and efficiency.

4.2.2 Temperature selection

Low temperature and low power required for the generation of low-temperature relationship shown in Figure 1 shows the decrease of temperature with the LNG to its acting as the power demand will increase, mechanical efficiency decreased. The temperature, heat and pressure gas storage facilities, etc, must be considered, the consumption of plant construction costs will be higher. In conclusion, LNG cold energy utilization process generally chooses to temperatures of around -160 °C better.

4.2.3 Limit of the amount
City gas and LNG plant on the demand for different periods, in order to make better use of LNG cold energy, we need to found LNG control system, which can easily suit the change of load. In summary, in order to meet the rational utilization of LNG cold energy comprehensive survey of gas supply and demand must be done.

4.2.4 Plant Location

In the process of LNG transportation (low temperature LNG, carbon steel occurs at low temperatures, the cold brittle and cracked, so the network can not use carbon steel materials, must be aluminum or 9% nickel steel for transport tubes), the pressure loss and etc, such factors as pipeline transport LNG from as short as possible, but the LNG cold energy utilization facility for their products to better circulation and to facilitate the purchase of raw materials, factory where more conveniently located as possible. Therefore, in the use process of LNG must fully consider the distance from the cold-energy-use factory to the LNG receiving station.

5 Outlooks

As the world economic crisis subsided, the global economy in general to pick up, energy supply and demand situation again facing enormous challenges in this context, LNG with its superior features, LNG cold energy will inevitably become the rational utilization of research. Which utilization in china must be based on the actual situation in China, which leaves people lots of thinking.

(1) Adjustment of thinking. First of all, mankind should realize the energy crisis, as gas workers should have a high sense of responsibility and mission, sense of commitment to better technology with optimal use of energy.

(2) Real challenges. In recent years, the domestic natural gas is still the single; city gas supply system is imperfect. LNG use in some extent, protect public safety. LNG properties for its own requirements for high gas system, underground gas storage wells to rational use of its space, although the technology is not mature enough now but the future is bound to be a good choice.

(3) The new process requirements. On the rational utilization of LNG cold energy in the transport process because of its temperature, pressure, corrosion, etc, which are to be taken into account. In this context, is bound to be more applicable to new materials and technology challenges.

(4) Information construction. Although remote sensing satellites is successfully use in service operation and management of the pipeline, but it is still not very well and have to meet the future oil pipeline construction and development, thus supporting the use of LNG cold energy facilities, information technology has long way to go.

References

[5]. Huang Jianmin, and so on. The comprehensive utilization of LNG cold energy research [J]. Shanghai Electric Institute, 2008,11 (2) :87-91(In Chinese)