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Discussion on LNG Cold Energy Utilization Methods

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ABSTRACT

Natural gas is known as a clean energy source due to its environmental benefits and economic viability, widely used in both industrial and residential sectors. Liquefied natural gas (LNG) is characterized by its small volume and low-cost transportation over long distances (by ship), with about 25% of international trade conducted using LNG. In recent years, China's LNG supply has been steadily increasing, and it is expected that by 2040, China's demand for LNG will exceed 15% of the global total. LNG is a low-temperature (−162°C) liquid mixture formed by purifying natural gas to remove acids and water, followed by low-temperature condensation. LNG receiving stations typically use seawater heating to vaporize LNG into gaseous natural gas for export, with the large amount of cold energy released during vaporization absorbed by seawater and discharged into the ocean, approximately 830 kWh/kg. Based on China's receiving capacity in 2018, the cold energy from LNG was equivalent to 2.07 billion kWh, and it is projected to reach 5.98 billion kWh by 2023, indicating a rich resource of cold energy. As China imports significant amounts of LNG, the comprehensive utilization of LNG cold energy becomes increasingly important.

KEYWORDS

LNG; Cold Energy Utilization; Pipeline Transportation and Regulation; Multi-Network Integration.

1. INTRODUCTION

The utilization of cold energy from liquefied natural gas (LNG) primarily relies on the temperature and pressure differences between LNG and its surrounding environment (such as air and seawater). LNG is stored under high pressure and low temperature, containing a significant amount of energy. When LNG is converted to natural gas at normal pressure and temperature, this energy can be recovered. During the vaporization process, LNG can release up to approximately 860 MJ/t of cold energy, highlighting its substantial energy potential.

Effectively recovering and utilizing LNG cold energy can significantly improve the energy efficiency of receiving stations and enhance economic benefits. Specifically, by installing specialized cold energy recovery equipment at receiving stations, the cold energy released during vaporization can be converted into other forms of energy. For example, this cold energy can be used to cool industrial equipment, provide refrigeration services, or generate electricity, achieving multiple uses. This efficient resource utilization can help reduce overall energy consumption and greenhouse gas emissions, aligning with sustainable development goals.

Moreover, the utilization of LNG cold energy can optimize regional energy structures. In the context of increasing energy consumption, effectively utilizing LNG cold energy can alleviate energy shortages and reduce reliance on traditional fossil fuels. For instance, using cold energy for local industrial refrigeration can lower operational costs for businesses, enhance competitiveness, and stimulate local economic development.

At the same time, policy support plays a crucial role in cold energy recovery. Governments can implement incentives to encourage enterprises to invest in cold energy recovery technologies, promote industry standards, and facilitate the research and application of various technologies. With policy guidance, a favorable market environment can be established, making the application of LNG cold energy more widespread.

In summary, the comprehensive utilization of LNG cold energy not only reflects technological advancement but also represents a vital part of energy transition and sustainable development strategies. Through appropriate technological applications and policy support, the future recovery and utilization of LNG cold energy is expected to be widely promoted globally, contributing significantly to the realization of a low-carbon economy and environmental protection.

2. CURRENT DEVELOPMENT STATUS OF COLD ENERGY UTILIZATION TECHNOLOGY

2.1. Cold energy separation technology

The cold energy separation technology of liquefied natural gas (LNG) is an innovative method that utilizes the low-temperature energy released during the gasification of LNG for air separation. The core of this technology lies in the low-temperature characteristics of LNG, allowing for the efficient separation of gases such as oxygen and nitrogen from the cooled air. Specifically, LNG is introduced into the air separation unit, where its temperature of -162°C cools the surrounding air, causing the components of the air to liquefy and enabling the separation of oxygen and nitrogen. Additionally, the environmental benefits of this technology cannot be overlooked, as reduced energy consumption leads to a significant decrease in greenhouse gas emissions, aligning with today's societal demands for sustainable development. The extracted high-purity oxygen and nitrogen are widely used in various fields, including chemical, metallurgical, and medical industries, meeting diverse industrial needs. This technology not only enhances resource efficiency but also promotes the development of clean energy, aligning with the global pursuit of a low-carbon economy and sustainable development. In summary, LNG cold energy separation technology, with its high efficiency and environmental friendliness, is emerging as an important innovative direction in industrial production, offering broad application prospects.

2.2. LNG Long-Distance Low-Temperature Pipeline Cold Energy Cascading Utilization Technology.

Liquefied natural gas (LNG) cold energy power generation is an innovative technology that harnesses the low-temperature cold energy produced during the gasification of LNG to generate electricity. The key to this power generation method lies in utilizing the low-temperature characteristics of LNG, typically at -162°C. Firstly, LNG is introduced into a cold energy power generation system, where its low temperature cools the working fluid. After passing through an expander, the working fluid transforms into gas, driving a generator to produce electricity. Moreover, LNG cold energy power generation is environmentally friendly, as it significantly decreases greenhouse gas emissions compared to conventional fossil fuel power generation, aligning with the principles of sustainable development. LNG cold energy power generation can provide a stable power supply for industries with high electricity demands, and it can also be integrated with renewable energy systems to enhance grid flexibility and stability. As global attention to low-carbon economies and clean energy increases, LNG cold energy power generation technology is gaining traction, and it is expected to find more applications in the future. This technology not only supplies electricity but also effectively utilizes

LNG cold energy, promoting comprehensive resource utilization to achieve a win-win scenario of economic and environmental benefits. In summary, LNG cold energy power generation, as an emerging power generation method, offers important support for global energy transition and sustainable development goals with its efficiency and eco-friendliness, presenting broad application prospects.

2.3. Turbine cold energy utilization

LNG gas turbine cold energy utilization refers to an innovative method that enhances overall energy efficiency and economic benefits by leveraging the low-temperature characteristics of liquefied natural gas (LNG) within gas turbine systems. In traditional gas turbine power generation, natural gas is typically used as fuel, burning at high temperatures to drive the turbine for electricity generation. However, during the gasification of LNG, a significant amount of cold energy is released, with temperatures as low as -162°C. As global focus on low-carbon economies and sustainable development increases, the technology of LNG gas turbine cold energy utilization is gaining attention, particularly in resource-rich areas with high energy demands, showcasing significant market potential. Overall, LNG gas turbine cold energy utilization not only enhances power generation efficiency and reduces environmental impacts but also offers new avenues for diversified energy use, making it an important pathway for promoting clean energy transitions and achieving sustainable development goals.

2.4. Low-temperature pulverization of waste rubber

The utilization of cold energy from liquefied natural gas (LNG) in the low-temperature pulverization of waste rubber is an innovative method aimed at enhancing the efficiency and resource value of waste rubber processing. In the rubber pulverization process, significant energy is typically consumed, but the low-temperature characteristics of LNG offer new possibilities. Additionally, this cold energy utilization helps to reduce heat generated during pulverization, minimizing material degradation and dust production, thus improving product quality and safety. Furthermore, using LNG cold energy reduces the reliance on traditional pulverizing equipment for electricity, lowering production costs. The physical properties of waste rubber also change after low-temperature treatment, enhancing the yield in subsequent processing and improving the quality and performance of regenerated rubber. This circular economy model not only reduces environmental pollution but also promotes efficient resource utilization, aligning with sustainable development principles. As environmental awareness grows and resource reuse technologies advance, the cold energy utilization of LNG in waste rubber pulverization is attracting increasing attention, especially within the rubber industry and waste management sectors, showcasing broad application prospects and market potential. In summary, utilizing LNG cold energy for low-temperature pulverization of waste rubber enhances recovery efficiency and economic benefits while promoting a green transformation in the rubber industry, achieving a win-win for environmental protection and economic development.

2.5. Low-temperature freezing and refrigeration

The utilization of cold energy from LNG low-temperature freezing and refrigeration is an efficient and environmentally friendly energy approach that leverages the extremely low temperatures of liquefied natural gas (down to -162°C) to support cold chain logistics and refrigeration systems. By applying the low-temperature characteristics of LNG in freezing and refrigeration systems, energy efficiency can be significantly improved, reducing the electricity demand of traditional cooling methods while minimizing greenhouse gas emissions. In cold chain logistics, LNG cold energy effectively maintains the safe temperature of food and pharmaceuticals, extending their shelf life and reducing waste. Additionally, utilizing LNG cold energy lowers operating costs for equipment and enhances the reliability and stability of the overall cold chain system. As environmental and energysaving demands continue to rise, the use of LNG low-temperature freezing and refrigeration is gradually becoming an important trend in the cold chain industry, showcasing broad market potential and driving the traditional cold chain sector toward greener and more efficient practices, contributing to effective resource utilization and environmental protection.

2.6. The production of liquid carbon dioxide and dry ice

The utilization of cold energy from the production of liquid carbon dioxide and dry ice using LNG low temperatures is an innovative application of low-temperature energy. First, the low-temperature characteristics of LNG enable the cooling of carbon dioxide to a liquid state, facilitating storage and transport, while simultaneously generating extremely cold dry ice, which finds extensive applications in cold chain logistics, food preservation, and pharmaceutical transportation. The low temperature of dry ice not only extends the shelf life of products but also effectively reduces the environmental impact of traditional refrigerants, aligning with green and sustainable trends. Moreover, the cold energy from LNG can provide additional energy support in the capture and utilization of carbon dioxide, enhancing the overall efficiency and economic viability of the system. With increasing attention to sustainable development and carbon reduction, the cold energy utilization from LNG for producing liquid carbon dioxide and dry ice demonstrates broad market potential, promoting efficient resource use and driving the development of a low-carbon economy, thereby providing strong support for achieving environmental protection goals. This innovative technology opens up new possibilities for cold energy utilization through the combination of LNG and carbon dioxide, marking a new chapter in the coordinated development of energy and the environment.

2.7. Separation of light hydrocarbons

The utilization of cold energy from LNG low-temperature separation of light hydrocarbons is an efficient energy conversion and resource recovery technology that leverages the extremely low temperatures of liquefied natural gas (down to -162°C) for the separation and extraction of light hydrocarbons. This ultra-low temperature effectively facilitates the condensation and separation of light hydrocarbons, especially in the extraction of key chemical raw materials such as ethylene and propylene, significantly improving separation efficiency and reducing energy consumption. Furthermore, the application of low-temperature cold energy effectively reduces greenhouse gas emissions, aligning with the global focus on sustainable development and low-carbon economies. In the light hydrocarbon separation process, the use of LNG low-temperature cold energy technology not only improves the utilization rate of raw materials but also enhances the economic and environmental performance of production processes. With a growing emphasis on efficient resource use and environmental protection, this application of low-temperature cold energy shows promising market potential, driving the petrochemical industry’s green transformation and contributing significantly to sustainable development goals. Through this technological innovation, the combination of LNG and light hydrocarbons offers new ideas and solutions for future energy utilization.

2.8. Wastewater treatment

The utilization of cold energy from LNG low-temperature wastewater treatment is an emerging environmental protection technology designed to improve wastewater treatment efficiency by harnessing the low-temperature energy released during the vaporization and storage of liquefied natural gas. With temperatures as low as -162°C, LNG effectively reduces the temperature of wastewater, thereby inhibiting microbial activity and decreasing the reactivity of harmful substances in the water, creating more favorable conditions for subsequent treatment processes. Additionally, the application of cold energy accelerates the precipitation and removal of certain pollutants in wastewater, enhances the efficiency of solid-liquid separation, and reduces the use of chemical agents, further lessening the environmental burden. As global demand for water resource protection and advanced wastewater treatment technologies continues to grow, LNG low-temperature wastewater treatment demonstrates strong market potential by effectively lowering energy consumption and operational costs while enhancing treatment performance. Through this technological innovation, the low-temperature characteristics of liquefied natural gas provide new solutions for the wastewater treatment industry, promoting green and environmentally friendly practices and contributing to the achievement of sustainable development goals.

3. NEW TECHNOLOGIES AND CONCEPTS FOR COLD ENERGY UTILIZATION

3.1. Integration of Receiving Stations, Satellite Stations, Refueling Stations (Tank Container Points), and Cold Chain Logistics

Considering cold energy resource utilization from the perspective of the entire industry chain, including receiving stations, satellite stations, and refueling stations, is significant. By integrating the rapidly developing cold chain logistics system in the country, the use of cold energy expands from a single receiving station to a collaborative cold energy supply network involving satellite and refueling stations. The receiving station captures the initial cold energy from liquefied natural gas, which is then redistributed through satellite stations and ultimately supplied to end users at refueling stations. This networked supply chain enhances the efficiency of cold energy utilization, reduces energy loss, and meets the low-temperature requirements of cold chain logistics, ensuring the quality and safety of goods during transportation. Additionally, this collaborative model lowers operational costs and increases the overall flexibility and responsiveness of the supply chain, providing strong support for the development of the cold chain logistics industry and promoting the achievement of green and sustainable development goals.

3.2. Skid-mounted Cold Energy Power Generation or Ice Production at Satellite Stations and Refueling Stations

Skid-mounted cold energy utilization facilities offer advantages such as easy mobility and short construction cycles, making them particularly suitable for the small-scale application of cold energy at satellite stations and refueling stations. These facilities can be flexibly deployed and quickly installed or adjusted according to demand, eliminating the need for large-scale infrastructure development and reducing initial investment and time costs. They can rapidly respond to various scenarios, such as temporary events or special needs, providing immediate cold energy supply. Additionally, skid-mounted facilities often feature highly modular designs, making maintenance and upgrades easier, thus enhancing operational efficiency and reliability. By integrating skid-mounted cold energy facilities with satellite and refueling stations, a flexible cold energy supply network can be established, improving cold energy utilization and supporting various cold chain logistics needs, ensuring product quality during transportation and storage. This innovative application promotes the optimized use of cold energy resources and provides crucial support for the sustainable development of the industry.

3.3. LNG Cold Energy Used in Deep Cooling Separation in the Ethylene Industry

The ethylene production process requires a deep cooling separation section that operates at approximately -100°C to ensure high purity and effective separation of the product. In this process, utilizing LNG (liquefied natural gas) cold energy as the cooling source for deep cooling separation, particularly as the refrigerant for the deep cooling section, offers significant economic advantages. By using LNG cold energy, companies can greatly reduce their dependence on traditional refrigeration equipment, thereby lowering investment and maintenance costs. Additionally, the use of LNG cold energy enhances energy efficiency, optimizes production processes, and reduces energy consumption, which is crucial for lowering the production costs of ethylene. With LNG's high cold energy density, the deep cooling separation process can be achieved more effectively, improving both production efficiency and product quality. This innovative approach to cold energy utilization not only promotes the green development of ethylene production but also provides companies with a stronger cost advantage in a competitive market, supporting the sustainable development of the industry.

4. LNG COLD ENERGY UTILIZATION PROJECT PLANNING RECOMMENDATIONS

4.1. Cold Energy Air Separation + Ice and Snow World/Low-Temperature Cold Storage/Dry Ice Production

The cold energy air separation project primarily utilizes the low-temperature cold energy from LNG, where the temperature after cooling by the air separation unit is approximately -100°C, still providing a substantial amount of high-quality cooling capacity. The temperature required for ice and snow production is around -70 to -10°C, while the operational temperature for low-temperature cold storage is maintained at -50 to -65°C, and the temperature demand for dry ice production is -60 to -50°C. Combining the cold energy air separation project with these three utilization methods is an ideal way to make full use of LNG cold energy.

4.2. Cold Energy Power Generation

Cold energy power generation technology is an efficient way to utilize cold energy, characterized by its ability to digest energy on-site with minimal external constraints. This technology can convert approximately 10% to 20% of the cold energy contained in the LNG vaporization process into electrical energy, significantly enhancing the overall resource utilization efficiency. The match between the supply and demand of cold energy and electrical energy is relatively high, making this technology highly promising for practical applications.

Among various cold energy power generation technologies, the single-working-fluid Rankine cycle method exhibits the highest level of technological and economic maturity. This method effectively converts cold energy into electrical energy while maintaining the pressure of LNG, preventing unnecessary losses. Consequently, the single-working-fluid Rankine cycle method is particularly suitable for integration with receiving station projects, enabling more optimized energy management and utilization.

By implementing cold energy power generation technology, we can not only enhance energy efficiency but also reduce environmental impacts, promoting sustainable development. This innovative approach to utilizing cold energy offers new ideas for future energy transformation, contributing to a greener and more efficient energy system.

4.3. Data Center

As an important hub for information resource distribution, data centers are rapidly evolving into a strategically significant emerging industry. However, cooling systems account for a substantial portion of energy consumption in data centers, with approximately 30% to 45% of electricity used to maintain optimal equipment temperatures. To reduce operational costs and enhance energy efficiency, utilizing cold energy from liquefied natural gas (LNG) as a cooling source to replace traditional cooling systems can significantly lower electricity consumption and improve economic benefits.

Data centers have high demands for safety and reliability, making the use of intermediate media as refrigerants for cold energy transfer a highly feasible solution. This approach not only effectively reduces energy consumption but also ensures that equipment operates at optimal temperatures, extending its lifespan. With advancements in technology and rising environmental standards, integrating LNG cold energy into cooling solutions will become a crucial direction for the future development of data centers, contributing to greener and more sustainable operational models.

5. EFFECTS

Considering the remaining utilization of cold energy, the integration of centralized cold storage and dry ice manufacturing with cold energy has resource utilization feasibility, which can enhance resource allocation efficiency and demonstrate technological advancement. The butyl rubber project occupies a small area and meets market demand, promising substantial economic benefits, while the data center solution shows feasibility in utilizing cold energy resources. The technology for cold energy power generation is mature, with low dependence on downstream markets and existing engineering promotion experience, making it a promising project for cold energy utilization.

6. CONCLUSION

The efficient utilization of LNG cold energy still faces significant challenges, and cold energy utilization projects often struggle to achieve profitability. The cold energy resources associated with LNG production are substantial, yet current utilization rates remain low, indicating that cold energy utilization is a potential growth point for benefits. Implementing cold energy utilization in a localized manner and unlocking the value of cold energy resources will help increase the added value of LNG, uncover new development momentum, and create new profit opportunities.

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