Applied Thermal Engineering 29 (2009) 2009–2015

Contents lists available at ScienceDirect

Applied Thermal Engineering

journal homepage: www.elsevier.com/locate/apthermeng

Economic evaluation of natural gas transportation from Iran's South-Pars gas field to market

H. Najibi [a,*], R. Rezaei [a], J. Javanmardi [b], Kh. Nasrifar [b], M. Moshfeghian [c]

[a] Faculty of Petroleum Engineering, Petroleum University of Technology (PUT), P.O. Box 63431, Ahwaz, Iran
[b] Chemical Engineering Department, Shiraz University of Technology, Shiraz, Iran
[c] Chemical and Petroleum Engineering Department, Shiraz University, Shiraz, Iran

ARTICLE INFO

Article history:
Received 28 February 2008
Accepted 19 October 2008
Available online 5 November 2008

Keywords:
Natural gas
Transportation
Economy
PNG
LNG
CNG
NGH

ABSTRACT

The worldwide consumption of natural gas is rapidly increasing. To satisfy such a demand, there are some plans to transport natural gas from South-Pars gas field, the largest natural gas field of Iran, to some energy consuming countries. There are several possible technologies for transporting gas from production fields to consuming markets as gas, including PNG (pipeline natural gas), LNG (liquefied natural gas), CNG (compressed natural gas) and NGH (natural gas hydrate). Gas transmission projects are sensitive to technology selection and depending on the capacity and distance; chosen technology may affect the economy of the entire project noticeably. In this work, transporting 100×10^6 standard m^3/d natural gas from port of Assaluyeh in south of Iran to potential markets using alternative technologies such as PNG, LNG, CNG and NGH has been investigated. To do such a study, required processes for converting natural gas to desired product and then transporting it to market have been designed and using an economical model, cost of transporting natural gas as a function of distance, has been estimated. Results show for the investigated case, PNG has the lowest production cost for distances up to 7600 km and for larger distances, LNG has the lowest production cost.

1. Introduction

Natural gas is one of the important energy resources and recently its worldwide consumption is rapidly increasing because of the growing demand for clean energy and environmental concerns. It is predicted that the natural gas demand increases at an average rate of 2.4 percent annually until 2030 in the world [1]. Fig. 1 shows the trend of worldwide natural gas consumption until 2025 [2]. To satisfy such a demand, there are plans to transport natural gas from South-Pars gas field, the largest natural gas field of Iran to potential markets.

South-Pars is geologically an extension of 10.2×10^{12} standard m^3 North Field of Qatar. It was first identified in 1988 and estimated to contain 3.4×10^{12} standard m^3 of natural gas or even more. Currently, four options for gas transportation to markets are considered. They are: (1) gas transmission by pipelines (PNG), (2) gas to transitory medium by volume reduction such as LNG (liquefied natural gas), CNG (compressed natural gas), and NGH (natural gas hydrates), (3) conversion to other products (GTL) such as Fischer–Tropsch (F–T) synthetic fuels and methanol, (4) conversion to other energy form such as electricity and transmission by cable to market (GTW). However, only the first two ones are known as methods, which transport gas energy as gas.

Nowadays PNG and LNG are the only commercial technologies for transporting natural gas to the market. So far, pipeline flows between countries or continents have largely dominated the international gas trade. At the end of 2006 LNG accounted for 28% of international gas trade (7% of world natural gas demand) [3]. These technologies require huge proved gas reserves and expensive capital investment.

In continuation of our previous works [4–6], in this work transportation of Iran's natural gas from port of Assaluyeh to potential markets using PNG, LNG, CNG and NGH technologies are reviewed and compared from economical point of view. It should be noted that PNG and CNG have been added to our previous studies.

2. Transportation technologies

2.1. Pipelined natural gas (PNG)

Pipeline is the oldest and most common method to transport natural gas. Underground, above ground or sub-sea large diameter pipes are commonly used for natural gas transportation. Worldwide transportation grid (national and international) has expanded from about 725,000 km in 1970 to 1,100,000 km in 2000. However, large-diameter and long distance pipelines imply very high capital

* Corresponding author. Tel./fax: +98 611 5551057.
E-mail addresses: hesamnajibi60@gmail.com, najibi@put.ac.ir (H. Najibi).

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doi:10.1016/j.applthermaleng.2008.10.008

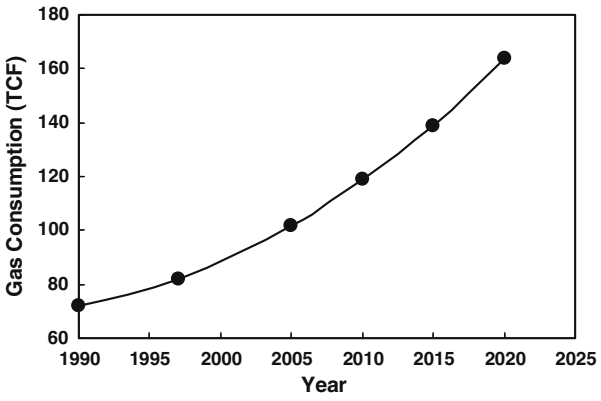

Fig. 1. Worldwide natural gas consumption [2].

investment. This transportation technique requires large and high-value markets and substantial proven reserves to be economically viable. Capital charges typically make up at least 90% of the total cost of gas transmission pipelines. Therefore, in some cases especially for transportation of stranded gases this technology is not viable [7,8].

2.2. Liquefied natural gas (LNG)

Whenever gas transmission pipelines are not economically viable, LNG is often considered as the alternative. Natural gas becomes liquefied in atmospheric pressure and a temperature around 113 K. Converting natural gas to LNG reduces the gas to one six-hundredth of its volume allowing transportation by specialized LNG tanker ships over long distances. The production and storage of LNG is usually conducted in onshore facilities. While LNG carriers can be efficient for shipping large volumes of gas over long distances; high initial expense of the liquefaction plant and associated facilities can make LNG unattractive for developing medium to small sized resource bases, especially where there is a degree of recourse size or political risk [8].

2.3. Compressed natural gas (CNG)

Although offshore transportation of compressed natural gas have been started from long time ago, till now, a number of studies to manufacture a commercial CNG carrier have failed primarily due to the high cost of the required pressure vessels. However, recently, commercial CNG carriers are on the implementation stage [2]. In CNG projects, most of the capital investment is spent on building the ships. Without the complicated and very capital-intensive cooling and re-gasification processes that LNG requires, the loading and unloading terminals would potentially be simpler and less expensive than those used for LNG. Concentrating capital in the mobile ships may be a way to mitigate the project's political or resource risk. Mobile capital also might mean that smaller resources can be exploited by reusing the same ships for many projects [8].

2.4. Natural gas hydrates (NGH)

Natural gas hydrate (NGH) is a viable alternative to LNG or pipeline for transportation of natural gas from source to demand. Hydrate is the product of mixing natural gas with liquid water to form a stable snow-like substance. The natural gas molecules are trapped in the cavities of the ice-like crystalline molecular structure. Preventing hydrate formation and therefore unplugging the gas transmission lines may be the preliminary concern of this phenomenon. However, it has found some new potential applications [4,6,9]. Hydrate may be considered as a media for gas storage, as 1 m^3 of hydrate will contain about 160 standard m^3 gas and 0.85 m^3 water. Large volumes of gas can be stored as hydrate at relatively low pressures and normal temperatures in comparison to high pressures in CNG and very low temperatures required in LNG technology. However, the hydrate technology is not on implementation stage yet and its operational conditions and process are not well established [8]. This technology is especially recommended for transportation of stranded natural gas reserves.

3. Project description

In this work, transporting 100×10^6 standard m^3/d natural gas from port of Assaluyeh in south of Iran to different destinations using mentioned technologies has been investigated. To do such a study, required processes for converting feed gas to desired product and then transporting it to market have been reviewed and using an economical model, cost of transporting natural gas as a function of distance, has been estimated. The feed gas is assumed dry and sweet for all the alternative technologies. Specifications of the feed gas are given in Table 1.

3.1. Pipeline basis

PIPESYS software is used to simulate the transmission process of feed gas in a 56″ pipe (5LX type, grade X70). Iran to India pipeline route with a total length of 2600 km is selected as the basis in this simulation. The results show that the cost of transporting is a linear function of distance; therefore, the cost function is extrapolated to find the costs for larger distances. Fig. 2 shows the Iran to India pipeline route. The pipeline originates from port of Assaluyeh in Iran on the coast of Persian Gulf near the Iranian South-Pars gas field. It travels to Pakistan through Khuzdar and Multan. From Multan, the pipeline travels to New Delhi, where it ends [10]. The required power consumption to transport natural gas from port of Assaluyeh to different destinations through pipeline is given in Table 2 [11].

3.2. LNG basis

The LNG plant designed to produce approximately 24 mtpa of LNG consists of six parallel units. Due to the operational problems, the impurities such as nitrogen and carbon dioxide should be removed from the feed gas before liquefaction. These removal processes include nitrogen removal units, sweetening units and dehydration units. The specifications of LNG production plants are given in Table 3 [11]. In these plants, Mixed Refrigerant Cycle has been used for liquefaction. Other alternatives such as cascade and expander cycles are older technologies. Virtually all base-load LNG plants in the last 20 years have used MRC cycle for liquefaction [5,12]. A schematic diagram for liquefaction unit is shown in Fig. 3. The capacity of each LNG storage tank is assumed to be

Table 1
Feed gas specifications.

Component	Mole %
C_1	87.31
C_2	4.90
C_3	2.03
i-C_4	0.36
n-C_4	0.51
CO_2	1.10
N_2	3.79
T (K)	323.15
P (MPa)	9.0