

Analyze of LNG Generation Investment Cost Under Market Linkage Mechanism

Liyun Lou¹ *, Lixin Tian^{1,2}

¹ Center for Energy Development and Environmental Protection, Jiangsu University, Zhenjiang, Jiangsu 212013, China

² School of Mathematical Sciences, Nanjing Normal University, Nanjing, 210046, China

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Abstract: The paper sets up a model of investing liquefied natural gas(LNG) power generation replacing existing fuel power generation based on real option theory. The model considering three uncertain factors: existing coal-fired power generation cost, carbon price and LNG power generation cost. From the perspective of power generation enterprises, we model and analyze the value of cost of LNG power generation replacing coal-fired power generation. In the simulation part, through the path simulation, we give the natural gas power generation, the original coal and the carbon price under random paths change curve, and give several uncertain factors under a single path path. This study from the perspective of power generation enterprise modeling analysis, the conclusions will help the power generation enterprise value assessment of LNG power generation project, and help them decide whether to invest in the project.

Keywords: LNG power generation; carbon value; real option theory; Black-Scholes model

1 Introduction

Liquefied Natural Gas (LNG) is a newly favorable international energy trade resource at present. Invest LNG power generation carries significant upfront costs and high uncertainty. For China, as the biggest carbon emissions country, with the development and utilization of gas, especially for gas power generation, changing the energy structure is the one of the most important means of reducing carbon emissions. Power generation enterprises need coal-fired thermal power generation. The burning of fossil fuels will produce large amounts of carbon dioxide, which is a big cost. LNG power generation can avoid this cost. We use real option theory to analyze LNG power generation cost, which can considerate the risks during the project.

At present, some scholars and researchers have applied the real option theory to some energy investment projects. R.C. Merton(1976) makes a analysis of the stock volatility based on the real option theory[1]. F.A. Longstaff and E.S. Schwartz(2001) make a simulate analysis of American options by using the least squares approach[2]. Davis G, and Owens B(2003) make a analysis of the optimal level of renewable electric expenditures based on the real option theory[3]. Schwartz ES(2004) analyzes the generation emission permits and enterprise R&D investment with the theory of real option[4]. Matt Thompson, Matt Davison, and Henning Rasmussen(2008) study the optimal storage of gas by applying the real option theory[5]. Ramn Yepes Rodriguez values the free long-term LNG supply based on the real option theory[6]. Hella Engerer, and Manfred Horn (2010) use the real option theory to evaluate the European gas transportation system[7]. Fan Y, and Zhu L(2011) use real option theory to study overseas oil investment and its application in China overseas oil investment[8]. Zhu L, and Fan Y(2011) use real option theory to make a analysis of the costs of CCS technology adopted by Chinese traditional thermal power enterprises[9]. Lai, Guoming; and Wang, Mulan X(2011) use real options to evaluate the downstream terminal liquefied gas (LNG)[10].

This article is divided into four parts. The first part is the introduction and literature review. The second part is the model description. The third part is path simulation. We give the simulation of natural gas price comparison and LNG power generation cost-saving. The fourth part is the conclusion and further work.

*Corresponding author. E-mail address: 490181378@qq.com

2 Model Description

In this paper, we consider four uncertain factors. They are LNG generation deployment cost, LNG power generation cost, existing coal-fired power cost and carbon value. We regard gas power generation project as composite investment options. We model the LNG power generation cost savings by replacing existing thermal power generation.

2.1 Modeling natural gas power generation cash flow uncertainties

2.1.1 The existing coal-fired power costs

The uncertainties of the existing coal-fired power cost are mainly due to the price of fossil fuels. Most previous studies depicted the fossil fuel prices with geometric brown movement, based on real option theory (see to [10]). Assume that the existing coal-fired power cost follows geometric Brownian motion:

$$dP_F = \mu_F P_F(t)dt + \sigma_F P_F(t)dX_F. \quad (1)$$

where dP_F is the geometric brown motion partial differential of P_F ; P_F represents the existing thermal power generation cost in units of yuan/KW h; $P_F(t)$ is a function of existing thermal power generation cost changing over time t , the unit is yuan/kW; dt the change of time; dX_F is a Wiener process; μ_F and σ_F respectively represents the drift and variance parameters of the thermal power generation cost; $\mu_F P_F(t)dt$ is the changing rate of the existing coal-fired power related to time t ; $\sigma_F P_F(t)dt$ is the changing volatility of the existing coal-fired power cost.

2.1.2 Carbon value

Development of gas power generation can reduce greenhouse gases produced by the traditional thermal power. We consider carbon value model here. The article makes the assumption and the reference [10]. We assume that the carbon price follows geometric Brown motion:

$$dP_C = \mu_C P_C(t)dt + \sigma_C P_C(t)dX_C. \quad (2)$$

where dP_C is the geometric brown motion partial differential of P_C ; P_C represents the carbon dioxide prices in units of yuan/KW; $P_C(t)$ is a function of existing thermal power generation cost changing over time t , the unit is yuan/kW; dt the change of time; dX_C is a Wiener process; μ_C and σ_C respectively represents the drift and variance parameters of the carbon value; $\mu_C P_C(t)dt$ is the changing rate of the carbon value related to time t ; $\sigma_C P_C(t)dt$ is the changing volatility of the carbon value.

2.1.3 LNG generation cost and the natural gas market linkage mechanism

LNG gas power generation cost is highly depend on the price of gas in domestic and foreign markets, which we considerate in this paper. According to the Henry Hub gas price points (Figure 2.2.3.1.), it shows that natural gas price will appear a huge skip rise in a very short period of time, on the basis of reasonable floating, and it may jump many orders of magnitude in an instant. Then, the price will quickly return to the original level in a very short period of time. It is resulted from the linkage between natural gas prices and domestic and international markets.

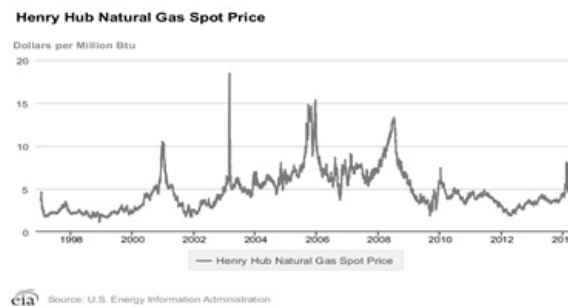


Figure 1: Henry Hub Natural Gas Spot Price 1996-2014: The unit US dollars per million Btu

For LNG power generation equipment, it is appropriate to use geometric Brown motion to describe LNG power generation cost.

$$dP = \mu P(t)dt + \sigma P(t)dX + M + \sum_{k=1}^N \gamma_k(P_t, t, J_k)dq_k. \quad (3)$$

where dP is the geometric brown motion partial differential of P ; P represents the LNG power generation cost in units of yuan/KWh; $P(t)$ is a function of LNG power generation cost changing over time t , the unit is yuan/kWh; dt is the change of time; dX is a Wiener process; M is LNG power generation technology adoption cost; μ and σ respectively represents LNG power generation cost after completing deployment of gas equipment; $\mu P(t)dt$ is the changing rate of LNG power generation cost related to time t ; $\sigma P(t)dt$ is the changing volatility of LNG power generation cost. $\sum_{k=1}^N \gamma_k(P_t, t, J_k)dq_k$ is LNG power generation market linkages; γ_k is the price or the arbitrary function of the time; J_k is subject to the arbitrary distribution of $Q_k(J)$. q_k is the poisson distribution of probability as follows:

$$dq_k = \begin{cases} 0, 1 - \epsilon_k(P, t)dt \\ 1, \epsilon_k(P, t)dt \end{cases} \quad (4)$$

where, $\epsilon_k(P, t)dt$ is a very small probability. Particularly, based on the hypothesis of LNG prices following geometric Brown motion, we add volatility $\sum_{k=1}^N \gamma_k(P_t, t, J_k)dq_k$, which represents LNG international market linkage effect, this effect is something the previous study did not be considered. Figure 2.2.3.1 depicts the variation trends of natural gas prices in 1996-2014. All of the sudden jump depicts the correlation of natural gas price and the market linkage mechanism. When natural gas price rise a sudden leap, volatility indicates the amount of natural gas price jump impact on natural gas power generation cost.

2.1.4 LNG ship transform cost

Here, we consider LNG ship transform cost M . It contains ship size, engine, power, days at sea and some other factors.

2.2 Modeling natural gas power generation cost saving effect

When power generation company has successfully completed the deployment of LNG power generation, the projects cost-savings value is $V_1(P_F, P_C, P, t)$, which depends on the cost saving cash flow. In this paper, the cost of LNG power generation projects saving model representation is as follows: Natural gas power generation projects cost-saving value = original coal-fired power cost + carbon value - natural gas power generation cost - LNG transform cost. Gas power generations symbolic representation is as follows:

$$E(V_1(P_F, P_C, P, t)) = V_1(P_F, t) + V_1(P_C, t) - V_1(P, t) - M. \quad (5)$$

In a given period of time, which is $t, t \leq T$, T is the given period for observing the cost saving effect after the completion of gas power generation deployment. Considering the carbon tax, the expected residual value of the gas power generation cost savings is:

$$\begin{aligned} E(V_1(P_F, P_C, P, t)) &= V_1(P_F, t) + V_1(P_C, t) - V_1(P, t) - M \\ &= q \cdot \int_t^T P_F \cdot e^{-\tilde{\gamma}(T-t)} d\tau + q \cdot a \cdot \int_t^T P_C \cdot e^{-\tilde{\beta}(T-t)} d\tau - \hat{q} \cdot \int_t^T P \cdot e^{-\tilde{\theta}(T-t)} d\tau - M \end{aligned} \quad (6)$$

Among them, a is emission factor, q is the existing coal-fired power generation capacity, q^* is the gas power generation capacity. We assume that a, q, q^* are constant during the observation period. $\tilde{\gamma}, \tilde{\beta}, \tilde{\theta}$ respectively represents the adjusted risk of thermal power, carbon dioxide price, gas power generation cost rates in NPV (net present value) analysis.

3 Model paramete

Table 1 shows the parameter selection of this study, including thermal power costs, carbon value, gas power generation cost parameters and so on. Among them, some parameter values refer to previous studies. Some of the parameters are set by this study according to the references.

All parameters and values in the model are given in Table 1, in which some parameters are obtained by the reference, some parameters are obtained by means of estimation in this paper.

Table 1: Model parameter values

Parameter	Model symbol	Value	Notes
Thermal power generation capacity	q	10^7 kwh	set by this study[11]
LNG gas generating capacity	q^*	$1.6 \cdot 10^6$	Set by this study
The thermal coal-fired power cost	P_F	0.35yuan/kwh	See to [9]
The thermal coal-fired power drift rat	μ_F	0.04/year	See to [9]
The thermal coal-fired power deviation rat	σ_F	9%/year	See to [9]
Natural gas power generation cost	P	0.85 yuan/year	set by this study
LNG power generation	μ	-0.03/year	Set by this study
LNG power generation	σ	13.99%/year	Set by this study
Carbon dioxide price	P_C	0.12yuan/kwh	See to [9]
Carbon dioxide price drift rat	μ_C	0.02year	See to [9]
Carbon dioxide price deviation rat	σ_C	11.5%/year	See to [9]
LNG total investment cost drift rat	β	0.5	See to [9]
Observation tim	T	Year2011-2013	Set by this study
The risk-free rat	r	5%	set by this study
Emission facto	a	778g CO_2 /kwh	IEA
LNG ship transform cost	M	$1.8 \cdot 10^7$ yuan	Set by this study

4 Path simulation

In section 2, we respectively studied the existing coal-fired power costs, carbon value and natural gas power generation cost for the simulation of the random path. In the simulation, this study investigated the existing coal-fired power costs, carbon value selection and natural gas power generation cost of 1000 of path simulated in period 2014 to 2034. Simulation results are shown in figure 2.6.7 and figure2.6.1. Further more, in view of the correlation of natural gas power generation market, this study takes natural gas power generation market linkages for comparison, with the presence of gas power generation cost under the market linkage single path comparison, the result is shown in figure 2.6.8. We explore natural

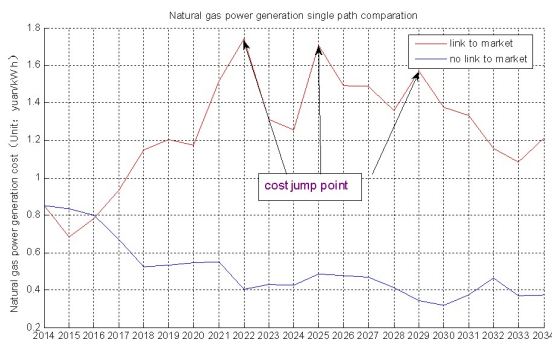


Figure 2: LNG power generation cost comparison simulation(single path)

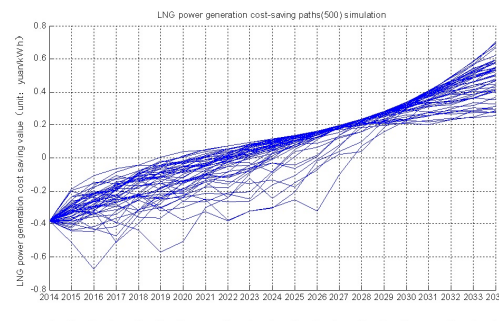


Figure 3: LNG power generation cost-savings simulation

gas power generation cost, especially the cost-savings value which enterprises use natural gas power generation instead of thermal power generation. When the cost-saving value is greater than 0, the investment is wise. Figure 3.2 shows the cost saving value under 50 random paths. We can find that companies which choose natural gas power generation would cost less than zero from 2014 to 2022. After 2022, the cost saving is beyond zero and it begins to produce. In the majority of cases, companies can produce cost savings cash flow from 2019 to 2028. During a 20-year observation period, it is inefficient that the project starts to produce cost-savings value after five years. It is a certain loss for power generation enterprises because there has no profit in this period. But because of the LNG ship transport cost is a huge cost, so before 2019, the negative cost-saving cannot be avoided. It is an investment challenge for power generation company.

5 Conclusions

For power generation companies, they may face a lot of uncertainties when invest LNG power generation. From the perspective of cost, based on multiple influential factors of cost, this paper analyzes the LNG power generation cost under the multiple random path simulations. Based on the power generation enterprise, we use the real option theory to evaluate LNG power generation cost of some power generation enterprises. The model takes many factors into account, such as traditional energy power generation cost, carbon value, LNG power generation cost, uncertainty of natural gas power generation deployment expenditure and cost and so on. Taking power generation enterprises in our country as the research object, this paper expounds LNG power generation cost through using mathematical model, and proposes the influence of different uncertain factors of it.

Since enterprise focuses on commercial profit, we first analyze the LNG power generation cost savings value by comparing with the original coal-fired power. In this article, we first consider the LNG power generation cost and market linkage at home and abroad. The market linkage of gas power generation cost results in instantaneous jump of natural gas power generation cost. Although this jump causes the natural LNG power generation cost to rise sharply, it just happens in a short period of time. In fact, it does not have great influence on the natural gas power generation cost saving value throughout the observation period.

After all, through the assumption of uncertainties, this article uses the real option theory to give the cost model of investing LNG power generation. For enterprise investment in natural gas power generation project, we only focus on the factors affecting the cost of the initial investment from the perspective of cost. Therefore, the model is limited to the analysis of the cost of investment. Due to the limitations of the data, some parameters in the model refer to literature research. And part of the data based on previous research are estimated by the author. In addition, this paper considers that the LNG generation power is constant. However it may change in reality due to the different seasons and markets. Relatively, it is constant in each cycle (here we believe that a cycle is one year). Thirdly, feed-in tariff is also not covered, whose impact on enterprise investment in LNG power generation also cannot be ignored. At present, LNG power generation feed-in tariff and traditional energy power feed-in tariff are priced separately in China. For the new clean energy power generation, the influence of fixed feed-in tariff and unfixed feed-in tariff on enterprise investment will be further studied and discussed.

Acknowledgments

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