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Research Article

Underground coal gasification (UCG): A new trend of supply-side economics of fossil fuels

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Abstract

China has a huge demand for energy. Under the present energy structure of rich coal, lean oil, less gas, limited and low-rising rate renewable energy, discussion focus is now on the high-efficient mining of coal as well as its clean-and-low-carbon use. In view of this, based on an analysis of the problems in the coal chemical industry and the present coal utilization ways such as Integrated Gasification Combined Cycle (IGCC), this paper proposes that underground coal gasification (UCG) technology is a realistic choice. By virtue of its advantages in many aspects such as safety & environment, integrated use of superior resources, economic feasibility, etc. this technology can serve as the front-end support and guarantee for coal chemical industry and IGCC. Under the present situation, the following proposals were presented to promote the development of this technology. First, R&D of technical products should be strengthened, a comprehensive feasibility study assessment system should be established, and the relevant criteria in the industry should be formulated. Second, precise market positioning of UCG products should be made with much concern on the integrated economic indicators of each product's complete flow scheme, following the principle of "Technical Feasibility First, Economic Optimization Followed". Third, a perfect operation and management pattern should be established with strict control over high-efficient, environmentally-friendly, safe, harmonious & compact objectives in the whole industry chain. In conclusion, to realize the large-scale UCG commercial production will strongly promote the optimization and innovation of fossil fuels supply-side economics in China.

Keywords: China; Underground coal gasification (UCG); Supply-side economics; Fossil fuel energy; Coal chemical industry; Integrated gasification combined cycle (IGCC); Energy safety

In 2014, China supplied 19% of the world's energy and consumed 23% of the world's total, with an increase of 8.6% in natural gas consumption and an increase of 3.3% in oil consumption. In the year, China imported 3×10^8 t of crude oil and 583×10^8 m^3 of natural gas, and its dependence on foreign oil and gas were 61% and 30%, respectively. Despite a global economic downturn, China still witnessed a further increase in natural gas consumption in 2015 reaching 1800×10^8 m^3, accounting for 5–6% of the world's total consumption. It is projected that China will surpass Russia as the world's second largest natural gas consumer in mid-2020 and surpass the United States as the world's largest oil consumer by around 2030 [1]. By 2030, China's total natural gas consumption will reach 5800×10^8 m^3, accounting for 10% of the world's total, and its per capita annual natural gas consumption will be 450 m^3, three times that at present, which, though basically at the current world average level, is still less than 20% of the US per capital by present. It has become the public consensus to increase the proportion of natural gas utilization, which can be further confirmed from the actual data of China's recent natural gas consumption, imports and increase rate [2], fuel gas consumption and increase rate [3], as well as national planning and guidance report on natural gas [4].

Despite a huge annual energy demand, China has an extremely low reserve-production ratio of conventional fossil energy sources, except for coal which has sufficient production

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and a high reserve-production ratio. The reserve-production ratio of oil is just 11.9 years and that of natural gas is just 25.7 years, and more seriously, the current rate of new proven oil and gas reserves is significantly below the increase rate of consumption [1]. It is forecast that by 2030, the self-sufficiency rate of clean fossil fuels (hydrocarbon) will be less than 40% in China, showing a serious supply and demand imbalance. Such a huge supply gap of fossil materials cannot be ignored internationally. Historically, what Japan and Europe suffered and what Ukraine is suffering have proven that a too low energy self-sufficiency rate will bring great constraints and a painful experience to the development of a country [5]. If China places too much hope on international supply in fossil fuels, price stability and supply sustainability will not be guaranteed, which will even pose threats to national security. Under the present energy structure of rich coal, lean oil, less gas, limited and low-rising rate renewable energy, discussion focus is now being shifted from the use of coal to the ways to mine and utilize coal in a secure, clean and efficient way. In the current situation, underground coal gasification is a realistic choice catering to current needs.

1. Underground coal gasification and research status

As one of the technologies for coal development, underground coal gasification (UCG) technology is an industrial process which converts coal into product gas through thermal and chemical action of coal for clean development and utilization of coal.

1.1. Industrial process

1.1.1. Research progress at abroad

The concept of underground coal gasification was conceived by Mendeleev in 1888. Since then, a number of countries have done a lot of research work in the field of underground coal gasification. By far, there have been some 33 underground coal gasification projects overseas, mainly in the Soviet Union, the United States, Australia, South Africa, Canada and Europe.

In the 1970s and 1980s in the United States, 38 tests were carried out on several project bases in the then Lawrence Berkeley National Laboratory and several other research institutions, and "regressive underground coal gasification" technology was developed [5]. The United States positioned this technology as a technical reserve for national energy security, which will be used in times of energy crisis. But no further research has been conducted in the optimization of its economic efficiency.

In the Soviet Union, Skochinsky National Institute of Mining developed underground gasification technology, which has been applied in a great number of mines within the Soviet Union and has been proven technically feasible. By far, six underground coal gasification projects have been implemented in the Soviet Union [6]. Among them, Ergo Exergy [7] in Uzbekistan is the world's only underground coal gasification project currently still under operation.

In partnership with the US companies and by reference to its UCG technology, a Canadian company developed εUCG technology [8] through continuous self-development and field experiments. The technology basically represents the mainstream of UCG technology in western countries, and has been applied directly or indirectly in UCG tests in Australia, South Africa, India, China and other countries. The Canadian company declares that it has achieved industrialization of the technology.

Australian underground coal gasification has been based on Canadian technology. By far, Australia has relatively the most complete industrial chain of industrial tests of underground coal gasification. A representative project is Linc's Chinchilla [9] Underground Coal Gasification Liquefaction Project.

South Africa has launched coal liquefaction projects and has some coal chemical industrial basis. However, its underground coal gasification technology is largely introduced directly or indirectly from Canadian εUCG technology. During 2006–2012 in South Africa, relevant industrial tests were carried out in Eskom [9] and other areas and more industrial tests on a much larger scale were planned to be implemented. However, no substantive work has been carried out yet.

Currently, countries ready for underground coal gasification technology research include Britain, Pakistan, Bulgaria, Vietnam and Poland; EU, India and other countries and regions are focusing on the development of this technology. Britain started its first underground gasification test worldwide in 1912. Recently, it approved the 61274×10^4 m^2 coal mining rights for underground gasification research in the North Sea basin. The Central Mining Institute (CMI in Poland) and Linc (in Australia) worked together to undertake the EU HUGE2 underground gasification project, which is a follow-up research of the HUGE, an EU Project of CBM in Deep Part. The Indian government is drafting underground coal gasification policies, and Pakistan is partnering with China University of Mining and Technology in preliminary tests in the desert 360 km north to its capital.

In terms of implementation effect, the Ergo Exergy Project and the Chinchilla Project can best reflect the overall level of the industry. Established in 1961 and with a production capacity of 100×10^4 m^3/d, the shaftless Ergo underground coal gasification station gasifies brown coal into power coal gas for the Exergy thermal power station and blended heavy oil power generation. Demonstrated in 1999, the project had been fully halted by 2013 due to years of disputes and the inability to demonstrate that the project will exert no environmental impact. Technically, this project features negative pressure gasification and direct conversion of gasified coal into synthetic oil. It is the first representative project in the world to enable coal gasification, gas purification, and synthetic oil all in one.

1.1.2. Current research in China

Yu Li [10], Wang Zuotang [11], Liang Jie [12], Yang Lanhe [13], Liu Shuqin [14] from China University of Mining and Technology, and Chai Zhaoxi [15] from the State Administration of Coal Mine Safety, Li Wenjun from North China