Research on Operation and Construction of the Development Model of "Gas Extraction-Gas Power Generation-Sales" in Small Coal Mine

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Abstract: Aiming at the problem that a large number of small coal mines in Yunnan Province are not effectively utilized, with a small coal mine in the region as the background, a variety of methods are used to analyze and study its low-concentration gas power generation project, and it is obtained that the key to the success of a low-concentration gas power generation project in a small coal mine is the integrated technology system of gas source security under the leadership of the concept of "gas management first". On the basis of the gas source guarantee, the low-concentration gas power generation project of this small coal mine has been running efficiently for 4 years, generating economic income of about 4032 million yuan per year, reducing the CO2 of about 44.7 ten thousand tons to improve the level of coal mine safety production, and guarantee the coal mine production standards.

1. Introduction
Concentration gas power generation is to use gas extraction as the gas source (research shows that 55% of the gas concentration in China is lower than 30%) and gas generator is used for power generation and sale or self use[1,2]. This technology can not only use high-efficiency and clean methane energy, but also reduce greenhouse gas emissions (the greenhouse effect of methane is 21 times of CO2); it can also increase economic benefits, promote the investment in gas control, and ensure the safe and efficient production of coal mines[3,4].

At present, gas power generation technology is widely used in medium and large coal mines[5]; small coal mines have a large change range due to small pure gas drainage volume and low concentration (gas concentration is less than 15%), which limits the operation efficiency of generating units and is slow to promote.

Fuyuan County of Yunnan Province is the core coal producing area in eastern Yunnan Province. There are 93 pairs of local coal mines in the county, including 81 pairs of small coal mines, accounting for 87%; 83 pairs of coal mines with surface gas drainage pump station, accounting for 89%; there are only 5 pairs of gas power stations, and only 2 pairs of stable operation, of which 1 pair is a small coal mine.

In view of the small coal mine gas power generation project construction faced with the small amount of pure gas, unstable problems; the author of the small coal mine low concentration gas power generation project as the background, using the methods of field investigation, analysis and induction, theoretical calculation, analyzes and studies the gas supply guarantee technology system, the key technology of low concentration gas power generation project construction, and the application effect of
gas power generation project, with a view to it provides reference for other small coal mines in Fuyuan County to carry out low concentration gas power generation project.

2. Survey of a small coal mine

The production capacity of the coal mine is 21 ten thousand t/a. There are about 27 coal seams in the mine field. See Table 1 for the structure and gas parameters of each minable coal seam.

| Coal seam number | Average distance between coal seams /m | Average thickness of coal seam /m | Gas content / (m³·t⁻¹) | Gas pressure / MPa |
|------------------|--------------------------------------|---------------------------------|------------------------|-------------------|
| C₇               | 17.23                                | 2.12                            | 8.24                   | 0.55              |
| C₈               | 16.15                                | 1.75                            | 6.14                   | 0.32              |
| C₉               | 14.54                                | 2.32                            | 9.12                   | 0.67              |
| C₁₅              | 18.58                                | 1.66                            | 7.97                   | 0.53              |
| C₁₆              | 33.26                                | 2.12                            | 8.31                   | 0.56              |
| C₁₉              | 10.99                                | 1.34                            | 7.47                   | 0.48              |
| C₂₁              | 8.71                                 | 1.46                            | 8.23                   | 0.55              |
| C₂₄              | 27.53                                | 2.13                            | 10.64                  | 0.47              |

The coal mine is a high gas mine, adopting downward mining, mainly mining C₇, C₈ and C₉ coal seams.

The coal mine has high and low negative pressure gas drainage system, and the pump model is BEC-52. In recent four years, the gas drainage rate is 37.23~50.64%.

In 2014, the coal mine carried out the construction of ground low concentration gas power station, which used the extracted low concentration gas to generate electricity, and then connected the output power to the regional power grid for sale after boosting the output power.

After nearly four years of practice, the coal mine has summed up a set of comprehensive technical system for gas source guarantee of small coal mines. It not only solves the problem of gas source, ensures the stable and efficient operation of power station, but also solves the gas threat in the process of mine production, and realizes the safe and efficient production of the mine.

3. Comprehensive technical system of gas source guarantee

Sufficient, high concentration and stable gas source is the basis of high efficiency and continuous operation of gas generator. Based on the actual situation of the mine, the coal mine has developed a set of comprehensive technical system for gas source guarantee, as follows.

3.1. Adjust the mining deployment, mining protective layer for the first time

Based on the gas occurrence data, geological exploration data, investigation and visit information of adjacent mines, and referring to the existing research, the Coal Mine determines that C₉ coal seam is the first mining protective layer, forming the mining pressure relief protection function for adjacent C₇, C₉, C₁₅ and C₁₆ coal seams.

3.2. Strengthen tunneling work to provide time and space guarantee for gas drainage

The coal mine has set up five tunneling teams and purchased six EBJ-120TP roadheader, and the tunneling speed can reach 500~600m/month. The driving capacity ensures the balance of coal reserves delineated by mine development, preparation, pre drainage and mining (by the end of 2017, the proportion of the four quantities is about 8.0:4.8:3.2:2.1), which has won sufficient time and space for gas control.
3.3. Upgrade drilling equipment and promote large diameter and long drilling
Five zdy-4000 drilling rigs have been purchased in the coal mine, which can be used to drill holes with a diameter of 85~120mm and a stable drilling depth of 180m.

3.4. Strengthen the management of sealing hole and formulate the examination method of sealing hole
The coal mine formulates the assessment method for sealing of gas drainage boreholes, which requires that: the drainage pipe shall be installed in the whole drilling process, the sealing method of "bag plugging at both ends and cement slurry injection in the middle" shall be adopted, and the sealing depth of coal and rock holes shall not be less than 16m and 14m, and the drilling quality responsibility system shall be implemented for listing management.

3.5. Using the pressure relief effect of stope mining to optimize the extraction design
(1) Before the mining face of C8 coal seam is mined, floor roadway and upward grid drilling holes are arranged at 15m of the floor of C16 coal seam at the lower part of the mining face. During the mining period, the pressure relief gas of C9, C15 and C16 coal seams affected by mining is extracted synchronously. Requirements: the distance between boreholes is 25m at C9 coal seam, and the final hole passes through C9 coal seam to 2m of roof.

(2) The coal mine adopts the observation method of drilling fluid leakage and empirical formula calculation method to comprehensively evaluate the height of gas conducting fracture zone in overlying strata of the stopes\textsuperscript{8-9}. The requirements are: the final hole of high-level borehole is located in the fracture zone and covers C7 coal seam.

(3) In the upper corner, the screen hole drainage pipe is hung in the whole process to drain the goaf to enrich gas
The results show that: the enriched gas in the goaf is located 20~30m behind the working face; the buried pipe in the upper corner can adjust the gas flow field in the goaf and prevent the gas accumulation in the upper corner\textsuperscript{10-12].

Therefore, the requirements of coal mine are as follows: first, build a closed wall at the upper and lower corners of the working face; secondly, hang a gas drainage pipe along the return air roadway of the working face (the height is not less than 1.5m, and the screen hole is processed and closed on the drainage pipe), and the screen hole enters into the corner sealing wall with the advance of the working face, so as to realize the following: not only can the shallow gas in the goaf be drained to prevent the gas accumulation in the upper corner, but also the gas drainage can be realizedGas is enriched in the deep of goaf.

4. Construction of low concentration gas power generation project in small coal mine
From 2014 to 2018, the absolute gas emission of the mine is 18.36~26.15m\textsuperscript{3}/min, the gas drainage volume is 10.55~12.36m\textsuperscript{3}/min, the gas concentration of high negative pressure system is 16.46~22.27\%, and the gas concentration of low negative pressure system is 10.53~26.25\%.

After investigation and research, the coal mine purchased 3 sets of 500GF1-3PwW low concentration gas generator of Shengdong group. The model can automatically adjust the air-fuel ratio according to the flow and concentration changes of the gas source. It is suitable for the gas source with 6~30\% concentration, and the pure gas consumption is about 3.0m\textsuperscript{3}/(min-set). The multi-stage fire and explosion suppression device and water mist transmission system are used to ensure the safe transportation of low concentration gas pipeline.

The gas power station is located at 50m to the east of the gas drainage station. The gas source at the exhaust end of the high and low negative pressure extraction pump is connected to the manifold and gas transmission pipeline through the gate valve, and then passes through the water seal flame arrester, the gas pipeline special flame arrester, the water mist conveying system, the overflow dewatering water seal fire arrester, the cyclone medium particle dehydrator and the generator set., and the low concentration gas generator is shown in Figure 1.
The gas power station was put into operation in August 2014, with a total investment of about 8.52 million yuan. As of December 2018, the average annual operation time of the three units has always reached 2.06 ten thousand h. The output voltage of the unit is 0.4kV, which will be connected to the regional power grid after being boosted to 10kV by the transformer and sold to the power grid company at the price of 0.44 yuan/(kW·h).

5. Investigation on application effect of gas power generation in small coal mine

5.1. Safety effect
(1) From 2015 to 2018, no high concentration (more than 3%) gas overrun occurred in all mining working faces of the coal mine, and the gas overrun of low concentration (1~3%) did not exceed 6 times/a; the threat of gas to mine safety production was basically eliminated. The specific statistics are shown in Table 2.

| Year | Times of gas overrun in mining face |
|------|-----------------------------------|
| 2015 | 4                                 |
| 2016 | 6                                 |
| 2017 | 5                                 |
| 2018 | 4                                 |

(2) From 2015 to 2018, the gas drainage rate of coal mine increased steadily (37.23~50.64%), the negative pressure of pre drainage borehole orifice reached 17.23~23.43kPa, the negative pressure of high-level borehole orifice reached 7.16~9.22kPa, and the working condition of gas drainage system was better.

5.2. Economic effect
(1) From 2015 to 2018, the annual operation time of three coal mine generating units is about 2.06 ten thousand h, the annual power generation is about 10.3 million KW·h, and the electricity sales income is about 4.532 million yuan/a. After deducting the maintenance cost and personnel salary, the annual income can be about 4.032 million yuan. The payback period of power station investment is 2.11a.

(2) From 2015 to 2018, the output of the coal mine was 21 ten thousand t/a; from 2011 to 2014, the output of the coal mine was less than 18 ten thousand t/a; the gas power station greatly improved the enthusiasm of the coal mine to carry out gas control work, and the effective gas control greatly released the output of the mine.

5.3. Ecological effect
(1) From 2015 to 2018, the three units of the coal mine use about 3.708 million m³/a, and reduce the emission of CO₂ by about 4.47 ten thousand t/a, with significant environmental benefits.
6. conclusion
(1) Make full use of stope mining effect to extract high concentration pressure relief gas to ensure the purity and concentration of gas source; improve the ability of tunneling and drilling equipment to ensure the time and space of gas drainage and ensure the lasting and stable gas source.

(2) A coal mine gas power generation project has been running efficiently for 4 years, with an annual economic income of about 4.032 million yuan. It is estimated that the investment can be recovered in 2.11 years, and the emission reduction of CO₂ is about 4.47 ten thousand tons, and the safety production and production of the coal mine are guaranteed.

(3) There are a large number of small coal mines in Fuyuan County, Yunnan Province. It is of great significance to carry out the utilization of low concentration gas. This study provides a feasible technical reference for this work.

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