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Study on the application of double corridor project in managing geological defects affecting transmission lines in mining areas

The iron tower of transmission lines and its foundation are often confronted with settlement, inclination, displacement, distortion, etc. caused by surface movement and deformation. The double corridor project takes advantage of the layout of working surface, basically the regular time and the slowness of surface movement and deformation. Combined with geological information and mining conditions, the project chooses to construct new corridors in stable goafs which have been moved and deformed by coal mining. Through detecting tower deformation and mastering its trend, the new corridor will be built as soon as the deformation degree reaches the early warning value (the deflection of tangent tower reaches 0.3% while that of angle tower reaches 0.7%). The old corridor is then transformed into a double-corridor project. This project provides new ideas for transmission lines construction in mining areas by solving the problems in rerouting and high cost.

Keywords: *Coal mining area, electric transmission lines, geological defects, management, double corridor project.*

1. Introduction

China's coal reserves are mainly distributed in Northern and Northwestern regions, concentrating in the North of Kunlun-Qinling- Dabie Mountains. Shanxi, Shaanxi and Inner Mongolia have the most abundant coal reserves, accounting for 60% of the total coal resources while Sichuan, Guizhou, Yunnan and Chongqing reserves 9% of them. Coal, as a major resource of power generation, is the basis of economic development. However, coal mining leads to tower displacement and deformation and causes great damages to transmission lines running through mining areas.

When there are widespread mined-out areas, the upper part of the strata will lose its support. The balance is destroyed and thus the rock mass above the goaf deforms. The deformation occurs gradually from the bottom to the top and the subsidence area can be seen as funnel-shaped, which is generally divided into three zones (Fig.1):

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a. Caving zone

The deformed and broken roof strata collapse down to the goaf under the influence of deadweight and overlying strata. The height of the caving zone is usually 2~5 times that of the goaf.

b. Fracture zone

The strata above the caving zone bend and deform under gravity. If the bending strength can no longer be borne by the strata, layer abscissions and fractures will occur and result in wedge-shaped connected fracture zones (also called layered fracture zones). The height of the fracture zone is about 18~24 times that of the goaf.

c. Bending zone

The bended and deformed strata affected by gravity above the fracture zone. The strata in the bending zone are less deformed. With low water transmissibility, the fractures are airtight and disconnected. It directly results in instable basins. Usually, the bending zone is 5 times as high as the fracture zone.

The three zones directly influence the deformation of the ground surface. Moreover, the surface stability can be achieved by controlling the deformation of the three zones.

The double corridor project in this paper can manage geological risks and solves problems in rerouting and high cost, thus, providing new ideas for transmission lines construction in mining areas.

The double corridor project can be used in deformed mining zones. Those zones are once underground deposits of coal, manganese ores or phosphate minerals. It takes advantage of the time differences of mining. Combining regular time of surface settlement in mining areas, it chooses deformed areas which are relatively stable. It constructs transmission lines by using inclined column foundation, pile foundation, straight column foundation or other conventional foundations instead of raft foundation, combined big slab foundation, independent flexible big slab foundation or other expensive foundations. Meanwhile, it provides new methods to mining areas with complicated geological conditions where big slab foundations cannot be constructed.

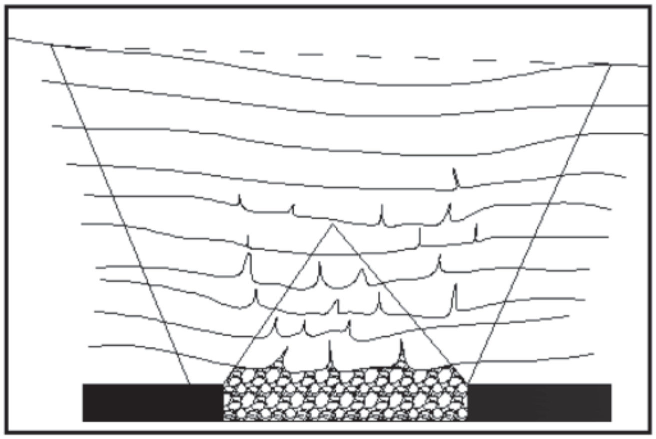

Fig.1 The deformation of the strata above the goaf

China's coal reserves are mainly distributed in Northern and Northwestern regions, concentrating in the North of Kunlun-Qinling-Dabie Mountains. Shanxi, Shaanxi and Inner Mongolia have the most abundant coal reserves, accounting for 60% of the total coal resources while Sichuan, Guizhou, Yunnan and Chongqing reserves 9% of them. Coal, as a major resource of power generation, is the basis of economic development. However, coal mining leads to tower displacement and deformation and causes great damages to transmission lines running through mining areas. The double corridor project in this paper can manage geological risks and solves problems in rerouting and high cost, thus, providing new ideas for transmission lines construction in mining areas. [1].

2. Implement conditions for double corridor project

The implementation of the project is based on the information collected on mining geology and conditions. The details are as follows:

(1) The mining geology and conditions are clearly known. The working surface of the coal seam is continuous.

(2) The production performance is detected. The surface deformation in mining areas follows certain rules.

(3) The hydrogeological conditions are clearly known. Large-scale deformation caused by later groundwater activities may not happen in general conditions.

3. Basic ideas of double corridor project

The basic ideas of double corridor project include new corridor design, tower deformation detection and new corridor construction. First, collect information on geology and mining conditions. Take advantage of the layout features of working surface and the time of exploitation. Calculate the basically regular time of surface movement and deformation according to the height of goaf which is more than 2.5 times of its buried depth. Use conventional foundation type to determine the position of the tower and choose a work surface with a certain time span to construct a new corridor.

Second, detect the tower deformation affected by preferred coal seam a month before its mining activity. Set the early warning value when the deflection of tangent tower reaches 0.3% and that of angle tower reaches 0.7%. Take good command of the trend and the degree of tower deformation.

Third, when the degree of tower deformation reaches the early warning value, new corridor should be built to accomplish the rerouting of transmission lines. [2-3]

4. Engineering application of double corridor project

The transmission line (Fig.1) runs through the mining area. According to the information on geology and mining conditions, Tower N37 and N38 are affected by coal mining. The workable seams from top to bottom are C9 and C15 with thicknesses of 2.57m and 2.13m separately. The distance between them are 40m and the dip angle of the seam is 7°. The hydrogeological condition is relatively good without concentrated runoff zones. The coal seam roof of C9 is dominated by carbonaceous shale and siltstone which tends to expand and soften when absorbing water. The direct roof is dominated by black or grey carbonaceous shale and calcareous shale with a thickness of 0~1m. It is extremely unstable. The coal seam roof of C15 is made of carbonaceous shale, calcareous shale and marlite. The direct roof, dominating by calcareous shale and marlite, is stable with a thickness of 0-0.3m. Longwall retreating method is used in mining and caving method is used in managing coal seam roof. The coal mining of C15 will not result in goaf activation as well as surface deformation.

Tower N37 is located at 10906 working surface. The underlying coal seam is C9 with a buried depth of 216m and a depth to thickness ratio of 84. The mining activity began in Jan. 2017 and the area will be mined out in Nov. 2018. Tower N38 is located at 10905 working surface with a buried depth of 244m. The depth to thickness ratio is 95. The work began in Jan. 2011. The mining sequence of working surface is 10901 → 10902 → 10903 → 10904 → 10905 → 10906. The daily mining speed reaches 1.6m/d (Fig. 2) [4-7].

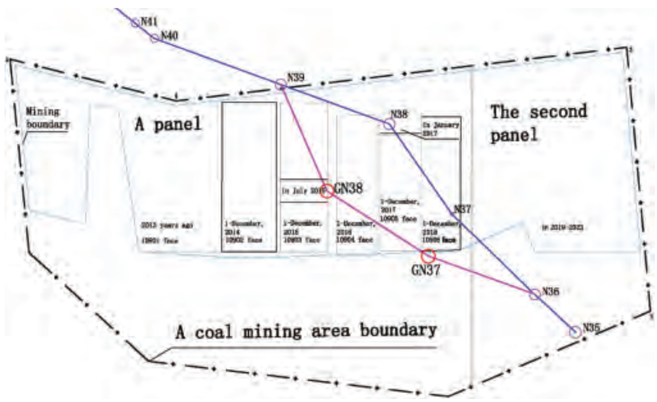

Fig.2 Working surface layout and mining plan for a coal mining area with transmission lines

4.1 Prediction on surface deformation of original mining areas with transmission corridors and towers

The main controlling factors of moving the tower to new corridor are maximum settlement, maximum settling velocity and the duration of surface movement or deformation. Tower N37 and N38 were affected by coal mining. Therefore, the capacity of surface movement and deformation should be predicted.

(1) Estimate the maximum settlement

Through predicting the surface movement and deformation of the mining area along the river and taking landslide into consideration, the prediction mode is updated (the thickness of the coal seam is 2.57m and the settlement coefficient is 0.68. The average dip angle is 7°, which means it belongs to gently inclined coal seam). As α = 7°<15°, the prediction formula is as follows:

Maximum settlement:

$$W_{cm} = q \bullet M \bullet \cos\alpha \ (mm) \quad \dots \quad (1)$$

M - normal thickness (m);

q - settlement coefficient;

α - dip angle (□);

r - radius of major influence (m);

The maximum settlement is 1.73m, which will impose destructive effect on the tower foundation.

(2) Duration of Surface movement

(a) Maximum settling velocity

The settling velocity reflects the severity of surface change. Considering hard overlying strata and caving method in roof management, the formula for maximum settling velocity is as follows:

$$V_{max} = k.W_{max}.c/H \quad \dots \quad (2)$$

V_{max} - maximum settling velocity (mm/d)

K - coefficient of settlement velocity (K=1.8)

W_{max} - maximum settlement (mm)

c - advancing speed (m/d)

H - average mining depth (m)

Through calculation, in mining area C9, the maximum settling velocities of N37 and N38 are 23mm/d and 20mm/d.

(b) Duration of ground surface

The process of surface settlement can be divided into initial period: active period and recession period. The settlement velocity in initial period is 1.7mm/d. It has little impact on the tower and will not lead to severe deformation. The velocity in active period is greater than 1.7mm/d and thus may result in severe deformation. The surface is relatively stable in recession period due to the end of settlement. There is little or no impact on the tower.

$$T = 2.5H \quad \dots \quad (3)$$

Therefore, the duration of surface movement of N37 is 544 days while that of N38 is 610 days. The active period of surface settlement exerts actual influence on the tower (Table 1).

Table 1: The duration of surface movement and deformation after the coal mining of C9

Tower	Initial period (d)	Active period (d)	Recession period (d)	Duration of movement (d)
N37	85	308	161	544
N38	91	329	190	610

According to Table 1, the initial periods of surface deformation of N37 and N38 are 85d and 91d. The time is enough for moving the deformed tower to the second corridor.

4.2 Evaluation of the stability and adequacy of the new corridor

According to Fig. 1, angle tower GN38 locates in the new corridor which runs through the goaf. The working surface is 10903 and the mining activity ended in July, 2015. The original tower N38 was slightly deformed on 3rd Feb. 2017 with a deflection of 0.6%. A new corridor was then constructed in 76 days and was finished on 20th April, 2017. The deflection of N38 had then reached 0.99%, which is regarded as severe deformation. The goaf where GN38 locates had been formed for 650 days and the thickness of overlying strata was 220m. The settlement was about to end and the ground surface was basically stable for building a tower. In this way, the safe operation of transmission lines is ensured and the geological defects affecting the lines in this mining area was eliminated.

5. Conclusions

According to the practice and experience gained in the mining areas in Guizhou, the depth to thickness ratio should be between 90 and 150. The location of the transmission tower should avoid fractured regions with steep terrains and structural deformation. In this way, the independent big slab foundation can effectively resist surface deformations caused by coal mining and thus ensure the safe operation of the transmission lines.

(1) The basic ideas of double corridor project are new corridor design, tower deformation detection in mining areas and new corridor construction.

(2) The main controlling factor of the project is basically the regular time of surface settlement in mining areas. Maximum surface settlement and maximum settling velocity reflect the rules and trend of surface deformation. The initial period of surface movement and deformation is the time for construction. Basically the regular time refers to the duration of the initial period and the active period.

(3) The double corridor project is a simple and practical method to deal with the geological defects confronted by transmission lines in the mining areas. This method is practical, reliable and economical.

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