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A Solution to Ensure Ventilation when Expanding the Area of Cam Thanh Underground Coal Mine, Ha Long Coal Company, Vietnam

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Abstract. In the process of underground mining, the mining system changes for various reasons. One of the main reasons is changes in the mining production plans, especially the scales and outputs. Nowadays, coal mines in Vietnam have been expanding in width and depth, and so have the mines' ventilation systems. Consequently, there will be changes in the alteration of the structure of the design ventilation system, which reduces the effectiveness of the ventilation and does not meet the main objective of mine ventilation, directly affect the safety of the working environment in the mine. Therefore, it is necessary to research the improvement of the ventilation system with the development and specific conditions of underground coal mines in Vietnam, improving the efficiency of the ventilation work and assuring the safety of the mine environment. Cam Thanh coal mine, Ha Long coal company, Vietnam, is the case study for this research. The article considers the plan of increases the mining output by more than 1.5 times, propose solutions to improve the ventilation system accordingly, helping the company proactively implement the production plan, ensure the working environment's safety, and reduce the costs of mine ventilation.

Keywords: Mine ventilation, Mine ventilation and safety, Cam Thanh mines area, Ventilation system adjustment, Fan operating points

1. Introduction

Ha Long Coal Company is a Vietnam National Coal and Minerals Holding Corporation Limited (Vinacomin) subsidiary. The company includes mining areas of Cam Thanh, Tan Lap, and Ha Rang, which coal output of 2020 is 1.75 million tons. Cam Thanh mining area plans to reach 400,000 tons per year, which requires three longwalls and eight preparation tunnels. Cam Thanh area will be a large area to increase production. After 2020, it is possible to increase the output to more or less 700,000 tons per year, with five longwalls [1, 2, 3]. It is imperative to develop a corresponding exploitation plan and, as a result, an appropriate ventilation system to increase the exploitation output of the area. This adaptation helps reduce natural hazards which may occur, such as fire and explosion due to accumulation of methane gas, suffocation due to accumulation of toxic gases, unsafe working environment conditions for workers, etc.

The study aims to apply appropriate solutions to complete the ventilation system for the mine in assuring environment and safety. The article helps to consider the economic efficiency of investment when the mine increases its production.

2. Research Methods

Cam Thanh mining area, Ha Long Coal Company, was selected as the research area. Statistics, inheritance, field studies, and theoretical studies are the main methods for detailed audit and assessment of the current mine ventilation system. The inspection results combined with the calculation of the planned ventilation requirements help us find suitable solutions and applied to improve ventilation efficiency to ensure mine safety.

3. Calculation of ventilation for Cam Thanh mine area

3.1. Calculate current of ventilation for the mining area

3.1.1. Diagrams of the current mine wind network

According to the current exploitation plan, to ensure 400,000 tons per year of output, Cam Thanh must operate three longwalls and eight preparation galleries. The plan of longwalls is shown in Table 1, and preparation galleries are in Table 2 [1].

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Tab. 1. Characteristics of longwalls in Cam Thanh mine area.

No	Longwalls name	Length *(m)*	Cross-section of the tunnel used *(m^2)*	Productivity (tons */24h)*	Number people working *(people)*	Maximum amount of explosives *(kg)*
1	Longwall XDY level -50/-20 V10 CB	55	4.5	260	20	4
2	Longwall TLD level -20/+40 V11B CB	94	4.5	253	22	4
3	Longwall TLD level -50/-20 V11B CB	60	4.5	260	22	4

Tab. 2. Parameters of preparation tunnel mirrors.

No	Name of preparation galleries	Length, *L (m^3/p)*	Cross-section, *S (m^2)*	Explosives, *A (kg)*	Number people, *n (people)*
1	Preparation tunnel level -50/-20 CB V10	70	8.4	4.5	8
2	Preparation tunnel level +5 +HS +0/+5 V11b CB	30	6.5	4.5	8
3	Preparation tunnel KĐ level -50/+40 CB V11	125	9.4	5	10
4	Preparation tunnel leve -40 +HS -50/-40 CB V11	40	8.4	4.5	8
5	Preparation tunnel level +25 +HS +25/+40 CB V11	60	8.4	4.5	8
6	Preparation tunnel level -45, HS -50/-45 CB V10	20	6.5	4.5	8
7	Preparation tunnel level -45, HS -50/-45 CB V11	30	8.4	5	8
8	Preparation tunnel KĐLC level -50/-20 V10 CB	250	8.4	5	8

The diagram of the current wind network is structured from the faces with three longwalls, and eight preparation galleries (Fig. 1). In general, this ventilation network is relatively complex. The mine area is ventilated by suction ventilation with a BD-II-6-No15/2x55kW fan station.

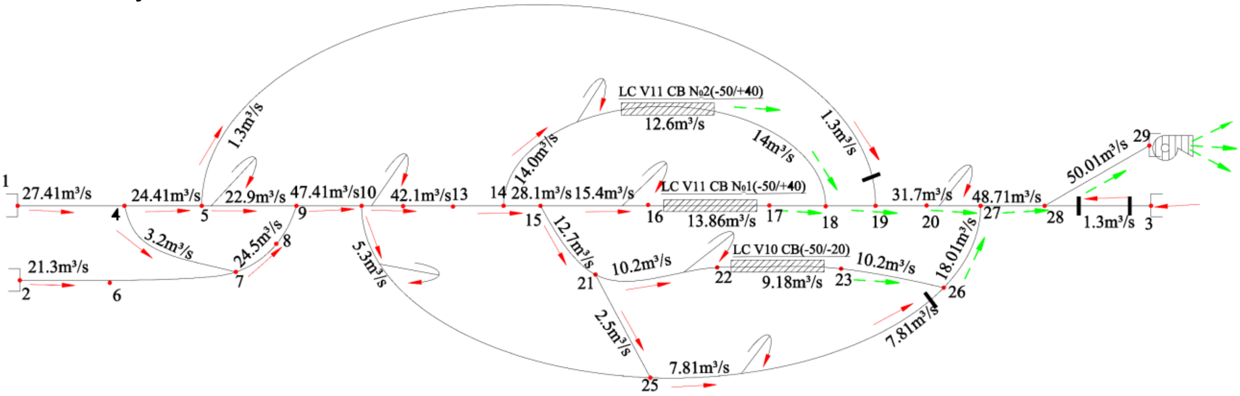

Fig. 1. Existing ventilation scheme in Cam Thanh mine area.

3.1.2. Calculation of current wind flow for the area

To calculate ventilation for Cam Thanh mine area, we apply the formula [4]:

$$Q_m = 1{,}1(K_{sl}.\ \Sigma Q_{lc} + \Sigma Q_{cb} + \Sigma Q_{ht} + \Sigma Q_{rg});\ m^3/s \quad (1)$$

Where:

1.1 - The coefficient refers to the uneven distribution of wind in wind currents.

K_{sl} - Coefficients to account for the increase in output of the longwall (select k_t = 1.1).

ΣQ_{rg} - Total leakage wind flow in mine, m^3/s.

ΣQ_{lc} - Total amount of wind flow required for the furnace oven, m^3/s.

ΣQ_{cb} - Total amount of wind flow needed for the digester mirror, m^3/s.

ΣQ_{ht} - Total amount of wind flow required for the station, m^3/s.

With the current mining status, we can calculate the wind flow for the site as follows:

$$Q_m = 1.1(1.1 \times 17.0 + 16.8 + 4.36 + 5.6) = 50.01 m^3/s$$

3.1.3. Calculation mine ventilation pressure

To calculate mine ventilation pressure, we calculate the low pressure of the wind currents and apply the formula [5]:

$$h_m = \sum h_{ms} + \sum h_{cb}, mmH_2O \quad (2)$$

In which:

$\sum h_{ms}$ - The total hypotension caused by the frictional resistance of the segments, following each other in a wind flow, is calculated from the beginning to the endpoint. This pressure lowering is calculated according to the formula [4]:

$$h_{ms} = \alpha_i \frac{L_i.P_i}{S_i^3}.Q_i^2, \text{ mm } H_2O \quad (3)$$

In which:

α_i - The aerodynamic resistance coefficient in the ith tunnel on the airflow, kGS^2/m^4;

L_i, P_i, S_i - Length, circumference, the cross section of tunnel I, respectively;

Q_i - The amount of wind going through the ith tunnel, m^3/s.

$\sum h_{Cb}$ - The total hypotension due to local resistance, calculated by a wind flow, is often taken from (10÷25%) H_{ms}.

Replace the parameters and calculate the results of the mine pressure lowering as follows:

h_1 = 85.03 mmH_2O (flow lowering pressure 1);

h_2 = 82.49 mmH_2O (flow lowering pressure 2);

h_3 = 78.80 mmH_2O (flow lowering pressure 3)

and h_4 = 67.26 mmH_2O (flow lowering pressure 4).

Adjust the wind window is a method to balance the mine pressure. The lower pressure of the selected mine is h_1 = 85.03 mmH_2O.

3.1.4. Determination of the current operating mode of the central blower

* Determine the airflow of the fans to create

To calculate the fan wind flow to be generated, we apply the following formula [4, 6]:

$$Q_q = K_r Q_m, m^3/s. \quad (4)$$

In which:

K_r - Leakage coefficient at fan station, semi-fixed fan station get K_r = 1.15

Q_m - Airflow required for the whole mine: Q_m = 50.01 m^3/s

The results of calculating the airflow for fans are as follows: Q_q = 57.51m^3/s.

* Determine pressure the fans to create

Pressure the fans to create is calculated according to the formula [2, 6]:

$$H_q = (k_1.R_m + R_{tbq}).Q_q^2, mmH_2O \quad (5)$$

In wich:

k_1- the coefficient refers to the leakage at the fan station, $k_1 = 1/k_r^2$, k_1 = 0.76

R_m - mine resistance, kμ; For the mine area, we have the mine resistance: R_m = 0.033998 kμ;.

R_{tbq} - Resistance of fan equipment ($R_{tbq} = a.\pi/D^4$): For the main fan of the mine, the fan resistance is as follows: R_{tbq} = 0.0031;

Instead we have: h_q = 102.5 mmH_2O = 1025 Pa;

* Determine the working mode of the main fans

The calculation to determine the operating mode of the main fans is calculated based on the general regulations and using the calculation method to determine the operating mode of the fans by the graph method [7, 8]. The calculation determines the operating mode of the main fans as follows:

- Equation curve characteristic mine: $h = 0.030978.Q^2$;
- Operating mode of the main blower

The determination result of the main wind fan is shown in Figure 2. The working point is point B, with the fan working parameters as follows:

Fan flow generated: $Q_{ct} = 59\ m^3/s$;

Fan pressure: $h_{ct1} = 108.2\ mmH_2O = 1082\ Pa$;

Impeller mounting angle of impeller: $\theta = +25^o$

And Fan performance: $\eta = 0.54$.

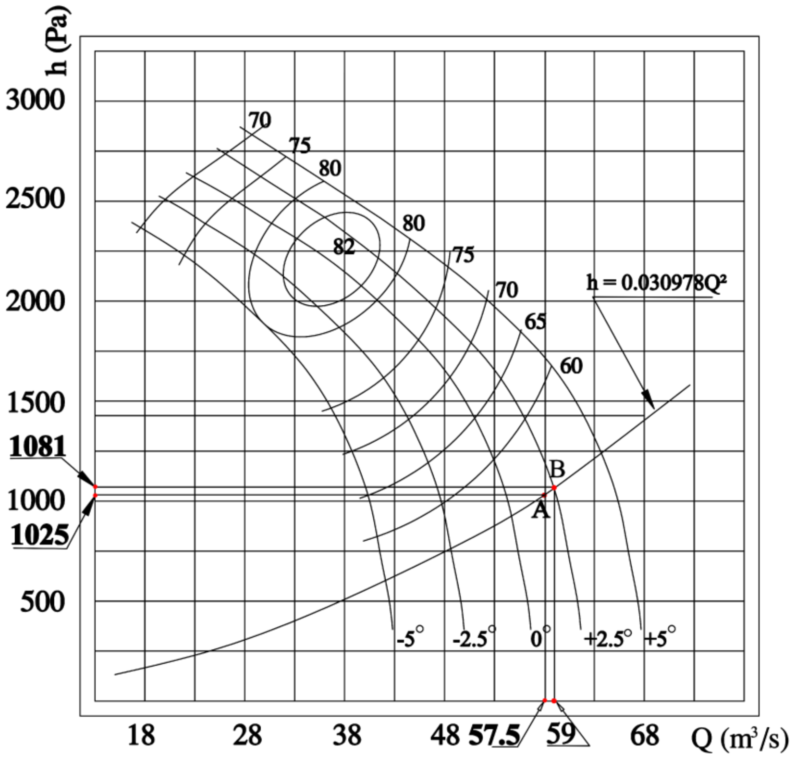

Fig. 2. Graph identifying the current operation mode of fan BD-II-6-No15 Mine area Cam Thanh, Ha Long Coal Company.

3.2. Calculate ventilation for the mine area when increasing production

The ventilation calculation of the mine area when increasing the mining output is similar to the current mine. However, the measure must take the parameters of the increasing mining output taken into account

3.2.1. Ventilation diagram of the mine site when increased production

To reach the output of the mine area to 700,000 tons per year, Cam Thanh exploits coal seams, including coal seam No10 and coal seam No11. The mine must operate five longwalls as shown in Tablé 3 and 10 preparation galleries as in Table 4 [2]. Figure 3. illustrates the mine ventilation diagram.

Tab. 3. Mobilization plan, longwall characteristics in production when increasing production.

No	Longwall name	Length *(m)*	Number of people	Explosives, *(kg)*	Cross section *(m^2)*	Productivity *(tons /24h)*	
						Min	*Max*
1	XDY level -50/-20 V10 CB	55	20	4	4.5	240	270
2	XDY level -50/-20 V10 CN	80	22	4	4.5	240	300
3	TLD level -20/+40 V11B CB	94	22	4	4.5	240	300
4	TLD level -50/-20 V11B CB	60	10	4	3.2	240	270
5	XDY level -50/+40 V11CB	120	10	4	3.2	240	270

Tab. 4. Plans and characteristics of the preparation tunnel lines to meet when increasing production.

No	Preparation tunnel name	Anti-retention material	Cross section *(m^2)*	Length needs ventilation *(m)*	Explosives, A *(kg)*	Number people, n *(people)*

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1	Level -25 (-25/-20) CBV10	iron	8.4	40	4.5	8
2	Level -50/-20 CB V10	iron	8.4	70	4.5	8
3	Level -40 (-50/-40) V11B CB	iron	8.4	50	4.5	8
4	Level +5 (+0/+5) V11B CB	iron	6.5	30	4.5	8
5	Level -40 (-50/-40) CB V11	iron	8.4	40	4.5	8
6	Level +25 (+25/+4)0 CB V11	iron	8.4	60	4.5	8
7	Level -45, (-50/-45) CBV10	iron	6.5	20	4.5	8
8	Level -20 LT.Cb V10	iron	6.5	70	4.5	8
9	Level -45, HS -50/-45 CB V11	iron	6.5	30	4.5	8
10	KDLC level -50/-20 V10 CB	iron	8.4	250	5	8

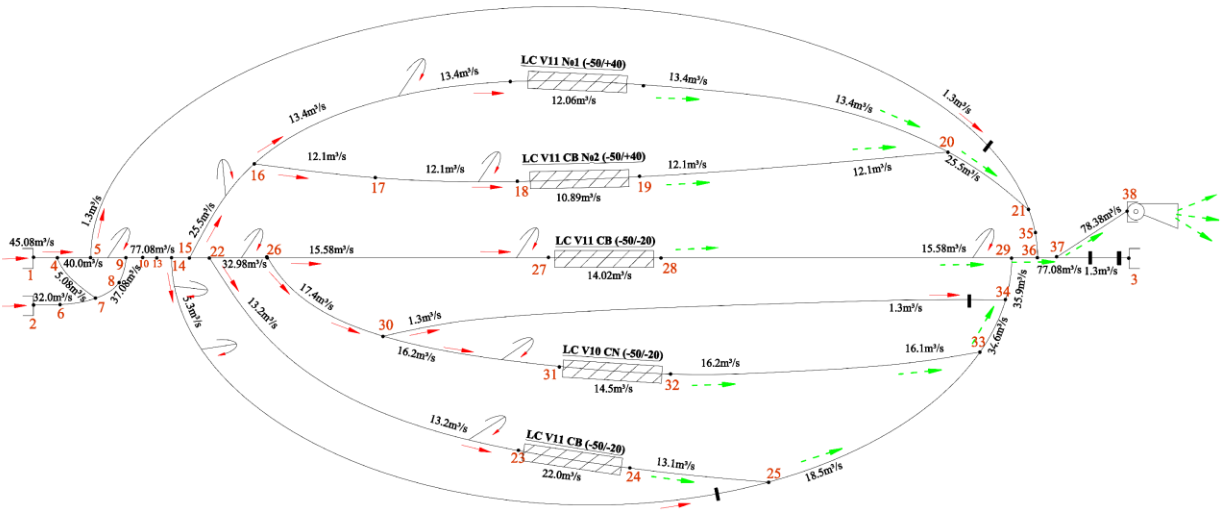

Fig. 3. Ventilation diagram of Cam Thanh mine area, when increasing exploitation output.

3.2.2. Calculate wind flow for the mine area when increasing production

With the condition that when increasing the mine area's exploitation output, the wind flow calculation results for the mine area are as follows:

$$Q_m = 1.1(1.1 \times 32.6 + 23.5 + 4.74 + 7.16) = 78.38\ m^3/s$$

3.2.3. Calculate pressure for the mine area when increasing output

As in Fig. 3, the wind network has five main air currents. Calculation results of the pressure of the specific wind flows are as follows: h_1 = 118.81 mmH_2O (XDY level -50/+40 V11CB); h_2 = 113.45 mmH_2O (XDY level -20/+40 V11CB); h_3 = 126 mmH_2O (XDY level -50/-20 V10 CB); h_4 = 130.58 mmH_2O (XDY level -50/-20 V10 CN); h_5 = 125.81 mmH_2O (TLD level -50/-20 V11B CB), in which the flow of h_4 is the largest. Hence, the h_4 = 130.58 mmH_2O is the pressure of the mine. The other flows are adjusted to pressure balance by setting the adjustment wind window.

3.2.4. Determine the operation mode of the central blower when increasing output

* Determine the wind flow of the fans to create

The calculation results of wind flow for the fans are as follows: Q_q = 86.2 m^3/s.

* Determining the pressure fan to create

The pressure to create fan: h_q = 161 mmH_2O = 1610 Pa;

* Determine the reasonable working mode of the main fan

The technical characteristics and working capacity of the current BD-II-6-No15/2x55kW fans of the mine currently in use will not meet the ventilation demand of the mine if only one fan is used and the other is in standby mode. Therefore, the plan to use existing BD-II-6-No15/2x55kW fans is only an immediate solution. In the long term, it is necessary to consider investing in a new type of fan.

When existing BD-II-6-No15/2x55kW fans are used, both fans must run in a combination of parallel modes close to each other with no backup. The result of determining working fan mode is as follows:

- Equation curve characteristic mine: $h = 0.0243.Q^2$;
- Operating mode of the main fan

The result of determining the operating mode of the main fan is in Fig. 4.

+ The common working point of the fan set is point B, with the working parameters as follows:

The total airflow generated by the fan set: $Q_c = 91.3$ m^3/s;

Lower the pressure generated by the fan unit: $h_{ct} = 195.0$ mmH$_2$O = 1950 Pa;

+ The working point of the component fan is the B_{ct1} point, with the following working parameters:

Fan flow generated: $Q_{ct} = 45.6$ m^3/s;

Lowering the fan pressure creates: $h_{ct} = 195$ mmH$_2$O = 1950 Pa;

Impeller angle of impeller: $\theta = 0^o$

And Fan performance: $\eta = 0.77$.

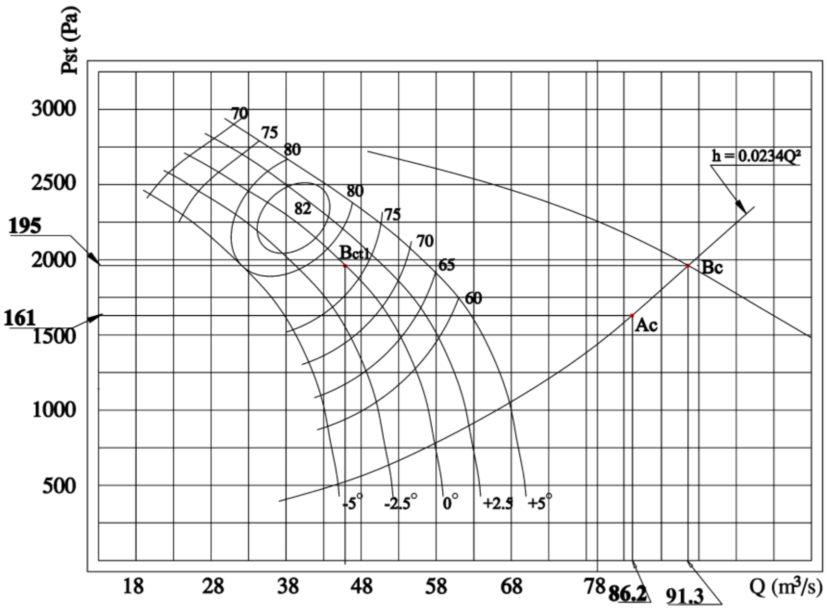

Fig. 4. Graph defining the operating mode of the main fan of Cam Thanh mine when increasing output. (using two BD-II-6-No15/2x55kW combined fans).

4. Solutions to complete the ventilation system of mine area when increasing exploitation output

With the research results and references from many research projects in mining [9, 10, 11, 12, 13, 14, 15, 16]. We propose several solutions to improve the operational efficiency of the mine ventilation system for Cam Thanh area nowadays and when the production output increase, as follows:

1- Orientation on ventilation method and fan placement

The work of ventilation for Cam Thanh mine area when continuing to exploit the plan from -50 to 40 is still carried out as at present. Specifically: General ventilation for the mine is still using the suction ventilation method, with 01 central fan station as today: type BD-II-6-No15/2x55kW) at the tunnel door of 117 level. However, if the catches of Cam Thanh mine area increase, this fan station will not meet, it is suggested: Raising the capacity of level +117 fan station from BD-II-6-N15/2x55kW up type fan 2K56-No24 or FBDCZ-6-No24/2x315 kW or fan with equivalent power.

2- Orientation of the general wind demand necessary to be put into the mine

The general wind flow of the mine needs to ensure the current clean wind demand (about 57.5 m^3/s) to maintain the production, and if Cam Thanh mine area mobilizes more longwall to increase the exploitation output. As planned, the demand for wind in Cam Thanh mine area will increase, so there must be appropriate calculation solutions.

3- Solutions to use the main fan

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The estimated wind flow for the mine area is about 78.38 m^3/s, which means that the central fan station needs to work with greater capacity, so the BD-II-6-No15/2x55kW fan type no longer responds. At that time, the mine area needs to change to other types of fan with higher capacity. Here, the research content considers the development needs of the mine until after 2025, so we will propose the use of 2K56-No24 fan (or a fan with a similar capacity). It is expected to calculate the operating mode of fan type 2K56-No24 when increasing exploitation output, as shown in Figure 5 [6].

The results determine the operating mode of the main fan, as shown in Fig. 5. With the fan working parameters as follows:

The point is the job is the B_{ct2} point;
Fan flow generated: $Q_{ct} = 87\ m^3/s$;
Fan pressure generated: $h_{ct} = 164.5\ mmH_2O = 1645\ Pa$;
Impeller mounting angle of impeller: $\theta = 2.5^o$
And fan performance: $\eta = 0.74$.

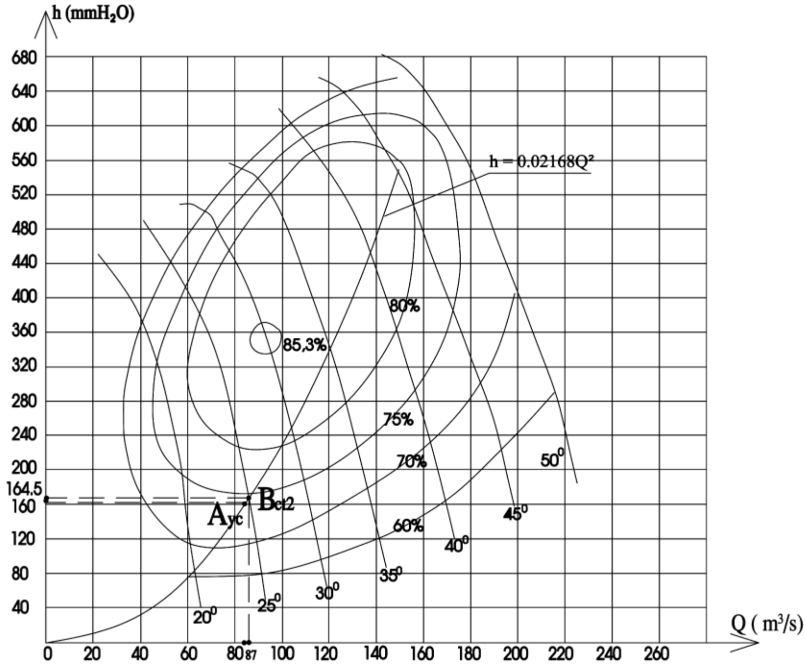

Fig. 5. Graph defining the operating mode of the central fan of Cam Thanh mine area when increasing output (plan to use fan 2K56-No24).

4- The optimal solution for the operating mode of the main fan

To improve the efficiency of mine ventilation and reduce the cost of mining, we propose a solution to use the inverter to adjust the operating mode of the fan and optimize the central fan to meet the needs of ventilation for mines. At the same time, it helps to economically and efficiently use of electricity and ensure environmental safety [5, 6, 17, 18, 19]. Here, with the conditions of the Cam Thanh mine, we recommend using a 3-Phase inverter LS LSLV5000H100-4COFD 500KW 380V and accompanying synchronous auxiliary equipment. Fig. 6. illustrates the model of automatic ventilation technology utilizing an inverter.

An inverter will adjust the fan's operating mode according to the required wind demand of the mine at each specific time. Here, the article takes data to change the operating mode of the main fan, so that the wind volume generated during holidays is 60% of the working days. The author's calculation software, and the results are shown in Figure 7. The efficiency when using the inverter to adjust the operating mode of the main fan will reduce power consumption by 41%, and according to current prices in Vietnam, the investment efficiency to over 90% [18].

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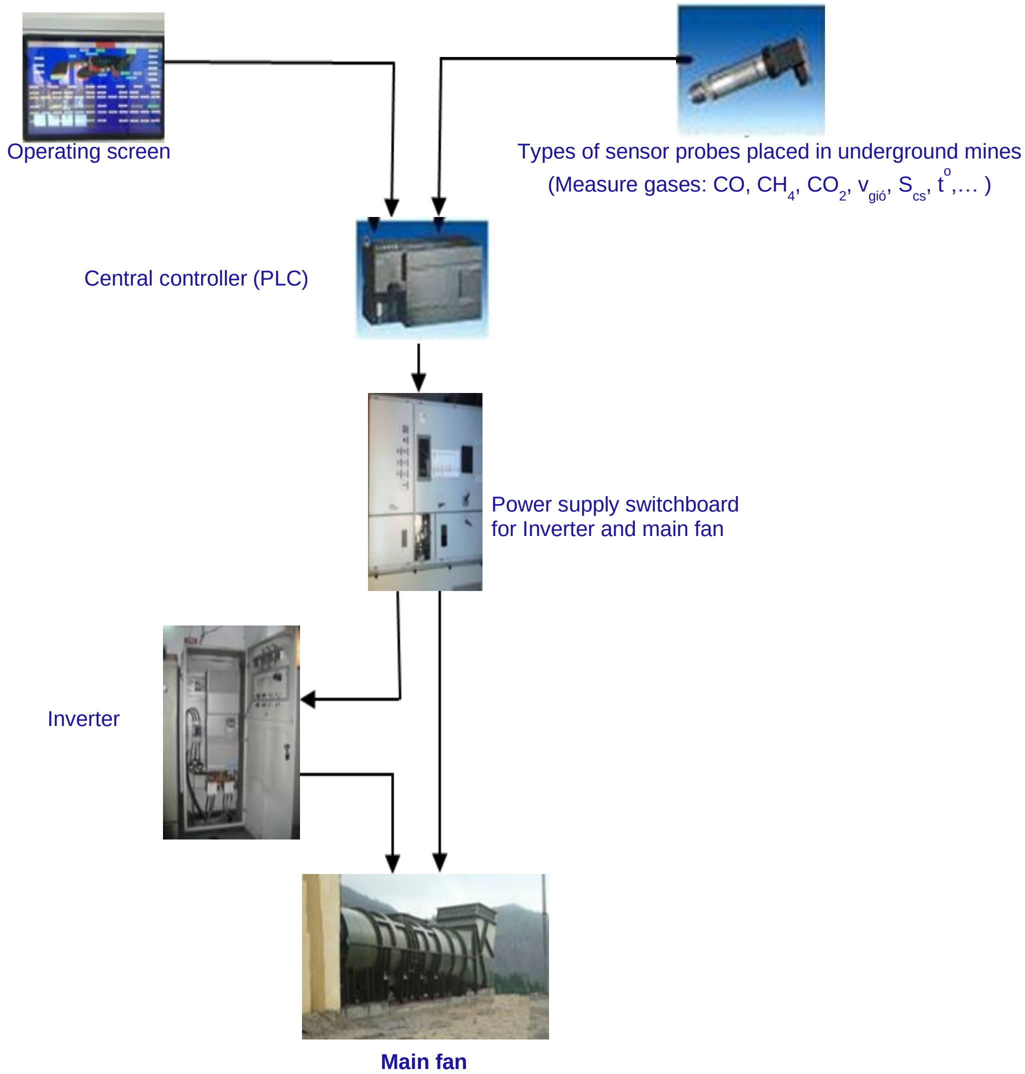

Fig. 6. Model of automatic ventilation technology using an inverter.

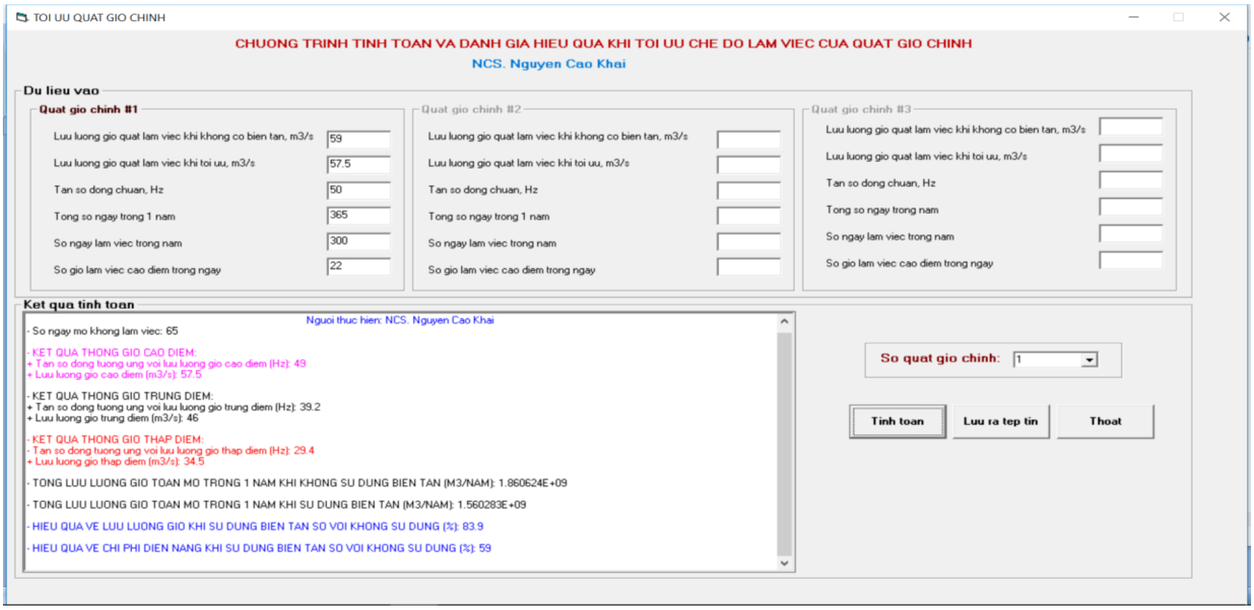

Fig. 7. The optimal calculation result of the current operating mode of fan type BD-II-6-No15/2x55kW.

5. Conclusion

The calculation of the current ventilation and the increase in mining output shows that the basic ventilation system of the mine still meets the requirements, such as the tunnel lines, wind shutters, etc. However, in the future, the wind flow needed for the mine will increase from 57.51 m^3/s to 90.01m^3/s, significantly affecting the ventilation capacity of the central fan station. To meet and further improve the efficiency of mine ventilation, the company needs to implement several solutions to perfect the ventilation system as follows:

1- The immediate solution

It is necessary to strengthen the management, especially the opening and closing of the wind doors, to ensure additional adjustment of the amount of wind shortage for the longwall, and improve working conditions. At the same time, it is always necessary to ensure the better quality of air ducts, reducing wind leaks to a minimum when ventilating the tunnel, building additional doors to check the operating mode of the central blower at the fan station. Processing and repairing windbreak doors, especially in the main fan station tunnel door, minimize leaking wind.

2- Orientation general direction for ventilation when increasing the exploitation output

When Cam Thanh mine area is put into longwall operation, to increase the output of the exploitation area up to five operating longwalls, it is necessary to replace the main fan type BD-II-6-No15 with a higher capacity fan, such as 2K56-No24 (or equivalent). Besides, the mine must invest in inverters to adjust the operating mode of the central blower to increase ventilation efficiency and reduce ventilation costs, contribute to reducing mining costs, improving safety and environmental conditions.

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