Coal Mine Substation Design

Liang Li [1, a], Shixu Li, Niandong Si, Jiefeng Mou, Nannan Liu, Huimin Sun

College of Mechanical and Electronic Engineering, Shandong University of Science and Technology, Qingdao, 266590, China.

[a]sdustliliang@163.com

Abstract

As we all know, the power supply for mines can be divided into deep well power supply system and shallow well power supply system. However, no matter which kind of power supply method, it can not supply power to the substation in the mining area[1]. It is the last link to realize the power supply to the downhole production. Underground power substations are underground where each power load is concentrated. Its location, environmental conditions, and the safety, reliability, and economic rationality of power supply will all directly affect the safety of people, mines and equipment, and the normal operation of production in mining areas[2]. Therefore, strict requirements must be placed on the location selection of power substations and the selection of power supply equipment so as to ensure smooth production. The designed transformer is selected from mine explosion-proof dry transformers and mining explosion-proof mobile substations; both high-voltage switches and low-voltage feeder switches use high-tech explosion-proof vacuum switches and low-voltage mine explosions with advanced and intelligent integrated protection devices. Type vacuum feeder switch, all kinds of equipment switch selection mine explosion-proof vacuum starter[3]. Cross-linked polyethylene insulated polyethylene sheathed power cables are used for high-voltage armored cables. Through the calculation of short-circuit current, switch relay protection setting and protection grounding, the design has high reliability, complete functions, flexible combination, and low power consumption, ensuring safe, economical and efficient operation of the power supply in the mining area[4].

Keywords

Substation, electricity, power supply, mining substation.

1. Introduction

For the power supply in the mining area, due to the particularity of the coal mine power supply and the poor working environment of the underground electric equipment, high demands are made on the layout of the power supply and the correct selection of electrical equipment so as to strengthen the maintenance and overhaul of the electrical equipment to meet the mine The need for production. The power supply in the mining area is usually a relatively fixed mining substation. It is through the radial cable network to the power distribution point where the electricity consumption is relatively concentrated. For the safety of the power supply, the two loops are usually used to supply power[5]. Therefore, for the mining area, Power supply, it is very important for the mining height of the mining area, the selection of electrical equipment and the choice of cables. After determining the electrical equipment, it is necessary to set the calculation of various distribution switches. After selecting the cables, To determine its distance, calculate the voltage loss of the cable branch and the voltage loss of each load cable. The sensitivity check of various protections is qualified, so the power supply in the mining area is a complex power supply, and a rigorous selection and power supply layout must be adopted to finally form a complete power supply for the mining area[6].

2. Low-Voltage Connection Line in The Substation of the Mining Area

The low-voltage side of each transformer is equipped with a low-voltage automatic feed switch as a master switch, with a leakage protection device (leakage detection relay); each low-voltage distribution line is equipped with an automatic feed switch as a distribution switch, control Protection and distribution lines; each transformer is operated in separate columns[7]. A lighting transformer complex provides the 127V required for lighting. All equipment is flameproof. Fig. 2-1 shows a typical substation power supply system[8].

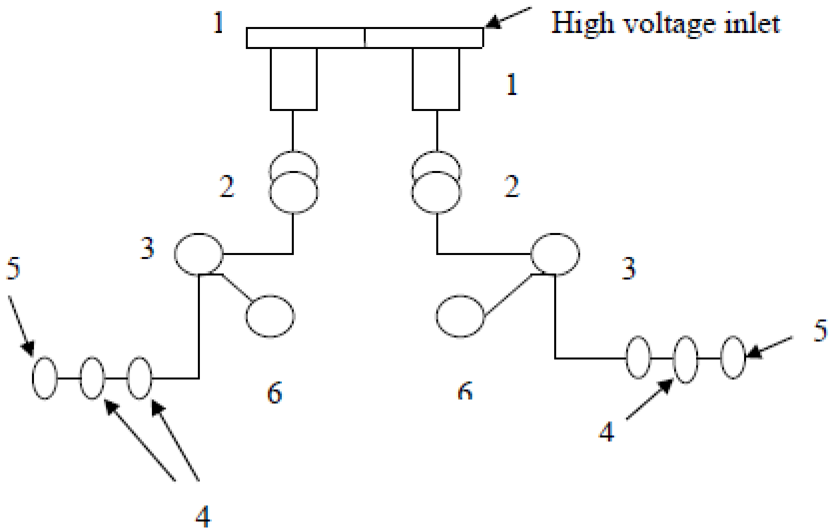

Fig 1. Substation power supply system

1. Flameproof high voltage distribution box 2. Mine transformer 3, 4 Flameproof automatic feed switch 5. Lighting transformer integrated device 6. Leak detection relay

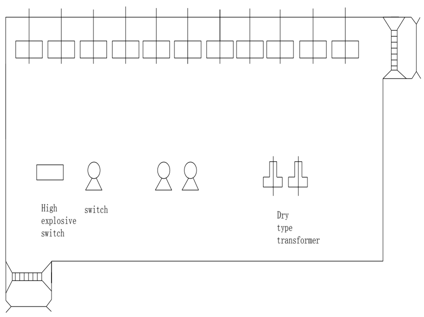

Fig 2. Arrangement of substations in mining areas

3. Power Supply Calculation

3.1 Total Grid Allowable Voltage Loss

Voltage Allowance for Voltage Level 1140V

$$\Delta UP1=U2NT-95\%UN$$
$$=1200-5\%\times1140$$

$$=117V \tag{1}$$

In the formula: U2NT——Secondary voltage of transformer

UN——Voltage on the cable

Voltage Allowance for Voltage Class 660V

$$\Delta UP1=U2NT-5\%UN$$
$$=693-5\%\times 660$$
$$=66V \tag{2}$$

In the formula： NT——Secondary voltage of transformer

UN——Voltage on the cable

3.2 The Voltage Loss of Each Online Electricity

Branch cable voltage loss according to the formula

$\Delta UZ = f\Sigma PeLZ103$) / ($Ue\gamma Ax\eta e$)

In the formula： —Load factor

ΣPe——Cable load KW

LZ——Actual cable length m

Ue——Grid rated voltage V

γ——Conductivity of cable conductor core m/(Ω.mm2)

Ax——Cable cross-sectional area mm2

ηe——Weighted average efficiency

Loss of voltage in Z1 section cable of coal mining unit

$$\Delta UZ1= (Kf\Sigma PeLZ103)/(Ue\gamma Ax\eta e)$$
$$=0.6\times 600\times 200\times 103/1140\times 48.6\times 25\times 0.9$$
$$=57.7V \tag{3}$$

Loss of voltage in Z2 section of spray pump station

$$\Delta UZ2 = (Kf\Sigma PeLZ103)/(Ue\gamma Ax\eta e)$$
$$=0.61\times 30\times 60\times 103/1140\times 48.6\times 4\times 0.9$$
$$=0.55V \tag{4}$$

Voltage loss of Z3 section cable of scraper conveyor

$$\Delta UZ3 = (Kf\Sigma PeLZ103)/(Ue\gamma Ax\eta e)$$
$$=0.65\times 264\times 200\times 103/1140\times 48.6\times 25\times 0.9$$
$$=27.5V \tag{5}$$

Voltage loss of the Z4 section of the emulsion pump station

$$\Delta UZ4= (Kf\Sigma PeLZ103)/(Ue\gamma Ax\eta e)$$
$$=0.61\times 90\times 10\times 103/1140\times 48.6\times 4\times 0.9$$
$$=2.75V \tag{6}$$

Transmitter Z5 segment cable voltage loss

$$\Delta UZ5 = (Kf\Sigma PeLZ103)/(Ue\gamma Ax\eta e)$$
$$=0.61\times 132\times 40\times 103/660\times 48.6\times 25\times 0.9$$
$$=4.5V \tag{7}$$

Shunt slot tape conveyor voltage loss of Z6 segment cable

$$\Delta UZ6 = (Kf\Sigma PeLZ103)/(Ue\gamma Ax\eta e)$$
$$=0.75\times 150\times 70\times 103/660\times 48.6\times 35\times 0.9$$
$$=7.8V \tag{8}$$

Voltage loss of cable segment Z7

$$\Delta UZ7 = (Kf\Sigma PeLZ103)/(Ue\gamma Ax\eta e)$$
$$=0.7\times 85\times 100\times 103/660\times 48.6\times 16\times 0.9$$
$$=12.9V \quad (9)$$

Voltage loss of cable segment Z7

$$\Delta UZ8 = (Kf\Sigma PeLZ103)/(Ue\gamma Ax\eta e)$$
$$=0.7\times 22\times 410\times 103/660\times 48.6\times 25\times 0.9$$
$$=23.5V \quad (10)$$

The voltage loss of the cable segment Z9 on the mountain belt conveyor

$$\Delta UZ9 = (Kf\Sigma PeLZ103)/(Ue\gamma Ax\eta e)$$
$$=0.75\times 160\times 200\times 103/660\times 48.6\times 35\times 0.9$$
$$=23.7V \quad (11)$$

3.3 Calculate Transformer Voltage Loss

Transformer voltage loss

$$\Delta UB2\% = SB[Ur\%\cdot \cos\Phi pj + x\%\cdot \sin\Phi pj]/Se \quad (12)$$

$$\Delta UB2 = \Delta UB2\%\times U2NT \quad (13)$$

In the formula:SB——Transformer load power;

Ur% ——Transformer resistance pressure drop percentage;

Ux%——Transformer voltage drop percentage

Se——Transformer rated capacity

U2NT——Secondary voltage of transformer

Dry type transformerKBSG—800/10/1.2

$$\Delta UB2\% = SB[Ur\%\cdot \cos\Phi pj + x\%\cdot \sin\Phi pj]/Se$$
$$=616.5\ [0.8\times 0.7+.43\times 0.714]\times 100\%\div 800$$
$$=.87\% \quad (14)$$

$$\Delta UB2 = 2.87\%\times 1200 = 34.44V \quad (15)$$

Dry type transformerKBSG—500/10/1.2

$$\Delta UB2\% = SB[Ur\%\cdot \cos\Phi pj + Ux\%\cdot \sin\Phi pj]/Se$$
$$=315.31\ [1.08\times 0.7+4.83\times 0.714]\times 100\%\div 500$$
$$=2.65\% \quad (16)$$

$$\Delta UB2 = 2.65\%\times 1200 = 1.8V \quad (17)$$

Mine KBS7—500/10/0.693

$$\Delta UB2\% = SB[Ur\%\cdot \cos\Phi pj + Ux\%\cdot \sin\Phi pj]/Se$$
$$=384\ [1.13\times 0.7+4.23\times 0.714]\times 100\%\div 500$$
$$=2.92\% \quad (18)$$

$$\Delta UB2 = 2.92\%\times 693 = 20.23V \quad (19)$$

3.4 Mains Cable Voltage Loss

Voltage loss of trunk cable G1

$$\Delta UGMS = UP1 - B2 - UZ$$
$$=117-.44-\ (41.21+2.75)$$
$$=38.6V \quad (20)$$

Voltage loss of trunk cable G2

$$\Delta UGMS=UP1-2-UZ$$
$$=117-31.80(27.5+0.55)$$
$$=57.15V \quad (21)$$

Voltage loss of trunk cable G3

$$\Delta UGMS=UP2-UB20\Delta UZ$$
$$=66-31.8- \ (4.5+7.8+2.9+.7)$$
$$=13.6V \quad (22)$$

3.5 The Minimum Cross-Section to Meet the Voltage Loss

$$A=\frac{K_f \sum p_e L_Z 10^3}{\Delta U_{GMS} U_e \gamma \eta_e} \quad (23)$$

In the formula: Kf—Load factor

ΣPe——Cable load KW

LZ——Actual cable length m

Ue——Grid rated voltage V

γ——Conductivity of cable conductor core m/(Ω.mm2)

ΔU_{GMS} ——Mains cable voltage loss V

ηe——Weighted average efficiency

Meet the minimum cross-section voltage loss of main cable G1

$$AG1=\frac{K_f \sum p_e L_Z 10^3}{\Delta U_{GMS} U_e \gamma \eta_e}$$
$$=\frac{0.7\times 630\times 130\times 10^3}{38.6\times 1140\times 48.6\times 0.9}$$
$$=29.78mm2 \quad (24)$$

So the minimum cross-section to meet the voltage loss of the main cable G1 is 29.78mm2.

Meet the minimum cross-section of voltage loss on the main cable G2

$$AG1=\frac{K_f \sum p_e L_Z 10^3}{\Delta U_{GMS} U_e \gamma \eta_e}$$
$$=\frac{0.7\times 354\times 90\times 10^3}{31.8\times 1140\times 48.6\times 0.9}$$
$$=14.06mm2 \quad (25)$$

Therefore, the minimum cross section satisfying the voltage loss of the main cable G2 is 14.06mm2.

Meet the minimum cross section of voltage loss of trunk cable G3

$$AG3=\frac{K_f \sum p_e L_Z 10^3}{\Delta U_{GMS} U_e \gamma \eta_e}$$
$$=\frac{0.7\times 384\times 90\times 10^3}{13.6\times 660\times 48.6\times 0.9}$$
$$=61.6mm2 \quad (26)$$

So the minimum cross-section to meet the voltage loss of the main cable G3 is 61.6mm2.

3.6 Long-Time Operating Current Check

Check the G1 cable with long operating current

$$Ica1=Kde\Sigma PN103/1.732Uncos\varphi$$
$$=0.6\times 616.5\times 103/1.732\times 1140\times 0.9$$
$$=208.1A \quad (27)$$

Check the table to allow the long-term allowable working current of 70mm2 cable to be 215A, so the cable cross section of the trunk cable G1 takes 70mm2.

Long-time operating current to verify the G2 cable

$$Ica2=Kde\Sigma PN103/1.732Uncos\varphi$$
$$=0.75\times 354\times 103/1.732\times 1140\times 0.7$$
$$=192.1A \quad (28)$$

Check the table for 50mm2 cable long-term allowable working current is 198A, so the trunk cable G2 cable cross-section take 50mm2.

Long-time operating current to verify the G3 cable

$$Ica3=Kde\Sigma PN103/1.732Uncos\varphi$$
$$=0.49\times 384\times 103/1.732\times 660\times 0.7$$
$$=235A \quad (29)$$

Check the table for 95mm2 cable long-term allowable working current is 260A, so the trunk cable G3 cable take 95mm2.

4. Conclusion

Finally select the section of each section of cable as follows:

Line Road	G1	G2	G3	Z1	Z2	Z3	Z4	Z5	Z6	Z7	Z8	Z9
Main core section mm2	70	50	95	35	4	25	4	25	35	16	25	35

5. Reference List

Table 1. Electric coal drill transformer comprehensive device

model	Rated Capacity（KVA）	Rated voltage（V）	Rated current（A）	protective device
BZ80/2.5	2.5	660-380/133	2.19-3.79/10.85	Leakage, short circuit
ZZ80-660/12	2.5	660-380/133	2.19-3.79/10.85	Leakage, short circuit
KSGZ-2.5/ 0.66~0.38	2.5	660-380/133	2.19-3.79/10.85	Leakage, short circuit

Table 2. List of commonly used KSG series explosion-proof dry-type transformers for mining

model	KSG-2.5/0.5	KSG-2.5/1.14	KSG-4/0.5	KSG-4/1.4
capacity（KVA）	2.5	2.5	4.0	4.0
Primary voltage（V）	660	1140/660	660	1140/660
Secondary voltage（V）	133， 127	133， 127	133， 127	133， 127
Resistance	4.5	4.5	4.0	4.0

Table 3. Coal Electric Drill Comprehensive Protection Controller Main Technical Features List

model	Rated voltage(V)	Rated current(A)	Protection type
ZB81-127/20	127	20	Leakage, overcurrent
ZB82-127/20	127	20	Leakage, overcurrent

Table 4. Flameproof mobile substation main technical characteristics

Main technical features	unit	KSGZY -200	KSGZY -315	KSGZY -400	KSGZY -500	KSGZY -630
Rated Capacity	KVA	200	315	400	500	630
High voltage load switch		FB-6	FB-6	FB-6	FB-6	FB-6
In line rated voltage	V	6000	6000	6000	6000	6000
Rated current into the line	A	19.3	30.3	38.5	48.2	60.6
Low-voltage feed switch		DZKD-200A/ 660，1140	DZKD-300A/ 660，1140	DZKD-400A/ 660，1140	DZKD-400A/ 660，1140	DZKD-400A/ 660，1140
Rated output voltage	V	660，1140	660，1140	660，1140	660，1140	1140
Rated output current	A	96，168	203，152	336，193	418，241	305

Table 5. Flameproof leak detection relay selection list

model	Rated voltage(V)	Model number	Rated voltage(V)
JY82-2	380	JY80	380/660
JY82-3	660	JJKB30	1140/660/380

Table 6. Commonly used technical parameters of explosion-proof feed switch in mining area

The main technical parameters	unit	DWKB 300—200	DWKB 300—400	DWKB —400	DW80 —350	DW80 —120
Rated voltage	V	1140/660	1140/660	1140/660	660	660
Rated current	A	200	400	400	350	120
Breaking ability	KA	6.5/7.5	7.5	7.5	8	7
Maximum cable diameter	mm	52	52	52	52	45
Note		With overload and leakage protection	With overload and leakage protection	With overload, short circuit and leakage protection	With overload protection	With overload protection

Table 7. Flameproof electromagnetic starter main technical parameter list

model	Rated voltage(V)	Rated current(A)	Can control the maximum power of the motor(KW)		Mechanical life(Million times)	Operating frequency(Times/time)	Isolation switch breaking capacity(KA)	Leakage blocking setting value (KΩ)
			660V	1140V				
QCKB30—30/660	660	30	20		300	600	180	7 22
QCKB30—60/660	660	60	50		300	600	360	7 22
QCKB30—60/1140	1140	60	50	85	300	600	360	22 40
QCKB30—660	660	120	100		200	300	720	7 22
QCKB30—300/1140	1140	300	250	400	200	300	1800	22 40
DQZBH—300/1140	1140	300	250	400	150	300	2400	22 40
DQBH—200/660	660	300	170		100	600	1200	22
Note	The maximum power that can be controlled is the data when η·cosφ=0.75							

Table 8. Shielded rubber cable for kV mine

Number of cores × nominal cross section (mm2)	UPQ series (voltage and other 1140V)				UCPQ series (voltage level 1140V)			
DC Resistance(R20) Ω/km	Reactance(X) Ω/km		The maximum outer diameter of the finished cable(mm)		DC Resistance(R20) Ω/km	Reactance (X) Ω/km	The maximum outer diameter of the finished cable(mm)	
			Semi-conductive eraser	Semi-conductive tape			Conductive eraser	Conductive tape
3×10+1×10	1.83	0.092	38.2	36.7				
3×16+1×10	1.16	0.090	41.2	39.9				
3×25+1×16	0.732	0.088	46.9	45.2				
3×35+1×16	0.522	0.084	49.4	47.9	0.579	0.084	52.3	50.8
3×50+1×16	0.380	0.081	55.0	52.5	0.416	0.081	59.4	57.9
3×70+1×25	0.267	0.078	61.4	59.1	0.293	0.078	65.7	63.0
3×95+1×25	0.195	0.076	67.7	64.1	0.209	0.076		
Number of cores	3 main cores and 1 ground core				3 main cores, 1 ground core, 3 control cores			

Table 9. Commonly used armored cable types and uses in mining areas

model	Cable structure	Core section Voltage(KV)			Use place
		0.5	1	6	
ZQ20	Copper core, oil-impregnated paper insulation lead, bare steel, armored		25~240	10~240	Laying within 45° and horizontal roadway, with flammable support and down hole chamber
VV20	Copper core, PVC insulation, PVC sheath, bare steel, armored	10~185	25~185	10~240	Laying within 45° and horizontal roadway, with flammable support and down hole chamber
ZQP20	Copper core, dry insulation, copper clad, bare steel, armored		4~150	16~150	Laying in a well below 45° with a height difference of no more than 100m

Table 10. Flameproof Manual Starter Main Technical Parameter List

model	Rated current (A)	Controlling the maximum power of a squirrel-cage induction motor(KW)		Fuse rated current(A)	weight(kg)
		380V	660V		
QS81A-40	40	20	25	60 80 100	63
QS81A-80	80	40	50	100 125 160 200	63
QSS81-40	40	20	25		75
QSS81-80	80	40	50		75

References

[1] Zhang Xuecheng Power supply for industrial and mining enterprises Xuzhou: China University of Mining and Technology Press, 1998.

[2] Liu Jiecai Factory Power Beijing Mechanical Industry Press, 1998.

[3] Wang Jiannan Relay protection and automatic device for power supply system of factory Beijing: Metallurgical Industry Press, 1998.

[4] Gu Yonghui, etc. Coal Mine Electrician's Handbook Volume II (below) Fourth Volume Beijing: Coal Industry Press, 1998.

[5] Chief Editor Zhang Xuecheng Power supply for industrial and mining enterprises Xuzhou: China University of Mining and Technology Press, 1998.

[6] Editor Wang Chunjiang Wire and Cable Manual Beijing Machinery Industry Press, 2002.

[7] National Coal Mine Safety Supervision Bureau Coal Mine Safety Regulations Beijing: Coal Industry Press, 2004.

[8] Chief Editor Liu Xueen Coal Power Supply Chengdu: Chengdu Publishing House, 1998.