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ELECTRIC POWER SUPPLY OF UNDERGROUND MINES FOR MACHINE PRODUCTION OF COAL

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ABSTRACT
The report summarizes results of many years of experience gained in the development and operation of the electric power supply system of machine complexes for underground coal production in the conditions of the Babino Mine belonging to Bobovdol Mines Co. at the town of Bobovdol.

INTRODUCTION

The today's mine for underground production of mineral resources is characterized by a high degree of machine implementation and automation of technological processes, big power consumers installed, large-scale concentration of operating personnel, high costs of investment construction, and a considerable amount of existing risks. The risk level is especially high in underground mines for machine production of coal.

The Babino Mine of Bobovdol Mines Co. at the town of Bobovdol is a modern mine where machine production of coal to a depth of 400 m has been carried out for more than 30 years.

During this period a considerable production experience was gained and many research and design solutions in different areas of the mining science were verified under real operating conditions.

One of the main factors being of crucial importance for the rhythmical, efficient and safe realization of production processes at the Babino Mine is the electric power system that supplies all consumers along the whole technological chain.

The report contains information about: today's achievements of the mining science and the industry that produces electrical equipment for up-to-date high-performance mining machines; a most general characteristic of the electric power consumers in the Babino Mine and the power supply circuit is presented; data for the basic electric equipment of a mechanized face with a Klöckner-Becorit complex are given; the main directions of the scientific support of Bobovdol Mines Co. provided by the Department of Mine Electrification are summarized. Some problems of urgent importance for the further development of the power supply system of the Babino Mine are defined as conclusion of the report.

1. Latest achievements regarding the electric equipment of machine complexes for underground coal production.

Table 1 contains technical data for electric motors used for driving of modern coal getters manufactured by world-famous companies and demonstrated at an international exhibition in 2000.

Table 1 imposes the following conclusions:

1. The motors used are intended for voltages of 500, 1000, 1100, 3300, 5000, or 6000 V, respectively.
2. Motors of power 300 kW each are mounted on both drums of the EDW-300LN coal getter (the company manufacturing the motors is Siemens from Germany), and motors of power 500 kW each are mounted on both drums of the EDW-450/1000 coal getter (the company manufacturing the motors is Eickhoff from Germany). Motors of type F-37 with a power of 300 kW are used on the ACE coal getters (of British Jeffrey Diemond Co., U.K.). British coal getters of series AM 500 made by Anderson Co. are equipped with one or two motors of types 2K1 or 2R1, and the coal getters of the Electra series produced by the same company are provided with electric motors of the EL type. Polish coal getters KGU of Famur Co. use electric motors manufactured by Celman Works (Poland).
3. The power of electric motors used on combined coal getters in Babino Mine is 230 kW or 350 kW, and the supplied voltage is 1000 V.

In 1991 91 combined coal getters operated in the USA, their power-oriented classification being shown in Table 2.

Australia occupies a leading position as concerns the development and implementation of most advanced machines for underground coal production. The design performance of coal getters for long faces has been increased from 800 t/h to 2500 t/h. The power installed of electric motors for coal getters is 750 kW, and the working feed rate is 10 – 12 m/s. The average 24-hour output from a face attains 10,000 t/h. At the present time design solutions connected with putting into implementation a complex with a new generation of combined coal getters are being prepared for realization. The Ulan complex involves a coal getter of Eickhoff Co. with a shearing

Table 1.

Parameters	Type of coal getter (motor)							
	EDW-300LN Siemens	EDW-400/1000L Siemens	ACE F37	Electra 500 EL12A006	AM500 2K1	AM500 2R1	Electra 1000	KGU Celman
Thickness of coal seam, m	0.8 - 1.7	2.4 – 4.4	Up to 1.2	1.2 - 6	2.6 - 3	2 - 3	1.3 – 4.5	-
Motor power, kW	300	500	300	230 X 2	375	450 X 2	375 X 2	132
Voltage, V	1000	3300 – 5000	1100	1140	1100	6000	Up to 3300	1000
Rotational speed, s^{-1}	1450	1500	1500	1500	1500	1500	1500	1440
Insulation class	F	-	F	H	H	H	H	H

drum and motor of power 1000 kW and a face conveyer with electric drive power 1050 kW. The powered support of working strength of 800 t is provided by Dowty Co. The complex output is 2500 t/h, and coal is transported by a belt conveyer with belt width of 1600 mm.

Table 2

No.	Working conditions	Type of coal getter	Motor power, kW
1	Flat seams of thickness 1.4 – 3 m	Electra 550 EDW-2L-2W	350 – 500
2	Flat seams of thickness 1.5 – 4 m	AM 500 Electra 1000 EDW-380/760	500 – 1000

A modern power supply system of voltage 10 kV for an underground coal mine has been developed and put into operation in Germany. It is expected that in near future there will emerge new electric equipment for even higher voltage.

2. Power supply network of the Babino Mine.

A main surface substation (MSS) for a voltage of 110/20/6 kV is built for supplying power to the Babino Mine and other mines of Bobovdol Mines Co. Two power transfer lines of 110 kV supply the substation. One of the power lines is 25 km long and connects the Babino substation with the Republika Thermal Power Station in the town of Pernik, and the other is 9 km long and makes a connection with the Bobovdol Thermal Power Station.

To supply powerful consumers located at considerable distances from MSS Babino, at the corresponding sites there have been built substations supplied with a voltage of 20 kV through overhead power transfer lines. Such are the substations of ventilation shafts VS-1, VS-2, VS-3, and that in the pithead of the main cage shaft (MCS). The near consumers are supplied directly with cables from MSS Babino. Such powerful consumers are the mine hoist winders (MHW) of the MCS, MHW of the main skip shaft (MSkS), nitrogen station, and ventilation installation of MSkS. To supply electric power to the underground consumers of the Babino Mine, on the principal horizon of the mine (level 292) there has been built a central underground substation (CUS) in the area of the shaft bottom of MCS and 7 section transformer substations (STS) located in different parts of the underground mine.

The most generalized characteristic of the power supply network of underground mine Babino is shown in Fig. 2. It can be reduced to the following:

1. Deep input of high voltage 6 kV into the underground mine that reaches production faces at a distance of up to 150 m.
2. Direct two-side power supplying from MSS Babino to CUS - at level 292 – and to STSs that are connected in a ring.
3. To improve the reliability of the power supply network, three rings have been formed: one for CUS at level 292, one for STS-2 and STS-9, and one for STS-6, 7, 8, 8A.
4. To supply electric power to underground consumers in the area of VS-1, there has been built an STS that is supplied by the central distribution substation CDS-VS-1. At certain moments the ventilation stream is directed upward. In order to meet the requirement of Regulations [6], an anti-leakage protection device of type RZEZS-1 developed by a team with the Department of Mine Electrification at MGU "St Ivan Rilski, led by Prof. G. Anev, Dr.Tech.Sc., has been mounted.
5. CUS at level 292 and STSs are provided with a switchgear KRU for 6 kV in which low-oil circuit breakers of type RVD-6 are mounted.
6. The mobile transformer substations are of types TKShVP, TSVP, and Siemens.
7. With certain small exceptions the power supply of all consumers is carried out at a voltage of 660 V.
8. Voltage of 1000 V is used for the operation of some of the electric motors at the mechanized production face where the complex of Klöckner-Becorit GmbH is working, namely the motors of the coal getter (1 pc.), face chain conveyer (2 pcs.), crusher (2 pcs.), and transfer conveyer (2 pcs.).
9. Voltage of 1000 V is also supplied to the same types of electric motors in the mechanized complex of Dowty Co.
10. Transformer substations of 6/1 kV are manufactured by Siemens AG.
11. CUS at level 292 and STSs are equipped with 85 low-oil circuit breakers of type RVD-6 and 43 mobile transformer substations of types TKShVP and TSVP.
12. 25,000 m of cables of type SVBT-6 with cross-sections 3 X 185 mm^2, 3 X 150 mm^2, 3 X 70 mm^2, and 3 X 50 mm^2 have been laid for the realization of the Babino Mine cable network for 6 kV.

3. Power capacities installed in the underground mine

Irrespective of the non-interrupted development of the mine after its first commission in 1974, two main periods should be considered as concerns the field of electric power supply, namely till 1986 and after 1986, when mechanized complexes for coal production from seams of thickness up to 5.5 m were put into operation after entire reconstruction of the transportation scheme and electric power supply network.

Table 3. Installed power capacities at Babino Mine

No.	Sites	Power installed, kW	
		Till 1986.	After 1986
	A) Surface premises	6 900	16 950
1.	Mine hoist winches	3200	6000
1.1	MHW of ventilation shaft No. 1 – 1 pc.	320	400
1.2	MHW of ventilation shaft No. 2 – 1 pc.	320	400
1.3	MHW of ventilation shaft No. 3 – 1 pc.	-	400
1.4	MHW of main skip shaft – 2 pcs.	1700	3400
1.5	MHW of main cage shaft – 2 pcs.	700	1400
2.	Ventilation installations	2000	5650
2.1	Main ventilation installation of VS-3	-	2500
2.2	Ventilation installation of VS-1	1000	1000
2.3	Ventilation installation of VS-2	1000	1000
2.4	Ventilation installation of MSkS	-	1000
2.5	Degassing installation of VS-3	-	150
3.	Nitrogen station	-	3500
4.	Machine-repairing workshop	750	750
5.	Administration complex	950	950
6.	Coal slurry facilities	-	100
	B) Underground premises	5100	10410
1.	Water-drainage installation	1100	1520
1.1	Main water-drainage installation at level 292	900	900
1.2	Water-drainage installation of the structural basin	-	200
1.3	Sump water drainage of 5 shafts	100	220
1.4	Water-drainage installation at level 484 of MCS	100	200
2.	Sections of mechanized coal production	1200	4200
2.1	First section	400	1300
2.2	Second section	370	1100
2.3	Third section	430	1100
2.4	Fourth section	-	700
3.	Preparation sections	1700	2490
3.1	Fifth preparation section	500	700
3.2	Sixth preparation section	600	820
3.3	Seventh preparation section	500	650
3.4	Eighth section – Investment construction	100	320
4.	Horizontal transportation	1100	2200
	Total A + B	**12000**	**27360**
	Recapitulation		
	A) Surface premises	6 900	16 950
1.	Mine hoist winches	3200	6000
2.	Ventilation installations	2000	5650
3.	Nitrogen station	-	3500
4.	Machine-repairing workshop	750	750
5.	Administration complex	950	950
6.	Coal slurry facilities	-	100
	B) Underground premises	5100	10410
1.	Water-drainage installations	1100	1520
2.	Sections of mechanized coal production	1200	4200
3.	Preparation sections	1700	2490
4.	Horizontal transportation	1100	2200
	Total A + B	**12000**	**27360**

Data about power capacities installed in the underground mine of Babino are given in Table 3 with the purpose of making comparison with world trends in power supply and electric drives of mining machines.

The transformer capacity installed in substations through which electric power is being supplied to the Babino Mine is given in Table 4.

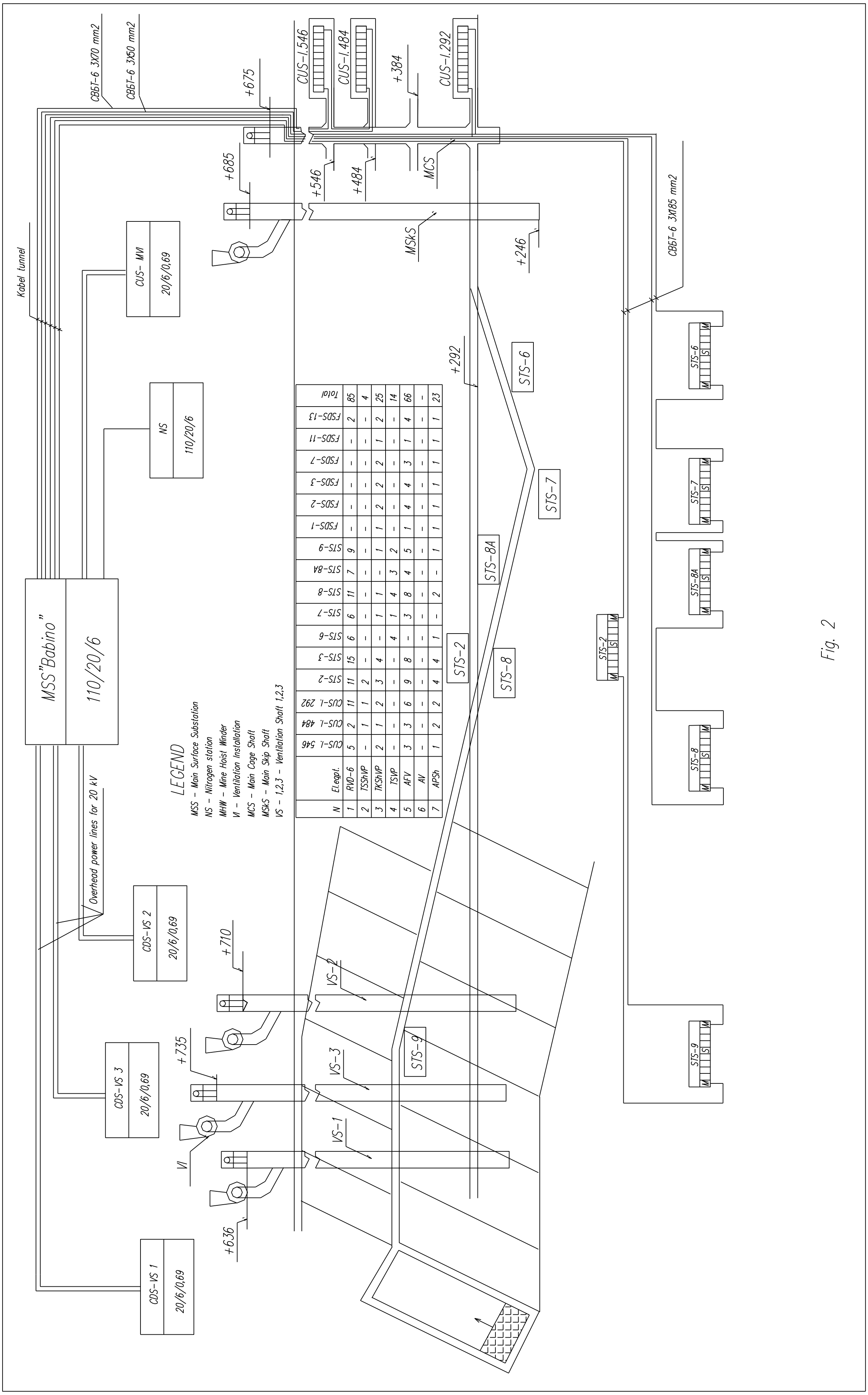
Table 4

No.	Substations	Transformers installed
1.	Main surface substation	No. 1 – 25,000 kVA, 110/20/6 kV No. 2 – 16,000 kVA, 110/20/6 kV
2.	CDS –VS-1	No. 1 – 2500 kVA, 20/6 kV No. 2 – 2500 kVA, 20/6 kV No. 3 – 100 kVA, 6/0.4 kV No. 4 - 100 kVA, 6/0.4 kV
3	CDS – VS-2	No. 1 – 1800 kVA, 20/6 kV No. 2 - 1800 kVA, 20/6 kV No. 3 – 100 kVA, 6/0.4 kV No. 4 - 100 kVA, 6/0.4 kV
4	CDS – VS-3	No. 1 – 4000 kVA, 20/6 kV No. 2 – 4000 kVA, 20/6 kV No. 3 – 630 kVA, 6/0.4 kV No. 4 - 630 kVA, 6/0.4 kV No. 5 – 160 kVA, 6/0.4 kV No. 6 - 160 kVA, 6/0.4 kV
5.	CDS of pithead	No. 1 – 1000 kVA, 20/6 kV No. 2 – 1000 kVA, 20/6 kV No. 3 – 1000 kVA, 20/6 kV No. 4 - 630 kVA, 6/0.4 kV
6.	CDS of mechanical workshop	No. 1 – 400 kVA, 6/0.4 kV No. 2 – 400 kVA, 6/0.4 kV No. 3 – 1000 kVA, 6/0.4 kV No. 4 – 1000 kVA, 6/0.4 kV

Table 5 shows the electric equipment of a section for mechanized coal production with a complex of Klöckner-Becorit GmbH.

Table 5

	Electric motors of mining machines	Installed capacity		
		Unit power	Qty.	Total power
1.	Coal getter	380 kW	1	380 kW
2.	Face chain conveyer	132 kW	2	264 kW
3.	Chain transfer conveyer	75 kW	2	150 kW
4.	Oil station	75 kW	2	150 kW
5.	GTL Gvarek - 1000	95 kW	2	190 kW
6.	Crusher	75 kW	2	150 kW
7.	Additional equipment	-	-	116 kW
	Total power			1400 kW
	Power train of composition:			
1.	Siemens underground transformer, U_1 = 6000 V, U_2 = 1000 V	630 kVA	2	
2.	Control station of type L_{11} - U_H = 1000 V, I_H = 1200 A		1	
3.	Control station of type L_{12} - U_H = 1000 V, I_H = 400 A		2	



N	El.eqpt.	CUS-I. 546	CUS-I. 484	CUS-I. 292	STS-2	STS-3	STS-6	STS-7	STS-8	STS-8A	STS-9	FSDS-1	FSDS-2	FSDS-3	FSDS-7	FSDS-11	FSDS-13	Total
1	RVD-6	5	2	11	11	15	6	6	11	7	9	-	-	-	-	-	2	85
2	TSShVP	-	1	1	2	-	-	-	-	-	-	-	-	-	-	-	-	4
3	TKShVP	2	1	2	3	4	-	1	1	-	1	1	2	2	2	1	2	25
4	TSVP	-	-	-	-	-	4	1	4	3	2	-	-	-	-	-	-	14
5	AFV	3	3	6	9	8	-	3	8	4	5	1	4	4	3	1	4	66
6	AV	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7	APSh	1	2	2	4	4	1	-	2	-	1	1	1	1	1	1	1	23

Fig. 2

4.Scientific support of the activities of Bobovdol Mines Co provided by the Department of Mine Electrification.

In connection with the exceptional importance of this issue it should be considered and analyzed individually. For this reason only some basic moments and trends in the scientific collaboration of many years between MGU “St Ivan Rilski” and Bobovdol Mines Co. will be pointed out in this report.

This collaboration could be generalized in the following basic directions:

1. Training of higher education specialists with a bachelor or master degree.
2. Improving the qualification of the chief executive personnel.
3. Participation of MGU’s researchers and teachers in expert committees discussing issues, problems and tasks connected with the development of Bobovdol Mines Co.
4. Regular periodic revisions of the Regulations on Technical Safety of Coal Production in Underground Manner (V-01-01-01).
5. Development and implementation of leakage protection devices for 6-kV cable network.
6. Re-designing existent leakage protection devices for cable networks of 1140 V.
7. Performing tests of electric equipment with explosion-proof design for mines.
8. Making expert assessments and providing consultations on diverse issues in the field of electric power supply and relay protection.

5. Important problems to be examined and solved in the field of electric power supply to the Babino Mine.

The production experience gained during the many years of operating the power supply system of the Babino Mine of Bobovdol Mines Co. shows there are many unsolved issues that limit and in certain cases reduce the effectiveness and safety of the underground mechanized coal production.

1. The optimization problem providing a scientifically substantiated relationship between mine conditions of coal seams in Babino Mine, necessary installed capacities of mining machines and rated network voltage has not been solved yet.
2. The task of determining the reliability of the power supply system depending on the productivity of production and preparation faces and the provision of technical means for its practical realization is of prime importance.
3. Substantiation, development and implementation of advanced systems of electric drive and control for various machines and mechanisms as a principal source of realizing considerable savings of electric power and increasing their working capacities.
4. Implementation of modern starting equipment with increased information resources, which should be understood as improving their structural scheme for providing continuous diagnostic information about their condition.
5. Optimization of repairing cycles of the electric mine equipment as well as of the amount of their preventive maintenance; development and implementation of an efficient program of technical maintenance and repair works for the entire complex of electrical and mechanical equipment with the purpose of providing maintenance according to the “technical condition”, and not in connection with failures as it is the case for the time being.
6. It can be easily explained why for the conditions of an underground mine of the type of Babino the requirements of the Regulations of Labor Safety [6] for verification of the faultless condition of devices for non-interruptible insulation monitoring and for protective turning off of the power supply network “before the beginning of each shift” cannot be accepted any more as a solution improving the safety in using electric power in underground coal mines. Finding a new, up-to-date solution of this problem is one of the topical tasks to be performed.
7. The electric power became the main driving force in the underground coal production in nearly all countries of developed mining industry. At the same time the statistical data demonstrate that the electrical power is one of the main causes of fire and explosion occurrences in underground coal mines and of electric current accidents.

In their majority the existent regulation documents concerning technical and labor safety are based on a qualitative approach in determining the conditions of safe application of electric power in underground coal mines, not defining quantitatively the level of safety. This represents an up-to-date problem of critical importance that is being studied by many research and university teams in countries of developed mining industry.

8. Development and implementation of protection devices against leakages in electric networks supplying power to regulated thyristor drives. Development of new means for protection against short-circuit currents in applications connected with the use of regulated thyristor drives.
9. Selection and realization of solutions for substantial reduction of the total mining consumption of electric power as well as of the power consumption of individual technological processes.

CONCLUSIONS

Based on the presentation above the following conclusions have been derived:

1. If compared to latest achievements of mining science and practice there are modern solutions implemented in the Babino Mine as far as the installed equipment and power supply system used are concerned, but lagging behind the tendencies of today can be observed as well.
2. As regards the rated supply voltage of electric motors in the Babino Mine a considerable lagging is found in comparison with today’s achievements and trends.
3. Evaluating comprehensively the experience gained in many years of designing and operating electric power systems for underground coal mines, including those in the Babino Mine, imposes also the obligatory conclusion that today’s requirements of mining organization and production have led to the formation of a number of new problems and tasks demanding urgent investigations and solutions.

These problems are even more urgent as concerns such high-risk production processes as underground coal mining.

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