ELECTRIC POWER SUPPLY OF UNDERGROUND MINES FOR MACHINE PRODUCTION OF COAL

Evtim Kartselin
Roumen Istalianov
“St Ivan Rilski” University of Mining and Geology, Sofia 1700, Bulgaria
E-mail: rgi@mgu.bg

Petar Petrov
Sashko Vasilev
Bobov dol Mines Co., Bobov dol

Lyudmil Todorov
Nikolay Nikolov
Minproekt Co., Sofia

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
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.

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.

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, TSV, 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 TSV.
12. 25,000 m of cables of type SBT-6 with cross-sections 3 X 185 mm², 3 X 150 mm², 3 X 70 mm², and 3 X 50 mm² 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>
<thead>
<tr>
<th>Parameters</th>
<th>Type of coal getter (motor)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness of coal seam, m</td>
<td>EDW-300LN Siemens</td>
</tr>
<tr>
<td>0.8 - 1.7</td>
<td>2.4 - 4.4</td>
</tr>
<tr>
<td>Motor power, kW</td>
<td>300</td>
</tr>
<tr>
<td>Voltage, V</td>
<td>1000</td>
</tr>
<tr>
<td>Rotational speed, s⁻¹</td>
<td>1450</td>
</tr>
<tr>
<td>Insulation class</td>
<td>F</td>
</tr>
</tbody>
</table>

Table 2.

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.

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 Republika Thermal Power Station in the town of Pernik.

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:

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

Table 2.
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
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.
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 [8] 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.

REFERENCES

Anev G.A. Investigation of 6-kV Power Distribution Networks in Bulgarian Open Mines and Development of Protection
Devices for These Networks (in Bulgarian). – Author’s Synopsis of a Dissertation Thesis for Acquiring the Scientific Degree of Doctor of Technical Sciences. Sofia, 1975


Shutskiy V., Anev G., Dankov E. Electrical Safety in Mining Enterprises (in Bulgarian), Sofia, Tekhnika, 1980.


Recommended for publication by Department of Electrical Engineering, Faculty of Mining Electromechanics