50 years University of Mining and Geology "St. Ivan Rilski"
Annual, vol. 46, part III, Mechanization, Electrification and Automation in Mines, Sofia, 2003, pp.129-131

SAFETY ANALYSIS OF THE POWER SUPPLY SYSTEMS IN OPEN-AIR MINES OF BULGARIA

Todor Varbev

University of Mining and Geology "St. I. Rilski",
Sofia 1700, Bulgaria,
E-mail: vat@mail.mgu.bg

ABSTRACT
This article deals with comparative safety analysis of the open – air mines in Bulgaria. The data of failures are collected and investigated for a long time period. Classification of failures by reason of events is presented. Distribution functions of the failures are estimated and compared. All statistical researches are carried out using **MATLAB** and **STATGRAPHICS** packages

The power supply systems of the mines are important element in structure of the industrial mining companies. Both the normal technological process and the breakdown situations depend on the safety work of these systems.

This article deals with failure analysis of the power supply systems of the open – air mines "Chucurovo", "Hristo Botev" and "Kremikovci". The first two enterprises mine coals and the third enterprise mines iron crude ore and supplies the metallurgical engineering company (having the same name), and is a structure element of this company.

The electrical power supply systems oh these enterprises are similar as a type. The loads are supplied with electrical power by a general reception point denoted as general mining substation (GMS). The national power supply system is connected with the GMS by its primary high voltage side. The connection of the GMS for each mine is built as follows: substation "Babino" supplies the mine "Hristo Botev" by electrical power line with 110kV voltage, substation "Taygova" supplies the mine "Kremikovci" by the same type electrical power line. The substation "Chukurovo" is connected by electrical power lines of 35 kV and 20Kv voltage, which is risen by voltage step-up transformer to 35 kV voltages.

The loads of mines are supplied by a longitudinal scheme of connection with radial located electrical air power lines with 6 kV voltages. They are realized by conductors of type AS.

The electrical power lines of the mine transform into electrical air power lines with conductors type Cu and they supply the mobile switching points and mobile transformer points. The loads are supplied by cable lines with 6 kV or 0,4 kV voltages.
The summary data of the air and cable electrical power lines are shown in Table 1.

Table 1

LineType	Air el. line		Cable line		Total length km
Company	Length, km	Type Section mm^2	Length, km	Type Section mm^2	
"Chukurovo"	11,41	AS-90	3,5	FEC-16	14,91
"Hr.Botev"	5,800	AS-35	7,7	FEC-16	13,500
"Kremikovci"	9,310	AS-50	4,740	FEC-16	14,05

The total lengths of the electrical power supply systems for the three mines are approximately equal. The electrical air supply lines of the mines "Chukurovo" and "Kremikovci" have length of 76,5% and 66,3% of the total length respectively.

The number of the main loads, which make the basic mining and dump formation, is uniform in these enterprises.
Mines have following equipment:

- Mine "Chukurowo" – 14 excavators and 7 drillings rig of different types.
- Mine "Hrosto Botev" – 14 excavators and 6 drillings rig of different types.
- Mine "Kremikovci" - 12 excavators and 4 drilling rigs.

The terminals of the mines are as follows:

- Mine "Chukurowo" (I) – 6 terminals.
- Mine "Hrosto Botev" (II) 3 terminals.
- Mine "Kremikovci" (III) –5 terminals.

The data of failures are collected for different periods of the discussed enterprises. The statistical analysis is done by the software package STATGRAPHICS (1996). The basic sample parameters are obtained for all data collections (Varbev et. al.; 2001; Varbev et. Al. ; 2003; Georgiev et. Al. 2003).

Table 2 shows length of the time period, number of the failures, average $\bar{x}$, variance **D** and standard deviation **S**.

Table 2

Mine	Period, month	Failures	Mean $\bar{X}$	Variance, D	Standard deviation, S
"Chujurovo"	48(60)	2502 (1437)	52,125	535,984	23,1513
"Hr.Botev"	23	557	24,2174	49,4506	7,03211
"Kremikovci"	24(48)	519 (1156)	24,625	74,1576	8,61148

The investigation of this type was done more over 30 years ago. The results from this investigation are published in (Anev G. 1974) and may be compared with the results from this article. It could be seen that the number of the failures from the mine "Chukurovo" is increased while in the mine "Kremikovci" this value is approximately equal for the both investigations.

The articles (Varbev et. al.; 2001; Varbev et. al.; 2003; Georgiev et. al. 2003) analyze the failures, reasons of the operation of protections.

In mine "Chukurovo" the over – current protection have operated 56,53% times and single – phase earth – fault protection have operated 46,47%.

In mine "Hristo Botev" the over – current protection have operated 23,5% times and single – phase earth – fault protection have operated 76,5%.
In mine "Kremikovci" the operation of the protections are: over – current protection have operated 34% times and single – phase earth – fault protection have operated 55%.

The both protections have operated in 11% of the events. Same important safety parameters of the power supply systems are estimated too. These parameters are: frequency of the failures ϖ ; time between the failures $\mathbf{T_И}$; time of the restore of the power supply $\mathbf{T_В}$; coefficient of condition of a system $\mathbf{K_Г}$; coefficient of the idle time $\mathbf{K_П}$.

These coefficients are calculated as follows Rosanov M.,(1987):

$$\boldsymbol{\omega} = \frac{\mathbf{m}}{\mathbf{n.T}}, \text{ year}^{-1};$$

$$\mathbf{T_И} = \frac{\mathbf{8760}}{\boldsymbol{\omega}} \text{ hour};$$

$$\mathbf{T_В} = \frac{\mathbf{1}}{\mathbf{m}}\sum_{\mathbf{i=1}}^{\mathbf{m}} \mathbf{t_i} \text{ hour};$$

$$\mathbf{K_Г} = \frac{\mathbf{T_И}}{\mathbf{T_И} + \mathbf{T_В}};$$

$$\mathbf{K_П} = \frac{\mathbf{T_В}}{\mathbf{T_И} + \mathbf{T_В}},$$

where: **m** – number of the failures, **n** – number of the similar observable elements; **T**-time interval of the observation of events (years); **t**i – time of the restore of power supply network at **i** – failure.
The results are represented in Table 3.

Table 3. Safety coefficients .

Mine	ω(y^{-1})	ω_1	$T_И$ (h)	$T_В$ (min)	$K_Г$	$K_П$
I	625.5	3.469	14.0	73.91 (1h14м)	0.919	0.0809
II	290.56	1.794	30.15	81.40 (1h22м)	0.9569	0.04306
III	259.5	1.539	33.75	224.05 (3h44м)	0.90014	0.09986

Failures of the three enterprises are compared by the frequency of the failures per unit length of the supply line obtained by the formula

$$\boldsymbol{\omega} = \frac{\mathbf{m}}{\mathbf{nL}\,\Delta t}, \text{ failures / km.month.}$$

where: **L** – total length of the electrical power supply (see Table 1.); **Δt** – time period (months)

The derived data are represented in Table 3. The frequencies of the failures ω and ω_1 are maximum number of the mine "Chukurovo". These frequencies are approximately equal for the mines "Hristo Botev" and "Kremikovci" but are two times less than failures in the mine "Chukurovo".

This fact is expressed by the time between the failures $\mathbf{T_И}$. This time for the mine "Chokurovo" approximately two failures per 24 hours and over one failure per 24 hours for the other mines.

It could be seen from Table 3 that in the first two enterprises the failures are repaired for equal time, while for the mine "Kremikovci" this time is three times long. This fact gives influence to the coefficients $\mathbf{K_T}$ and $\mathbf{K_П}$.

The distribution of the failures is derived for the three investigated enterprises and the probability density functions are represented in (Varbev et. al.; 2001; Varbev et. al.; 2003; Georgiev et. al. 2003). The following distributions are obtained: for the mine "Chukurovo" the failures are described by the Gamma distribution. For the mine: "Kremikovci" the distribution of the failures is Normal or Weibull with significant values of the Kolmogorov test and test of the Pearson λ and χ^2 . For the mine "Bobov Dol" the possible choice is between the distributions Normal , Weibull and Gamma, ordered by the values of the test in decreasing sequence.

The following conclusion could be drown so far:

1. It is difficult to analyze failure reasons in the power supply system because there is lack of the information about "unselective switches".

2. The great part of the failures appears after operation of the single – phase earth – fault protections for the mines "Hr. Botev" and "Kremikovci" while in mine "Chukurovo" the operations of the over - current protection and earth – fault protection are equal one toeach other.
3. It could be emphasized for the above conclusions that the equipment of the power supply system as: cable lines, distribution boxes, junction boxes, switching points, mobile switching point, is a serious reason for the safety operation of the system.
4. The basic estimates of the summary statistics parameters are derived for the discussed mines after 30 years lack of statistical investigations.
5. It could be said that for the estimate of the failures distributions for the mines "Bonov Dol" and "Kremikovci" the additional investigation could be done.

REFERENCES

Magnugistics Inc., Statgraphics, User Guide,1996.

Varbev T., Tz. Georgiev, Failure Analysis of the Electrical Power Supply System of the Open – Air Mine, Vi – National Conference with Foreign Participations of Open Air Mining of Mineral Resources, Nesebar, 2001, pp. 373 – 378.

Varbev T., Tz. Georgiev, P. Petkova, Data Failure Analysis Of Power Supply System In Mine "Kremikovtzi"

Georgiev Tz. ,Varbev T., , Failurs Of The Power Supply System Of Open – Air Mine "Hristo Botev" Of Mines "Bobov Dol" Ltd.

Anev G., Investigation of power supply networks of the open - air mines in Bulgaria and design of the safety equipments, Thesis for the "Doctor of Science" degree, Sofia, 1974 (in bulgarian).

Rosanov M., Safety of the Power supply Systems, Thehnika, 1987 (in bulgarian),

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