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DATA FAILURE ANALYSIS OF POWER SUPPLY SYSTEM IN MINE "KREMIKOVTZI"

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ABSTRACT
This article deals with safety analysis of the electrical power supply systems in mine "Kremikovtzi". The data of failures are collected and investigated for a two years time period. Classification of failures by reason of events is presented. All statistical researches are carried out using **MATLAB** and **STATGRAPHICS** packages.

The power supply systems are important key subsystem in the structure of the industrial manufacturing companies and also in mines. The mine "Kremikovtzi" is one of basic enterprises that feed with the crude the metallurgical engineering company "Kremikovtzi". The safety of the mine power supply system is of fundamental precondition for carrying out the continuous technological process and feeding the metallurgical company with crude ore.

The mine power supply system is mixed type using air and cable lines. The electric power supply of the mine is connected with the substation "Taygova" by 6kV voltage. The national power supply system is connected with 110kV - voltage of the primary side of substation "Taygova". The mine includes two distribution substations denoted as "DS1" and "DS2". The substation "Taygova" by same air electric power lines denoted as "Mine 1", "Mine 2", "Shaft" and "Tower" supplies these distribution substations.

Lattice towers and conductors of type AS-150 with total length of 8600m build up the electric power lines. The substation "DS1" supplies the loads in the mine by radial scheme with air electrical power lines denoted as "3", "4" and "5". This substation by other terminals "8" and "9" supplies the waste banks and embankment of the mine.

The substation supplies the loads of the "mine drainage shaft" and mine drainage complex of the mine. The loads that work on the east side of the mine and goods railway station are supplied by the (air) terminal "13.

The air electrical supply lines that supply the load in the mine are two types: stationary and mobile. The stationary part of the power supply lines are built up by conductors of type AS-50 while mobile electrical lines is built up by conductors of type M-16. These electrical power lines supply the mobile transformer points and the mobile switching points. The mobile supply points are connected with the loads of the mine, excavators with 6kV voltage and drilling rids, and pumps with 0,4 kV voltage, and supply these components of the technological process. The total length of the cable lines and air lines, coming out from the substations "DS1" and "DS2" is 14,05 km.

The investigation is done for the period 1.09.2000 - 1.09.2002 (two years). The data are collected from the massage log journals of the substations "DS1" and "DS2", which apply the electrical power system of the mine.

The total number of failures of the investigated period is 591 failures classified by substation as: for "DS1" they are 382, and for the "DS2" – 209 failures. The data are represented in Table 1.

Table 1. Failures of the substations "DS1" and "DS2".

Month	Year	Failures	Terminal	Failures
09	00	26	№3	123
10	00	26	№4	42
11	00	38	№5	142
12	00	15	№8	27
01	01	18	№9	48
02	01	40	№13	153
03	01	25	Pump №1	7
04	01	30	Pump №2	0
05	01	34	Pump №3	6
06	01	34	Pump №4	1
07	01	29	Pump №5	0
08	01	20	Pump №6	24
09	01	30	Pump №7	1
10	01	15	Pump №8	17
11	01	30		
12	01	6		
01	02	27		
02	02	19		
03	02	29		
04	02	27		
05	02	13		
06	02	11		
07	02	21		
08	02	28		
Сума	-	591		

The table shows that the maximum number of failures are obtained from the terminals "13", "5", and "3", and they are 153, 142 and 123 respectively. These numbers of the failures are 70,73% from the total number of the failures. The maximum number of the failures was recorded in February 2001, and the minimum number of the failures was recorded in December 2001. The failures are recorded in other nine terminals but its number is less than 30% of the total number of the failures. The failures are not met for the terminals "Pump №2" and "Pump №3". The next table shows the reasons of the operation of protection for a one year period. The results are: the over – current protection was operated 199 times or 34%, while the single– phase earth – fault protection was operated 329 times or 55% of the total number of failures.

Table 2.

№	Protection operation	9.00 – 8.01г	9.00 – 8.02г	Брой
I	Over-current protection	148	51	199
1	Short connection in junction box	6	4	10
2	Short connection in cable separation	1	-	1
3	Lightning storm	-	-	-
4	Unselective switches	138	47	185
II	Earth—fault protection	160	169	329
1	Short connection in junction box	15	11	26
2	Short connection in cable separation	1	2	3
3	Lightning storm	-	-	-
4	Unselective switches	144	156	300
III	Over-current protection, Earth—fault protection	27	36	63
1	Short connection in junction box	1	3	4
2	Short connection in cable separation	-	1	1
3	Lightning storm	-	-	-
4	Unselective switches	26	32	58

The operation of the two protections simultaneously was done 63 times, which is 11% of the total number of failures. The table 2 shows that 543 times (91,88%) the unselective switches are met in set of the failures. This fact presents one of the difficulties of the data analysis. The rest of the failures are classified as follows: "short connection in junction box" - 40 failures, "short connection in cable separation" – 4 failures and 3 failures are from "lightning storm".

The statistical analysis is done by software package STATGRAPHICS (1996). The results from the analysis is represented in Table 3.

Table 3. Summary statistics

Count	24
Average	24,625
Median	26,5
Geometric mean	22,7809
Variance	75,1576
Standard deviation	8,61148
Standard error	1,75781
Minimum	6,0
Maximum	40,0
Range	34,0
Coefficient of variation	34,9705%
Sum	519,0

Frequency tabulation is used for preliminary investigation of the population distribution of the failure sample. The results are represented in Table 4.

Таблица 4. Frequency tabulation of the failures.

No	Class	M.P.	Frec.	Wi	Frec.	∑Wi
0	-∞-0		0	0,0000	0	0,0000
1	0-8,333	4,1667	1	0,0417	1	0,0417
2	8,333-16,667	12,5	4	0,1667	5	0,2083
3	16,667-25,0	20,833	5	0,2083	10	0,4167
4	25,0-33,333	29,1667	10	0,4167	20	0,8333
5	33,333-41,667	37,5	4	0,1667	24	1,0000
6	41,667-50,0	45,833	0	0,0000	24	1,0000
7	50,0-∞		0	0,0000	24	1,0000
	Mean Value = 24,6225			Standard deviation = 8,61148		

Frequency histogram is shown in Fig.1 based on results from table 4.

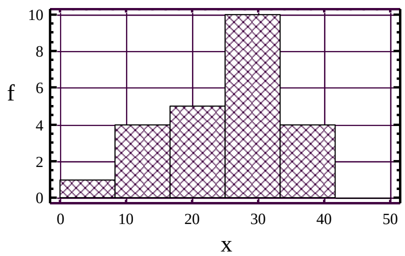

Figure 1. Histogram of the failures.

The labels in figure are: **x** – number of the failures, **f** – frequency of the failures.

It could be assumed from the preliminary calculation of the parameters by Bekeron (1975) and the shape of the histogram that the failure data comes from normal distribution, gamma or Weibull distributions.

Two tests are run to determine whether the variable of the failures can be adequately modeled by a normal distribution, gamma or Weibull distributions.

The chi-square test divides the range of the investigated variable into nonoverlapping intervals and compares the number of observations in each class to the number expected based on the fitted distribution. The Kolmogorov-Smirnov test computes the maximum distance between the cumulative distribution of the variable and the CDF (cumulative distribution function) of the fitted theoretical distribution.
In this case, the following P – values are derived:

- Normal Distribution,

  Kolmogorov-Smirnov test $P[\lambda] = 0{,}679416$,

  Pearson test $P[\chi^2] = 0{,}586082$;

- Weibull Distribution,

  Kolmogorov-Smirnov test $P[\lambda] = 0{,}658172$,

  Pearson test $P[\chi^2] = 0{,}586082$.

Probability density functions are represented as follows:

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}}.e^{\frac{-(x-\mu)^2}{2\sigma^2}},$$

where μ is mathematical expectation (population mean), σ is standard deviation .

The following estimates are obtained $\mu = 24{,}625$; $\sigma = 8{,}61148$. The distribution is represented in Fig.2 based on the derived estimates

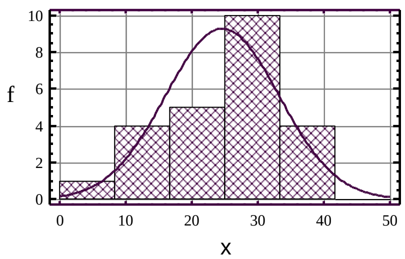

Figure 2.

The probability density functions of the Weibull distribution is

$$f(x) = a.b^{-a}.x^{b-1}.e^{-\left(\frac{x}{a}\right)^b}, x \geq 0,$$

where a is scale parameter , and b is shape parameter of the distribution.

The estimates of the parameters are : $a =$ 27.4534; $b =$ 3.32119.

Probability density functions of discussed distribution is represent in Fig. 3.

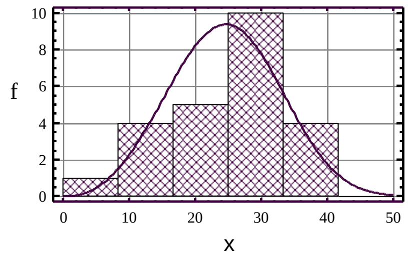

Figure 3.

The labels in figures are: **x** – number of the failures, **f** – frequency of the failures.

CONCLUSIONS

The following conclusions could be drown so far:

1. The lack of information about “unselective switches” is a difficult problem for data analysis of the power supply system.
2. The great part of the failures appears after operation of the earth – fault protection. This fact shows that the problems are due to some equipment element such as cable lines, distribution boxes, junction boxes, switching points, mobile switching point et. s.
3. The P – values show that two probability distributions are possible. The exact estimation of the distribution could be establishes on the next step of the investigation based on the long data sample.
4. The result from this investigation shows that the design problems of the equipment units are very important for the reliability of the power supply system for example junction boxes, cable separation boxes et. s.
5. The summary statistics parameters are calculated and investigated.

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