Exported Potentials in the Grouding System of the Mine „Brod – Gneotino ”

Nikolce Acevski[1] and Alekandar Jurukovski[2]

Abstract - **This paper is presenting the problem of exported potentials in the grounding system of the mines with surface exploitation of minerals. An example is taken from mine Brod - Gneotino near Bitola which is a complex technological technical unit which consists of multiple items such as bulldozers, power stations, belt conveyors, transformers and other consumers. Using the software package MATLAB - Simulink estimated voltage of touch-up and step grounding of all places, and then exceeds to the assessment of conditions of safety of too high touch voltages and steps around various types of grounding.**

Keywords - **grounding system, touch voltages and step.**

I. Introduction

Export of electricity potentials in buildings in case of fault to ground in HV transmission network is a problem that is given attention because the dangerous consequences that it may cause. This paper was reviewed mine "Brod - Gneotino" which is a complex technological and technical unity and it 6kV cable distribution network is connected to the power transformers T1 and T2 of TS 110/6kV and whose role is to supply powered surface mine in mine. The mine is given special consideration to meet the requirements for safety in 6kV cable network in the 0.4 kV network. The specificity of the elements of the grounding system Mine (earthing Plant 6 / x kV, operating machinery, excavators, transporters, etc.). Despite the complete earthing galvanic connection of the entire system through the protective conductors of cables EpN 78, are also required to ensure conditions of safety regulations defined by the potential of 6kV neutral grounding point, because the mine where about mining systems is always present working staff who serve their level maintenance and occasionally moving (along with their earthing).

When a single-phase short circuit in the plant 110 / 6 kV / kV at the mine or the 110 kV network in the vicinity of the mine that power is distributed to all the earthing system (earthing of the poles of 110 kV transmission lines, earthing of substation110/6 kV and medium earthing the individual consumers). Because mutual galvanic connection of the earthing powered facilities in 6 kV input power network in case of any fault to ground 110 kV network, the metal parts of equipment in the mine could occur potentials considerably higher than the potential of the surrounding soil.

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II. Modelling Grounding System

2.1 Modelling mesh grounding and calculation of its grounding resistance.

The TS 110 / 6 kV Brod - Gneotino is set earthing mesh that connects all electrical equipment in the plant. Mesh grounding affecting the entire area inside the fence, beyond which the plants are located 110 and 6 kV, with ancillary facilities. About grounding is placed outside a fence that is separated from the plated mesh grounding.

In this paper calculations are made, more grounding resistance and the corresponding values are shown in Table 1, depending on the applied method.

Table 1. Grounding resistance which was obtained in several ways

Applied methods	Resistance $R_{TS}\,[\Omega]$
Software - Mrez.zaz	0,783
Model of a circular plate	0,657
Formula Laurent	0,787
Formula Sverak	0,777
Formula Thapar	0,908
Formula Nahman	0,796

From Table 1 we can conclude that the formula of Nahman and Laurent are gained about the closest value to the value of resistance circulation which was obtained by using the software Mrez. zaz.

In this paper calculations are made for the percentage values of touch voltage and step Ed% and Ec% and the TS 110 / 6 kV by using the software package (Zazem), and is: Ed = 30.2% and Ec = 5,8%.

2.2 Modeling of overhead lines with protective rope

Overhead lines also participate in exports of currents and potentials in case of short links in the 110kV system, and because any such line should be represented in an appropriate manner so-called "π- replacement scheme". Protective rope is of the type OPGWAA / St 77/43 - 10,3 Fe from 50 mm^2, and a range of power lines lj = 320m.

Impedance of the protective conductor (cable) for a span is calculated according to the formula:

$$\overline{Z_{r1}} = \left(r_j + jx_j\right)\cdot l_j = \left(1{,}322 + j0{,}31\right)\Omega \qquad (1)$$

r_j, x_j - active and inductive resistance of the rope per km length

$$r_j = \rho_j \frac{10^3}{S_j} = 4{,}13\Omega / km \qquad (2)$$

$$x_j = 0{,}1445 \cdot \log \frac{2 \cdot De}{d_j} + 0{,}016 \cdot \mu_r = 0{,}97\Omega / km \qquad (3)$$

dj - diameter of the rope for which Sj = 50mm^2 is: dj = 0,009 m.

De - equivalent distance between the protective conductor and Phase conductors of power lines (m).

Rs - grounding resistance of each of the columns, which for 110 kV is the average power lines: Rs=10Ω.

The equivalent impedance of the grounding of power lines is:

$$\overline{Zek.v} = \sqrt{\overline{Zr_1 \cdot Rs}} - \frac{\overline{Zr_1}}{2} = (2{,}97 + j1{,}61)\Omega \qquad (4)$$

2.3 Modelling 6kV cables and characteristics of their models

6 kV cables used for distribution of electricity in 6 kV input power network in the area of the mine, despite the power conductors (three phase conductors), have more and signal conductors or a conductive sheath. Signal conductors (ie conducting sheath) are isolated in terms of land and phase conductors, and the emergence of single-phase short links in 110 kV network through them the export potentials in the grounding system of the mine.

Thus, each cable, watched with its return route across the ground, may be presented with a I-replacement scheme, ie an ordinal impedance Z = z·l. Thus, ie longitudinal impedance impedance per unit length in this case i will be calculated using known formulas Carson-'s:

$$\underline{z} = r + jx = \left(\frac{1000}{k \cdot s} + 0{,}05 \right) + j \log \frac{D_e}{D_S} \qquad (6)$$

k [Skm/mm^2] - conductivity specific material from which is made cable signals;

S [mm^2] - total cross section of signal cables;

De [m] - the equivalent depth of return current path across the ground (soil);

ρ [Ω · μ] - average value of the specific resistance of the terrain through which the cable passes;

Ds [m] - own middling geometric distance band signal conductors of the cable.

$D_S = \sqrt[3]{r_p \cdot (D/2)^2}$ - when the signal cable has three conductors, placed in the vertices of an equilateral triangle with side D / 2.

r_p is the radius which is indicated by the conductor signal cable, and D is the outside diameter of the conducting sheath.

2.4 Modelling of grounding of TS 6 / x kV / kV

Each TS 6 / x kV will be modeled with transverse mounted active resistance R. The calculation of resistances is done using the well-known model of high potentials, and to this end it is necessary to know the specific resistance to ground and geometry of each grounding.

2.5 Modelling of auxiliary groundings

Auxiliary groundings of the various types of mining facilities and machines are modeled in an identical manner as the town's transformer stations grounding TS 6 /x kV / kV. It should be noted that cases are possible when more diverse plated grounding are connected to the same grounding spot. In that case, the replacement scheme grounding system will emerge as active resistors connected in parallel as there are various grounding, cadmium connected observed grounding places.

2.6 Modelling the surface grounding

2.6.1 Rails and strips placed on the surface of the earth

Resistance to ground of the sliding bar or a length l and an equivalent diameter d, placed on the surface of the earth, with the average specific resistance of soil is ρ, will be:

$$R = \frac{\rho}{\pi \cdot l} \ln \frac{2l}{d} \qquad (7)$$

If the bar is on one end tied to the grounding system and thus is free of its other end, then it will be presented with a transversely mounted active resistance R.

The picture we are given is a replacement scheme of the track when the two ends are connected to different plated grounding.

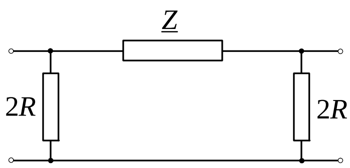

Fig. 1 π- replacement scheme

The value of the parameter Z is calculated by the relation:

$$Z = \left[\frac{\rho_{Fe} \cdot l}{S} + 0{,}05 \right] + j \left[0{,}1445 \log\left(\frac{2D_e}{d} \right) + 0{,}0157 \mu_r \right] \qquad (8)$$

ρ_{Fe} [Ω·mm^2/km] - specific resistance of iron

l [km] - the length of rail / bar;

S [mm^2] - cross section of rail / bar;

μ_r - relative magnetic permeability of the material;

De [m] - the equivalent depth of return current path across the country, calculated according to Carson - 's model, using the following relation:

$$D_e = 658\sqrt{\rho / f} \qquad (9)$$

d [mm] - equivalent diameter of the bar / rail, with approximately valid $d = 1{,}128 \cdot \sqrt{S}$.

If there is cessation of bar / rail, at least of one place, then the replacement scheme of the picture would have to go to the next branch Z.

2.6.2 Modeling of excavators and other machines with a large land area

Excavators and other mining machinery and buildings that have large land area, with its caterpillars achieve good electrical contact with the ground. Thus, in case of short circuit in a 110 kV network, where they will get some potential, through the said contact lead the current in the ground and in their current environment creates a field that can be dangerous for people who are in their immediate nearby.

For the purposes of modeling the equivalent scheme grounding system, they can be treated as concentrated earthed grounding that the appropriate place of the equivalent scheme would introduce an active resistance Rp. Analyses show that the land surfaces of the excavators, machine with caterpillars and other devices that have contact with the ground surface, can be satisfactorily modeled by a suitable mesh grounding system, mounted horizontally on the ground of a certain small depth h. Moreover reticulated grounding system should have the same geometry as the geometry of land area of the dredge / device, and modeling can only be successfully performed if land surface is replaced by a dense network of horizontal strips, placed on a small distance between (the example D = 50 cm), buried in shallow (eg h = 5 cm).

III. Currents in the Grounding System in Case of Short Connections

The emergence of single-phase short and double, phased ties with a country in 110 kV distribution facilities of the mine "Brod – Gneotino" or at any place of manifolds 110 kV TS 110 / 6 "Brod - Gneotino " - TS 400/110 "Bitola 2 ", comes to leak currents through the earthing of the plant.

Analyses show that the most unfavorable case, in terms of the potential size of earthing, is when it comes to single - phase short circuit occurs in the distribution plant, ie the first pillar of the manifolds 110 kV, as is shown in Fig. 2.

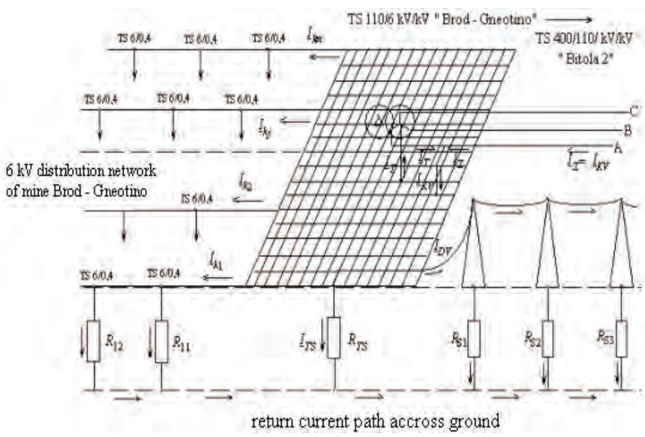

Fig.2 Grounding system in the mine " Brod - Gneotino"

Single - phase current short circuit at 110 kV by the TS "Brod-Gneotino" is calculated using the software package NEPLAN 5.2.2 13610 A and refers to the maximum mode when all units of TEC REK Bitola is in motion.

IV. Results of the Calculations

Resolving GS with a larger number of nodes in a classical way without using a computer is practically unfeasible. This paper will be considered one way of resolving the GS using MATLAB - Simulink, which is basically a simulation program, but can be successfully applied to solve the grounding systems. Simulink (simulation and connection) is an addition to MATLAB working with its support and allows modeling, simulation and analysis of dynamic systems. This program includes a wide range of tools from the library for linear and nonlinear analysis.

For purposes in this paper that current is injected into the system before grounding TS HV/MV in the replacement scheme the grounding system will be modeled with an ideal current generator, with power equal to the injected grounding system set in place of short circuit or in the case, the node that marks TS HV/MV. Assuming current fault anywhere from MV replacement grid pattern remains the same except that the ideal electric generator sets in place of an fault. In this case the site of short circuit is at 110 kV on the TS 110 / 6 kV.

Belt conveyors together with power stations are considered as distributed earthing introducing three nodes in the network (beginning, middle and end).

Using the software package MATLAB - Simulink, estimated distribution of current in short circuit single - phase in GS, the fault of HV side of the TS 110 / 6 kV / kV, and voltage is calculated to touch and move. Grounding system in the mine Brod - Gneotino "consists of 75 grounding posts. In Table 2 there are given grounding places with the touch voltages higher than 200V, ie the highest voltages are obtained. Voltage step is always smaller than the touch voltage.

Table 2. Results of the calculations of voltage and current circumstances of the grounding points in the mine "Brod – Gneotino"

Name	U(V)	Uc(V)	Ud(V)	Iz(A)
TS110/6	1020	36,99	284,1	1303
RP1	700,9	98,13	228,5	182,1
RP4	720,2	100,8	234,8	187,1
TS6/0,4	971,1	174,8	253,4	117,1
RP10	618,2	86,55	201,5	160,6

1. Name of grounding place;
2. Voltage of grounding place;
3. Voltage step of grounding place;
4. Touch voltage of grounding place;
5. Current which is injected in the grounding site.

V. Interpretation of the Results of Calculations

In assessing whether the calculated touch voltages and step up in limits, should be acceptable:

1. time off of the single - phase short circuit, ie total duration of short circuit, counting from the moment of occurrence of single - phase short circuit until its termination;

2) allowable touch voltages and steps, depending on the time of exclusion, defined by appropriate technical regulation.

The technical regulation in the former Yugoslavia, the allowable touch voltages and steps are given depending on the time of disconnection. Thus, according to the diagram in the article. 111 of the Regulation on technical norms for electricity plants with a rated voltage above 1000 V (Official Gazette of SFRY no. 4 / 74 and no. 13/78), if time off is t = 0,1 s, the allowed voltage step outside the plant is estimated at 320 V, but in the case when it comes to public roads with traffic, the voltage is at 180 V. The question about the amount of allowable touch voltage is processed in the Regulation on technical standards for electrical installations and equipment in mines with surface mining of mineral raw materials (quarries) [5]. Under article 29 of the Rules, if the time off of the short circuit was 0,1 seconds, the allowable touch voltage is 300 V. According to U.S. standards (ANSI / IEEE Std80-1986), the lowest values touch voltages and step for a man whose weight is 50kg is calculated by the formula:

$$\Delta U_{d.doz} = \Delta U_{c.doz} = \frac{116}{\sqrt{t}} \qquad (10)$$

for a man weighing 70 kg, with the formula:

$$\Delta U_{d.doz} = \Delta U_{c.doz} = \frac{157}{\sqrt{t}} \qquad (11)$$

We can conclude that the value here is higher and is 367V for a man who is 50kg.

From here you can draw the conclusion that if the time off of the single - phase short circuit occurred in the 110 kV network is 0,1 seconds, allowed to touch voltage or voltage step, in accordance with Rule [5] is:

$$\Delta U_{d.doz} = \Delta U_{c.doz} = 300 \text{ V} \qquad (12)$$

The values of specific resistances to ground in the area of the mine ranges from 25 < ρ <100 Ωm, Sd correction factor for the touch voltage ranges from 1,04 to 1,16, while correction factor Sc for the touch voltage ranges within the limits of 1,31 to 1,63.

From the above we can conclude that these values are too high and it illustrates the severity of the cited regulations. The presence of adequate equipment (rubber boots, gloves, etc.) in an even greater extent to increase these differences, and consequently the calculated results will always give a pessimistic picture regarding the actual risks and hazards of electric shock.

VI. Conclusion

Problem analyzed in this paper belongs to the rare events but its importance is undeniable in terms of security of the people who serve. During the studies carried out in preparation of this paper is developed in detail at the GS mine Brod - Gneotino, developed detailed models of power cables with insulated metal sheathed type EpN 78, and models of overhead lines with protective rope with a nominal voltage 110 kV and analyzed in details reticulated earthing, also is calculated its resistance circulation and calculated the percentage of touch voltages and step through computer programs Mrez.zaz and Zazem and using a developed software package NEPLAN 5.2.2 is prepared part of the power system around TE REK Bitola, which is calculated single – phase short circuit current of the HV side of the TS 110/6kV/kV of "Brod - Gneotino" and with the maximum mode generator when all are in operation. Using the MATLAB software package it is calculated the distribution of current in short circuit in single-phase GS fault on HV side of the TS 110/6kV/kV Brod - Gneotino and it is calculated touch voltages and step grounding of all places.

From the results we can observe that there is no danger of too high touch voltages and steps along the shipping lanes through the mine. Possible occurrence of a critical voltage is only in the vicinity of their home so they can be modeled by a concentrated active resistor placed in their home whether both their ends are connected to different plated grounding stations.

After determining the distribution of the currents and potentials of the grounding system, is applied to evaluate the safety conditions of excessive stress on the touch and move around the various types of earthing in accordance with existing regulations listed above, which are largely related to unjustifiably increasing costs for construction of earthing. In this context it is necessary to emphasize the need of revision sooner or mitigation of these regulations.

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