Analysis of the Grounding System of the Thermal Power Plant Oslomej

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Abstract: **This study presents an analysis about grounding system of the thermal power station Oslomej and the objects that are located in the area. Using the software package NEPLAN 5.2.2. it is made a model of medium voltage network of the thermal power plant and it is estimated current value when single phase short circuit happened on 110 kV side of the switchgear.**

Keywords: **grounding system, one phase short circuit current, touch and step voltages**.

I. Introduction

Thermal power plant Oslomej is complex technological and technical unity consist by mine with surface exploitation of minerals and thermal power plant along with object located in the area. Thermal power plant through 110 kV switchgear is connected with the high voltage transmition system of Republic of Macedonia, with three power lines, towards substation 110 kV – Kicevo, substation 110 kV – Vrutok, substation 110 kV Samokov. On the 110 kV switchgear is connected generator G1 with block transformer AT1 through witch is connected to power grid. Also in the thermal power plant are located transformer BT1 and transformer BT2, whose role is to supply the electricity consumption it the power plant, asynchronous motors, including coal mills, smoke ventilator, cooling water pump, power pump, fresh air ventilator, compressors etc. Nominal data of the elements are given in follow:

Nominal data for AT1 are:

- P = 150 (MVA);
- Un= (110/13,8) kV: Yd5

Nominal data for transformer BT1 are:

- P = 25 (MVA);
- Un = (115/6.3) kV, Yd5

Nominal data for transformer BT2 are:

- P = 40/20/20 MVA
- Un = (115/35/6.3) kV, Yy0d5

In the thermal power plant Oslomej is performed complex grounding system, set as earthing mesh that connects all electrical equipment in the plant, affecting the entire area inside the fence, with ancillary facilities. Mutually connected are grounding of elements in TPP Oslomej and parts of the switchyard 110kV plant in the TPP, 110kV power plant and conveyors for supply of coal from the mine to the plant storage.

II. Grounding System

A. External grounding system of TPP Oslomej

The complex facilities of TPP Oslomej, is set earthing mesh on wich is connects all metal equipment. Earthing connection of the equipment is performed as follows:

- Metal parts such as: iron constructions, pipelines with bigger thickness, fences and other material, are welded galvanized strip FeZn 25x4mm. Welded place of the galvanized strip is protected against corrosion by coating with minimal dye and sealed with bitumen. The conection is performed with terminal with sealing lead.
- Intersection of the two alignments of earthing is realized with electric terminal of bronze and coupling location is protected from corrosion by sealing bitumen.
- The connection with copper cable Cu 50mm² and galvanized strip is brought by a combination of two terminals.
- Between Copper and terminal lead is inserted, and the connection is isolated against corrosion.
- Grounding of the outer fence is performed with copper rope Cu 50mm². The rope is placed at a distance of 1m outside of the fence and a depth of 0.5m.
- Lightning protection is connected to the earthing mesh with copper rope Cu 50mm ².

B. Connecting grounding of complex objects TPP Oslomej to grounding 110kV swichyard

Connection of grounding of complex objects TPP Oslomej with the 110kV switchyard is performed through 4 copper ropes Cu 50mm ². Ropes are placed under the cable channel that connects the complex structures of TPP Oslomej and 110 kV switchyard, on every 50m ropes are all bound together by transverse link. Copper ropes Cu 50mm² are serving to even the potential between two objects, Copper ropes Cu 50mm ², used for potential leveling between two objects and are merged transmission lines about connection of switchgear and transformers.

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C. Grounding system of 110 kV switchyard

Grounding system of 110kV switchyard at TE Oslomej is designed as earthing mesh by placing copper cable Cu 50mm² into the earth at depth of 0,8 m . To this earthing mesh is connected all equipment located within the facility, including:
- Switches, each gender separately
- Output disconnectors each pole separately
- Current Transformers
- Voltage Transformers
- Portal concrete poles
- Command equipment
- Electrical equipment in building
- Iron carriers of devices and iron structures that come under voltage
- Protective ropes of transmission line

Grounding system of 110kV switchyard is made based on: network of 110kV switchgear is with direct ground neutral conductor, and all protective earthing at all voltage levels are connected together on the same common earthing and on the voltage level 0,4 kV is implemented TN earthing system.

III. Estimation & Results

A. Current value injected in the grounding system in case of a short circuit 110kV side

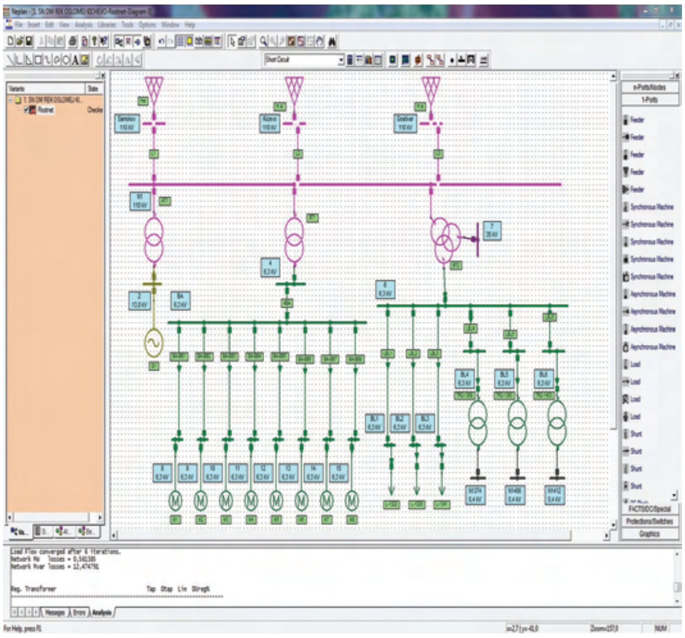

Fig. 1. Modelling the TPP Oslomej with software package NEPLAN 5.2.2

During the analysis of the grounding system, the problem with export potentials and protection from hazardous touch and step voltages, we take the single phase short circuit 110kV side of the plant switchyard as the most suitable for this kind of analysis.

In case of single phase short circuit in switchgear 110/35/6 Elektrana, current is distributed to all earthing system as earthing of 110 kV poles, earthing of 110/35/6 Elektrana and grounding system of mine.

Using the software package NEPLAN 5.2.2 it is made electricity grid of MV of TPP Oslomej and it is estimated the value when single phase circuit happened on the 110 kV switchyard. Elements modeling is according to the standard models for the analysis of short-circuit.

TABLE I
CURRENT VALUE WHEN SINGLE SHORT CIRCUIT HAPPENED ON 110kV SWITCHYARD

	Fault Location	To Node	Distance from	Element name	Type	Un	UL-E (RST)	Ik'' (RST)	ip (RST)	Ib (RST)	Ik (RST)
	From Node		Fault			kV	kV	kV	kA	kA	kA
1	elektrana	Faulted	0			110	0	11,122	30,76	11,122	11,122
							70,482	0	0	0	0
							70,857	0	0	0	0
2	elektrana	Samokov		L1	Line			2,029	5,611		0,194
								0,578	1,599		0,189
								0,578	1,599		0,207
3	elektrana	Kicevo		L2	Line			2,029	5,611		0,194
								0,578	1,599		0,189
								0,578	1,599		0,207
4	elektrana	Gostivar		L3	Line			2,029	5,611		0,194
								0,578	1,599		0,189
								0,578	1,599		0,207
5	elektrana	2		AT1	2W Transformer			4,647	12,852		4,647
								1,642	4,541		1,642
								1,627	4,499		1,627
6	elektrana	4		BT1	2W Transformer			0,197	0,544		0,197
								0,099	0,273		0,099
								0,099	0,273		0,099
7	elektrana	7		BT2	3W Transformer			0,194	0,536		0,194
								0,189	0,523		0,189
								0,207	0,572		0,207

	Fault Location	To Node	Ith (RST)	Idc (RST)	Ib asy (RST)	Sk'' (RST)	Zf (012)	Azf (012)	R/X (012)	Fault	CB dalay
	From Node		kA	kA	kA	MVA	Ohm			type	s
1	elektrana	Faulted	12,286	14,274	18,095	706	6,31	88,68	0,023	1phase g	0,02
			0	0	0	0	6,143	89,06	0,016		
			0	0	0	0	6,397	89,21	0,014		
2	elektrana	Samokov	2,241	2,604		129					
			0,639	0,742		37					
			0,639	0,742		37					
3	elektrana	Kicevo	2,241	2,604		129					
			0,639	0,742		37					
			0,639	0,742		37					
4	elektrana	Gostivar	2,241	2,604		129					
			0,639	0,742		37					
			0,639	0,742		37					
5	elektrana	2	5,133	5,963		295					
			1,814	2,107		104					
			1,797	2,088		103					
6	elektrana	4	0,217	0,252		12					
			0,109	0,127		6,3					
			0,109	0,126		6,3					
7	elektrana	7	0,214	0,249		12					
			0,209	0,243		12					
			0,228	0,265		13					

B. Resistance of earthing mesh at TPP Oslomej

For dimensioning and calculation of grounding resistance there are taken in mind the following data:

I''_k = 11 122 A - current value injected in the grounding system in case of a short circuit 110kV side, has two components:

I''_{km} = 8 122 A – component of short circuit on the network

I''_{kc} = 3 000 A – component of short circuit on side of power plant

ρ = 110 Ωm – specific resistance of the ground

F = 150 000 m² - surface area covered by the complex of facilities in TE Oslomej. This surface is obtained as a product of length A = 500m and width B = 300m.

Using empirical formula earthing mesh is calculated:

$$(B) = \frac{\rho I''_{km}}{F} = 5.96\left[\frac{\Omega\, mA}{m^2}\right] \quad (1)$$

The surface area F=150000mm² where lies the earthing grid is approximated as rectangular.

m = B/D + 1 = 300/50+1 = 7, the number of lines parallel to side A

m = A/D + 1 = 500/50+1 = 11, the number of lines parallel to side A

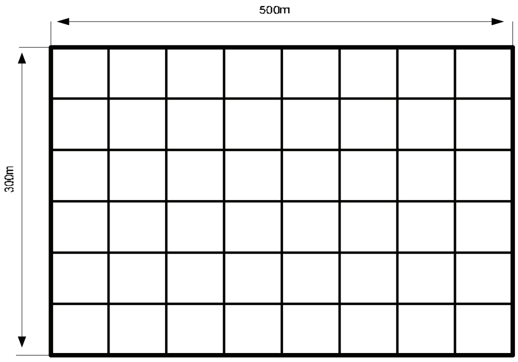

Fig. 2. Surface area of spreading the earthing mesh

The total length of mesh earthing is:

L= mA+mB= 7·500+11·300=3500+3300=6800m (2)

Grounding resistance is :

$$R_{11} = \frac{\rho}{\pi L}\left[\ln(\frac{2L}{a_1}) + k_1\frac{L}{\sqrt{F}} - k_2\right](\Omega) \quad (3)$$

ρ - (Ωm) specific resistance of ground

L - (m) active length of earthing

$$a_1 = \sqrt{d \cdot h}\ (\mathrm{m})$$

$$a_1 = \sqrt{9\cdot 10^{-3}\cdot 0.8} = 8{,}48\cdot 10^{-2} \quad (4)$$

d_1 - (m) conductor diameter

h - (m) conductor setting depth

F - (m²) area included in the earthing

k_1=1.32, k_2 =5.53 (coefficients according to TP-23)

Grounding resistance is:

$$R_{11} = \frac{110}{\pi 6800}\left[\ln(\frac{13600}{8{,}48\cdot 10^{-2}} + \frac{6800 - 1.32}{387} - 5.53\right]$$

$$R_{11} = 0{,}152\,(\Omega) \quad (5)$$

C. Calculation of step voltage using the empirical formula

$$U_c = ks\cdot ki\cdot\rho\frac{I^n k}{L}\ [\mathrm{V}] \quad (6)$$

$$ks = \frac{1}{\pi}(\frac{1}{2h} + \frac{1}{D+h} + \frac{1}{2D} + \ldots + \frac{1}{11D}) = 0{,}218 \quad (7)$$

$$k1 = 0.65 + 0.142\,n = 0.65 + 0.172\cdot 7 = 1{,}854 \quad (8)$$

$$U_c = \frac{0.2197\cdot 1.854\cdot 110\cdot 5938}{6800} = 39\ [\mathrm{V}] \quad (9)$$

D. Touch voltage calculation using the empirical formula

$$U_{dm} = km\cdot\rho\frac{I^n k}{L} = 1.336\cdot 110\cdot\frac{5943}{6800} = 128\ [\mathrm{V}] \quad (10)$$

$$km = \frac{1}{2\pi}\cdot\ln(\frac{D^2}{16\,hd}) + \frac{1}{\pi}\ln(\frac{3\cdot 5}{4\cdot 6}\cdot\frac{7}{8}\cdot\frac{9}{10}\cdot\frac{11}{12})$$

$$km = 1{,}336 \quad (11)$$

When single phase short circuit happend on 110 kV side of switchyard Oslomej because of the direct earthing on 110 kV side of the transformers, all grounded metal parts will get a certain potential. Measured values are given in Table 2 at measuring currents A, which should be reduced to the value of real single phase short circuit, by the coefficient of single phase short circuit, which is:

k=Izk / Im = 11 122 A / 18 A = 618 (12)

Izk a short circuit current of single phase 110 kV busbars received with the software package Neplan 5.2.2.

Im is the measured current at the time of measurement

Touch voltages are measured using a resistor of 1000 Ω, which stimulates the resistance of the human body. The measured voltages are multiplied by the coefficient k = 618 to get the touch voltages at single phase short circuit on110kV side.

Udk110 = k·Udm (13)

Table II
Toucht voltages in some terminals at the power plant when single phase short circuit happened at110 kV switchgear (Ref.[7])

	Terminal	Udm (V) when R =1000Ω	Udk110 = k Udm
1	Candelabra No.1 under dump coal	0.003	1,85
2	Candelabra near dump coal facility	0.003	1,85
3	Strip no.1 equip coal	0.005	3,10
4	First column of the skew bridge	0.009	5,56
5	Metal construction on tape UT12	0.007	4,33
6	TS -15 6/0,4kV	0.008	4,94
7	Reservoirs on compressor station	0.007	4,33
8	Candelabra near mincers on western side	0.012	7,42
9	Hydrogen station	0.005	3,10
10	Metal fence of blog transformer	0.019	11,74
11	Fence of measuring transformer 110kV - western side	0.004	2,47
12	Column for speaker on fire protection station	0.005	3,10
13	Hydrant at the entrance of the administrative building	0.03	18,54
14	Small candelabrum before the fuel oil station	0.005	3,10
15	Water reservoir	0.008	4,94
16	Fire detection installation on fuel oil reservoir	0.006	3,71
17	Station for gas emissions	0.006	3,71
18	Upper Gate	0.037	22,87
19	Upper Gate,with water on cement	0.053	32,75
20	Fence, the right of the upper gate	0.204	**126,07**
21	Fence towards administrative buildings - right	0.008	4,4
22	Fence towards administrative buildings - left	0.012	7,42
23	Candelabra between 1 and 2 building	0.007	4,33
24	Earthing of building 1	0.005	3,10
25	Distributing panel of building 1	0.024	14,83
26	On the Fe-Zn tape of the lower port of fence	0.195	**120,51**
27	Fence from parking - west	0.032	19,78

E. Resistance of earthing mesh at 110kV switchyard

Switchyard 110kV at TPP Oslomej consists 9 fields such as TR BT1, TR BT2, AT1, a junction field, measurements field, reserve, fiend for connection with Kicevo TS 110, TS 110 Gostivar, TS 110 Samokov (Fig.3), and covers an area of 27,5x81m. According to the dimensions of the earthing covering 110kV switchgear, depth of placement of the rope and the quality of land can be determined resistance of spreading the earthing as follows:

$$R = \frac{\rho}{2D} + \frac{\rho}{l} \ (\Omega) \qquad (14)$$

ρ = 110 Ωm – specific resistance of ground
l = 1300 cm – length of the rope
D = 1, 13 $\sqrt{S}$ = 72m - diameter

S = 40x100 = 4000m² - area included in the earthing

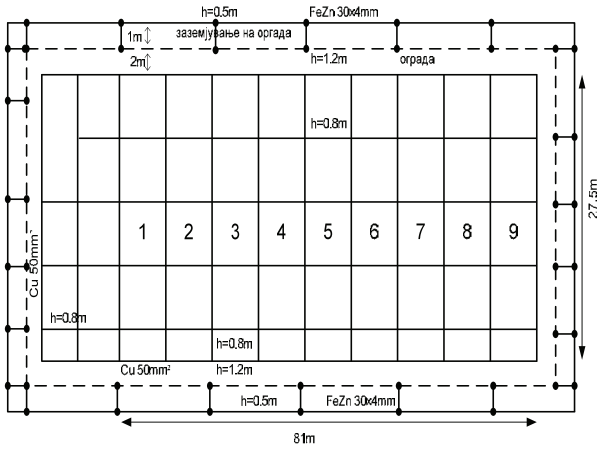

Fig. 3. Modelling the earthing mesh at 110kV switchyard

Resistance of earthing mesh at 110kV switchyard is:

$$R = \frac{110}{2 \cdot 72} + \frac{110}{1300} = 0.85\,(\Omega) \qquad (15)$$

Resistance of earthing mesh of 110 kV switchyard is $R = 0.85\Omega$. In addition, also given percentile values of touch and step voltages $Ed\,\% = 2.5$ и $Ec\,\% = 2.5$.

IV. Conclusion

By analyzing the grounding system, and performed measurements, can be determinate the risks of to high voltages and critical points in the network, and then propose the corresponding technical solutions for proper care and proper design of grounding system. According to calculations touch and step voltages, are in accordance with existing regulations, by which inside the plant are limited to 250V, on the outside are limited to 125V, during off t = 0.25sek.

On the external fence of high voltage power plants permitted touch voltage are limited to 65V, therefore according to the data in Table 2, for positions no.20 and no.26 recommends performing local earthing and should be connected to main earthing mesh of the power plant.

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