International Journal on
"Technical and Physical Problems of Engineering"
(IJTPE)
Published by International Organization on TPE (IOTPE)

ISSN 2077-3528
IJTPE Journal
www.iotpe.com
ijtpe@iotpe.com

March 2010 | Issue 2 | Volume 2 | Number 1 | Pages 45-49

DESIGN OF GROUNDING SYSTEMS IN SUBSTATIONS BY ETAP INTELLIGENT SOFTWARE

N.M. Tabatabaei [1] S.R. Mortezaeei [2]

1 Electrical Engineering Department, Seraj Higher Education Institute, Tabriz, Iran, n.m.tabatabaei@gmail.com
2 Electrical Engineering Department, Azarbaijan University of Tarbiat Moallem, Tabriz, Iran
Young Researches Club, Islamic Azad University, Gonabad Branch, Gonabad, Iran, rmortezaeei@yahoo.com

Abstract- Under ground-fault conditions, the flow of current will result in voltage gradients within and around the substation, not only between structures and nearby earth, but also along the ground surface. In a properly designed system, this gradient should not exceed the limits that can be tolerated by the human body. The purpose of a ground mat study is to provide for the safety and well-being of anyone that can be exposed to the potential differences that can exist in a station during a severe fault. The general requirements for industrial power system grounding are similar to those of utility systems under similar service conditions. The differences arise from the specific requirements of the manufacturing or process operations. Some of the factors that are considered in a ground-mat study are the following:
a) Fault-current magnitude and duration
b) Geometry of the grounding system
c) Soil resistivity
d) Probability of contact
e) Human factors such as
1. Body resistance
2. Standard assumptions on physical conditions of the individual

Keywords: System Studies, Intelligent Software, ETAP5.0.3, Grounding Study.

I. INTRODUCTION

In designing and construction of an electric substation, one of the most important issues that must be considered is designing of protective system to the earth. Flow of the earth system, cause voltage gradients ground level which case different parts of the earth and the reference (ground round). The potential difference should be carefully and automatically designed. This may have enough voltage to reach the safety of people in place and causes risk. In this situation, people feel exposed to high voltages between the location of two steps (Step voltage) and also if a person at this moment in contact with the ground is a metal device, the voltage between that point and exposed earth place your foot (contact voltage).

Earth system must be designed so that the order should contact voltages and maximum values possible step event and substation where conditions are faulty. The maximum values of contact and step voltages tolerated human body should be less.

A method for designing the earth system is based on the use of the land network in the same intervals. The results using this method largely increases system costs and the need for land will be provided in addition to better meet the safety conditions, will prevent the additional costs.

In the past, papers presented for optimizing the land in these articles, but only for optimizing the parameters are considered, the length conductors earth system. In reference [1] related to voltage changes and call the number step conductors earth system to determine efficiency in reducing conductors increased contact and step voltages provided the tolerance values, has been compared to evaluate safety. In references [2, 3 and 4] study on compression ratio and its relationship with the conductors and the voltage step was to contact and appropriate compression ratio achieved with minimal contact voltage compared with the values of tolerance not to evaluate safety is. In reference [5] the help of genetic algorithm optimization of the network but the number conductors and earth have already been fixed and the purpose of minimizing voltage contact, but not compared with the values of tolerance. In reference [6] for optimizing the relationship between the earths system during consecutive meshes is considered. But the only optimization variable, the total length of network Conductors earth.

In references [7-9] genetic algorithm optimization performed by the reference [8]. The vertical rods considered but the authorities only as total length conductors earth system optimization point is variable. Considering the above observation is that all articles provided for optimizing the system, earth, only during the earth system as a whole Conductors variable optimization is considered if the studies done, other parameters of the immune system of the earth effective.

II. GROUND NETWORK DESIGN ALGORITHM

Block diagram in Figure 1 is the sort earthing studies of power networks and the algorithm can be expressed as follows:

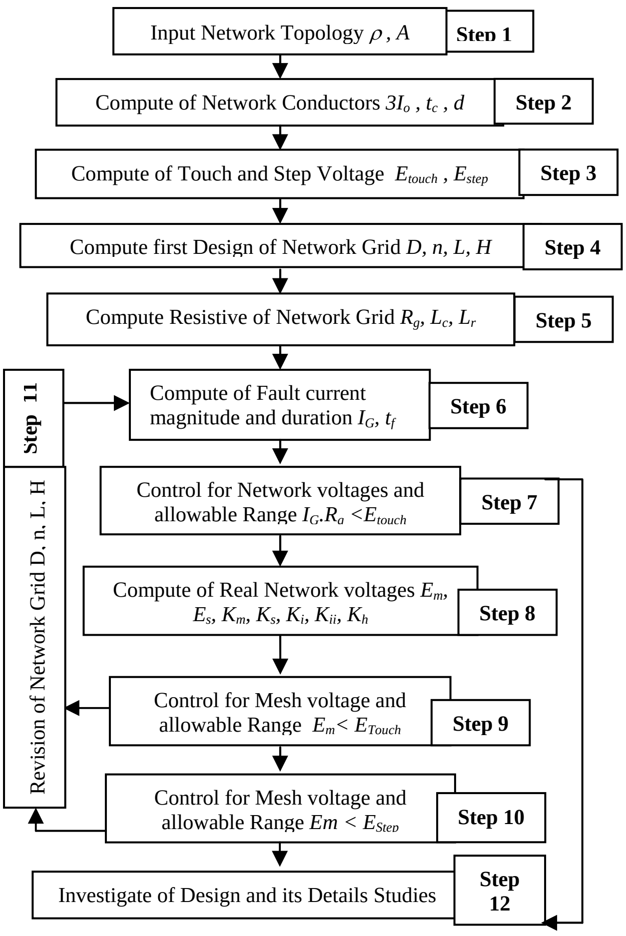

Figure1. Block diagram for earthing network design

Step 1 - Map earth global network page view the necessary evaluation and locations for the land required to be constructed and electrical resistance of soil profiles and if necessary changes and prepare standard types or two layers known be.

Step 2 - Cross section used for wireless networks based on land related equations, it is calculated and determined flow error ($3I_o$) the maximum amount must be injected to the network during the probable future developments and continuing up to time Short circuit current (t_f), which includes the protection of backup is to be determined (equations 1 and 2).

$$3I_o = \frac{V}{3R_g + (R_1 + R_2 + R_0) + j(X_1'' + X_2 + X_0)} \tag{1}$$

$$A_{mm^2} = I_{(KA)} \sqrt{\frac{t_c.a_r.\rho_r.10^4 / TCAP}{\ln\left[1 + \frac{T_m - T_a}{k_o + T_a}\right]}} \tag{2}$$

Step 3 - About tolerable step voltage and contact relationships based on equations 3-5 are determined. Select a time period short circuit designer and engineer responsible for the assessment he will be required.

$$E_{step} = (R_B + R_{2FS}) * I_B \tag{3}$$

$$E_{Touch}^{50kg} = (1000 + 1.5C_s(h_s, k) * \rho_s) * \frac{0.116}{\sqrt{t_s}} \tag{4}$$

$$E_{Touch}^{70kg} = (1000 + 1.5C_s(h_s, k) * \rho_s) * \frac{0.157}{\sqrt{t_s}} \tag{5}$$

Step 4 - Preliminary design a range around the network and the number of conductors required for the formation of cross-conductors will be the home network, so that the connections of all devices that are specified. Intervals and used during conductor and ground rods required plan must be evaluated based on flow injection to the network and the earth is around (equation 6).

$$\frac{K_m.K_i.\rho.I_G}{L} < (1000 + 1.5C_s(h_s, k).\rho_s).\frac{0.116}{\sqrt{t_s}} \tag{6}$$

Step 5 - Resistance entire network study based on land relations were presented in part be pre calculated and evaluated. For the final project must be of earth rods that much depth in the soil before stations is also to be considered. Modified resistance per network based on ground rods presented in parts before relations be specified. Using computer networks can be computer for total resistance parameters, it more accurate and can be evaluated (equation 7).

$$R_g = \rho\left[\frac{1}{L} + \frac{1}{\sqrt{20/A}}\left(1 + \frac{1}{1 + h\sqrt{20/A}}\right)\right] \tag{7}$$

Step 6 - Flow injected to the network and from there around the Earth based on relationships presented in previous sections is evaluated. Plan to prevent excessive network required only part of the short circuit current ($3I_o$) that is injected to the network and cause the earth voltages and voltage step and contact the remote point (GPR) posts is, criteria action should be (equations 8-9).

$$I_g = S_f.I_f \tag{8}$$

$$I_G = C_P.D_f.I_g \tag{9}$$

Step 7 - If the voltage increased post (GPR) in the preliminary design of voltage tolerance of contact is less, the need to revise the plan and not just additional earth connections, all connections to clothe the earth system may be required.

Step 8 - Calculate and evaluate network and step voltages in the project based on relationships and should be done before recommendation of presented the parts to be adjusted (equations 10 and 11).

$$E_m = \rho K_m K_i I_G / L \tag{10}$$

$$E_s = \rho K_s K_i I_G / L \tag{11}$$

Step 9 - If the voltage of network is less tolerable voltage can contact the project completed could imagine otherwise, the plan should be revised.

Step 10 - If the calculated voltage step and contact them about tolerance is less, only minor amendments, such as project completed and all the fittings required to connect to the network would be otherwise, should be revised plan, the case that the intervals conductors are less than or more joint ground rod be placed, etc.

Step 11 - After determining voltages of necessary steps and call, additional reforms such as plans connected lightning rods, neutral transformers and some other devices to the network and earth rods can be useful.

III. DESIGN OF NETWORK GRID BY ETAP SOFTWARE

In this section, we complete the previous studies and aided software ETAP, a comprehensive optimization with regard to different parameters affecting the immune system to offer the land. The earth system for different conditions, the study is performed in three cases.

First project is designed with the earth system network is presented with the same intervals. The second project is designed with optimum Conductors land based network optimization single variable, (Total Conductors earth).

The third project is also a comprehensive multivariate optimization (based on optimizing the number of conductors and earth Rods network) with regard to different parameters affecting the immune system, the earth.

Figure 2 shows demo accelerator as three-dimensional and two dimensional designs and three number one offers, so that location and the frequency conductors and earth rods network clearly shows. The profile network such as land size and depth of buried conductors, length and width and number of conductors in the network length and width and length unit prices are also presented in Table 2.

The results of above projects are given in Tables 3 and Table 4. The information in Table 4 are including conductors cost per rods network design, calls to step voltages per plan which are presented in accordance with the results, the use of third plan to increase optimization and substantial reduction in costs is the earth system.

Also, each proposed plans network parameters such as maximum flow error, and network flow factors *K*, C_s and D_f are based on Table 1. It is worth mentioning that the above studies for a person 50 kg, temperature 40 °C and carried out according to IEEE80 and ground network in each case of Dual Layer formed.

So that the earth resistance of 2500 ohm meter level network, first layer made of Moist Soil resistance 100 ohm meters and 5 meters depth and the second layer made of moist soil (Wet Organic Soil) 10ohm resistance meters and 5 meters in depth is considered. The short circuit current networks as 4kA of ground conditions, $t_f = t_c = t_s$=0.5 sec is defined.

IV. CONCLUSIONS

Engineering design of grounding grid in substations is a very complex process that gets easier if one uses an optimization technique as the one detailed in this paper. This allows us to identify the most adequate design solution driven by the whole cost of the installation subjected to technical and safety constraints that ensure that the maximum allowed touch and step voltages are not violated.

The optimization problem involves geometry aspects, depth of excavation, number of rods and radius of the conductors together with the geometry and size of the complementary electrodes, if these are required. It is important to refer that this approach and the calculation of the touch and step voltages are consistent with the grounding grid design described in the standard IEEE-80-2000.

The design of a substation grounding system is very complex due to the number of involved phenomena. One of them comes from the fact that lightning influences the local resistivity of the soil given that, when lightning occurs, non-linear phenomena appear in the soil. Nevertheless, this is not the only difference regarding the low frequency case. Indeed, the high frequency response of both grounding grids and human body are not the same for fast transients and power frequency.

This very complex phenomenon was not considered in the research reported in this paper. The case study detailed in Section 4 to illustrate the developed approach is based on a real designing problem of the grounding grid of a substation and it indicates that it would have been possible to reduce the total installation cost at the same time that all constraints are fulfilled.

This indicates that there is a large potential of application for this kind of approaches that would certainly help designers to solve complex problems as the one addressed in this paper.

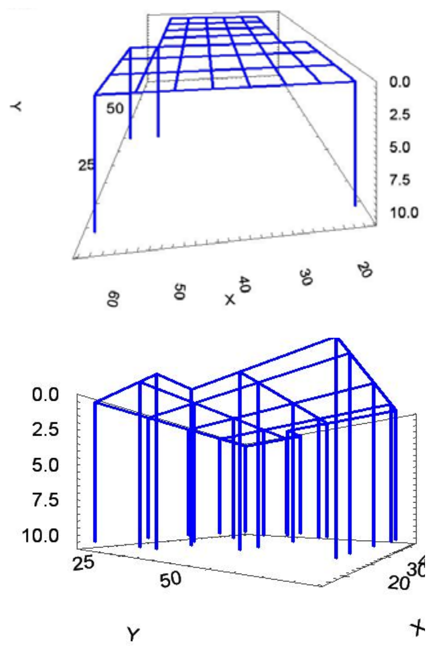

Figure 2. Network grids designed in one and third plan

Table 1. Network parameters

Total Fault Current	4KA
Maximum Gride Current	4.076KA
Reflection Factor (*K*)	-0.923
Surface Layer Derating Factor (C_s)	0.921
Decrement Factor (D_f)	1.019

Table 2. Grid configuration in every plan

Definition Parameters		First Project	Second Project	Third Project
Conductor Size (mm^2)		120	120	120
Depths (m)		0.5	0.5	0.5
Grid Length (m)	Lx. Long	50	50	50
	Lx. Short	35	35	35
	Ly. Long	58.2	58.2	58.2
	Ly. Short	25	25	25
Number of Conductors in Direction	X	8	9	5
	Y	8	8	4
Separation (m) In Direction	X	7.1	7.1	16.7
	Y	8.3	7.3	14.6
Cost ($/m)		10	10	10

Table 3. Total cost in every plan

Result		First Project	Second Project	Third Project
Conductor	Total No.	16	17	9
	Total Length (m)	739.1	774.1	419.6
	Cost ($)	$7391	$7741	$4196
Rod	Total No.	4	4	22
	Total Length (m)	40	40	220
	Cost ($/m)	$400	$400	$2200
Total Cost		$7791	$8141	$6396

Table 4. Touch and step voltage in every plan

Result		First Project	Second Project	Third Project
Rg Ground Resistance (Ω)		1.019	1.014	1.047
GPR Ground Potential Rise (Volt)		4153.9	4131.4	4268.1
Touch Potential (Volt)	Tolerable	730.5	730.5	730.5
	Calculated	726.1	693.3	726.7
	Calculated %	99.4	94.9	99.5
Step Potential (Volt)	Tolerable	2429.7	2429.7	2429.7
	Calculated	483.1	483.1	366.9
	Calculated %	19.9	19.9	15.1

V. SYMBOLS DEFINITION

In this paper, "grounding resistance" is used for complementary electrodes, whereas "equivalent impedance of the grounding grid" is used for grounding grid according to the IEEE Std 80-2000. The grounding system conforms to grounding grid and grounding complementary electrodes.

Table 5. Symbols definition

Symbol	Description
$3I_o$	Symmetrical short-circuit the flow station according to Ampere
I_G	Maximum flow is transferred to the network and from there to the land environment (including components, DC) according to Ampere
ρ	Soil electrical resistance according to Ohm Meter
ρ_s	Substation carpeted surface electrical resistance according to Ohm Meter
h_s	Substation carpeted surface thickness in meters
C_p	Substation Coefficient for the future development
C_s	Substation carpeted surface to reduce resistance coefficient
t_c	The continuity error for estimating the earth conductor size in seconds
t_f	The continuity error for estimating the earth conductor size in seconds
t_s	All continuity errors in the shock passing allowed to determine the flow of the body in seconds
h	Conductors earth burial depth in meters
d	Earth conductor diameter in meters
A	Total surface coverage in square meters land
D	Physical distance in meters between Parallel Conductors
D_f	Reduction coefficient for the I_G
N	Total Conductors in parallel in one direction
K_m	Distance correction factor to determine the mesh voltage
K_s	Distance correction factor to determine the voltage step
K_i	Network geometry correction factor
K_{ii}	Network geometry correction factor
K_h	Effect of burial depth correction factor H.
L	Overall length Conductors used in the network and includes all land rods to meter
R_g	Overall length Conductors used in the network and includes all land rods to meter
E_m	Voltage mesh network side in the middle Home
E_s	Voltage step network
$E_{touch50}$	Contact tolerable voltage for a 50 kg person per volt
$E_{touch70}$	Contact tolerable voltage for a 50 kg person per volt
E_{step50}	Tolerable step voltage for a 50 kg person per volt
E_{step70}	Tolerable step voltage for a 50 kg person per volt

REFERENCES

[1] Y. Gao, R. Zeng, X. Liang, J. He, W. Sun and Q. Su, "Safety Analysis of Grounding Grid for Substations with Different Structure", IEEE International Conference on Power System Technology, Vol. 3, pp. 1487-1492, Dec. 2000.

[2] H.S. Lee, J. Kim, F.P. Dawalibi and J. Ma, "Efficient Ground Grid Design in Layered Soils", IEEE Trans. Power Del., Vol. 13, No. 3, pp. 745-751, July 1998.

[3] W. Sun, J. He, Y. Gao, R. Zeng, W. Wu and Q. Su, "Optimal Design Analysis of Grounding Grids for Substations Built in Nonuniform Soil", IEEE International Conference on Power System Technology, Vol. 3, pp. 1455-1460, Dec. 2000.

[4] J. He, Y. Gao, R. Zeng, W. Sun, J. Zou and Z. Guan, "Optimal Design of Grounding System Considering the Influence of Seasonal Frozen Soil Layer", IEEE Trans. Power Del., Vol. 20, No. 1, pp. 107-15, Jan. 2005.

[5] F. Neri, "A New Evolutionary Method for Designing Grounding Grids By Touch Voltage Control", Industrial Electronics, IEEE International Symposium, Vol. 2, pp. 1501-1505, May 2004.

[6] M.C. Costa, M.L. P. Filho, Y. Marechal, J. Coulomb and J.R. Cardoso, "Optimization of Grounding Grids by Response Surfaces and Genetic Algorithms", IEEE Trans. On Magn., Vol. 39, No. 3, pp. 1301-1304, May 2003.

[7] A.F. Otero, J. Cidrbs and C. Garrido, "Genetic Algorithm Based Method for Grounding Grid Design", Proc. of the IEEE International Conference on Evolutionary Computation, pp. 120-123, May 1998.
[8] A. Covitti, G. Delvecchio, A. Fusco, F. Lerario and F. Neri, "Two Cascade Genetic Algorithms to Optimize Unequally Spaced Grounding Grids with Rods", IEEE International Conference on Computer as a Tool, Vol. 2, pp. 1533-1536, 2005.
[9] Z. He, X. Wen and J. Wang, "Optimization Design of Substation Grounding Grid Based on Genetic Algorithm", IEEE Third International Conference on Natural Computation (ICNC 2007), Vol. 4, pp. 140-144, Aug. 2007.

BIOGRAPHIES

Naser Mahdavi Tabatabaei was born in Tehran, Iran, 1967. He received the B.Sc. and the M.Sc. degrees from University of Tabriz (Tabriz, Iran) and the Ph.D. degree from Iran University of Science and Technology (Tehran, Iran), all in Power Electrical Engineering, in 1989, 1992, and 1997, respectively. Currently, he is a Professor of Power Electrical Engineering at International Ecoenergy Academy, International Science and Education Center and International Organization on TPE.
He is also an academic member of Power Electrical Engineering at Seraj Higher Education Institute and teaches Power System Analysis, Power System Operation, and Reactive Power Control. He is the secretaries of International Conference and Journal on TPE. His research interests are in the area of Power Quality, Energy Management Systems, ICT in Power Engineering and Virtual E-learning Educational Systems. He is a member of the Iranian Association of Electrical and Electronic Engineers (IAEEE).

Seyed Reza Mortezaeei received the B.Sc. in Islamic Azad University, Gonabad Branch, Iran in 2007 and M.Sc. degree from Azarbaijan University of Tarbiat Moallem, Tabriz, Iran in 2009 all in Power Electrical Engineering. He is currently researching on Power System Operation and Control, Power System Study by Intelligent Softwares as ETAP.