Impact of Buried Conductor Length on Computation of Earth Grid Resistance

S. D. Buba*, W. F. Wan Ahmad*, M. Z. A. Ab Kadir*, C. Gomes*, J. Jasni, M. Osman****
* Department of Electrical and Electronic Engineering, Faculty of Engineering, Universiti Putra Malaysia, UPM Serdang, Selangor, Malaysia
** Department of Electrical Power Engineering, College of Engineering, Universiti Tenaga Nasional, Kajang, Selangor, Malaysia

Article Info

Article history:

Received Mar 2, 2015
Revised Jul 18, 2015
Accepted Jul 29, 2015

Keyword:

Buried conductor length
CDEGS
Earth grid
Earth rods
Grid resistance

ABSTRACT

Effective design of substation earth grid implies achieving low earth grid resistance and fulfillment of the safety criteria at the lowest possible cost. This paper presents an evaluation of IEEE Standard 80-2000 Equations 50 to 52 to determine the impact of buried conductor length on earth grid resistance. Calculated results indicated that a saturation point is reached beyond which further addition of more conductor length does not significantly reduce the earth grid resistance but incurs more economic implications. These were validated by earth grids designed using CDEGS where good agreement between the calculated and simulated results was found.

Corresponding Author:

S. D. Buba,
Department of Electrical and Electronic Engineering,
Faculty of Engineering, Universiti Putra Malaysia,
43400 UPM Serdang, Selangor, Malaysia.
Email:sanibintahirl@gmail.com

1. INTRODUCTION

Distribution substations are basically electrical facilities comprising of many equipment such as transformers, circuit breakers and capacitor banks that are necessary for transformation, regulation and distribution of electrical energy. As a result of its function, a substation is potentially a hazardous environment that is prone to various kinds of power system faults which may have its origin within the substation or along the distribution lines emanating from or terminating at the substation. Therefore, it is mandatory to ensure that the safety of personnel and the general public is guaranteed against any potential hazard such as electric shock resulting from direct or indirect contact with energized parts and that substation equipment are protected against over voltages. Protection of personnel, equipment in substations and its immediate vicinity is normally achieved by connecting and bonding all the metallic frames of equipment and other metallic structures such as fences and utility pipes to a common earthing system. Hence, an earthing system in this context refers to a connection of metallic conductors or wire(s) of different geometrical structures such as single horizontal earthing wire, vertical rods, ring conductors and earth grid occupying a large area, or a suitable combination of above mentioned structures between an electrical circuit and the soil with the aim of achieving a permanent and continuous electrical conducting path to the ground [1]. In a nutshell, the substation earthing system is an interconnection of all earthing facilities in the substation area, including the earth grid, overhead earth wires, neutral conductors, underground cables, foundations and deep wells [2].

The main function of substation earthing grid is to provide a means to dissipate fault currents into the ground without exceeding any operating and equipment limits under both normal as well as fault conditions, and to assure that a person in the vicinity of earthed facilities is not exposed to the danger of critical electric shock. Other functions performed by the earthing grid in a substation is to ensure the efficient operation of the distribution system, and to guarantee the safety of personnel and equipment by limiting the touch and step voltages and earth potential rise during earth fault conditions to tolerable limits. In order for a substation earthing system to perform its functions effectively, the earth grid resistance R_g must be low enough to assure that fault currents dissipate mainly through the earth grid into the ground. Usually, the acceptable range of R_g for smaller distribution substations is from 1-5Ω depending on the local soil conditions [3-6]. Consequently, one of the most important considerations during the design of substation earthing is to achieve low resistance path to ground through which fault currents and lightning strikes are discharged and to ensure the protection of equipment and personnel against transferred potentials [3, 7].

To design a substation earth grid, certain site-dependent parameters such as, maximum grid current I_g, fault duration t_t, shock duration t_s, soil resistivity ρ, surface material resistivity ρ_s, and grid geometry are considered to have substantial impact on the grid performance. The grid geometry, area occupied by the grid, conductor spacing, depth of burial of grid and thickness of the surface layer material are the parameters that influence the magnitude of mesh, step and touch voltages and earth potential rise (EPR), while the conductor diameter has no impact at all on the safety criteria of the grid [3, 8]. Soil resistivity and area occupied by the grid are the most important factors that determine the value of R_g. Generally, the lower the resistance of a substation earth grid with respect to remote earth, the more effective it is [9]. There are two basic approaches to the design of substation earth grid used worldwide. In some countries, an earth grid is considered adequate when the value of R_g satisfies the recommended values by applicable standards. While in other countries, such as the U.S.A, an earth grid is considered safe when step and touch potentials are made lower than the permissible values. Among the two approaches, the second is assumed to be more valid as the magnitude of tolerable current flowing through the human body is taken into consideration [10].

IEEE Standard 80:2000 which is considered as the earthing encyclopedia worldwide has recommended the use of three different equations, i.e. equations (50) to (52) to determine the value R_g of an earth grid expressed as equations (1) to (3) in this paper, respectively. This paper presents an evaluation of these equations to calculate the values of R_g considering the contribution of buried conductor length to the overall grid resistance. As stated earlier, soil resistivity, area occupied by the grid are the most influential factors that determine the resistance to remote earth of an earth grid system. In addition, increasing the length of buried conductors by addition of vertical earth rods to the horizontal grid conductors has been found to affect the value of R_g hence the addition of conductor terms in IEEE equations (51) and (52). However, the extent to which the addition of the buried conductor length affects the value of R_g has not been reported in available literature. Therefore, this paper evaluates the IEEE equations (51) and (52) by increasing the conductor length to different grid configurations to assess the extent to which the grid resistance could be reduced. An earth grid with the same dimension was designed using SESCAD and executed in MALT module of CDEGS for comparison purposes.

2. METHODOLOGY

The normal procedure in designing a distribution substation earth grid and any type of substation for that matter is to conduct a preliminary survey at the proposed site to inspect the presence of utility installations such as water or gas pipelines, followed by soil resistivity measurement to determine the soil model which would provide information on the number of soil layers at the site, thickness of each layer and the appropriate depth at which the earth grid should be buried. In this paper, soil resistivity measurement was conducted at a proposed distribution substation site located in front of the prayer room, College 12, Universiti Putra Malaysia, Serdang, Selangor, Malaysia using Wenner method with a 4-Pole Megger Earth Tester. The RESAP module of CDEGS software was used to determine the soil model from the measured soil resistivity field data. Tables 1 and 2 list the soil resistivity field data and the soil model, respectively. Note that, IEEE Std. 80-2000 equation (50) was initially used to estimate the values of R_g considering the soil resistivity and area occupied by the grid. Subsequently, equations (51) and (52) were used to calculate the value of R_g by adding vertical earth rods initially at the grid periphery and then at all conductor intersections, respectively. The calculation commenced with a small grid dimension of 5m x 5m and increased in steps of 10m until a grid dimension of 70m x 70m which yielded a value of R_g lower than 5Ω. The spacing between the grid conductor rows and columns was varied between 3m, 4m and 5m depending on which grid dimension was exactly divisible by any of the spacing. Typical values of R_g for equations (50) to (52) and grid dimensions are listed in Table 3. Note that, it was necessary to increase the grid dimension to ensure that R_g<5Ω was obtained to fulfill the acceptable range recommended in [3] for small distribution substations.

Finally, the earth grids were designed using SESCAD and executed by MALT module of CDEGS to determine the value of R_g for comparison purposes. Only three grid dimensions of 50mx50m, 60mx60m and 70mx70m were considered due to the fact that computed results indicated these dimensions yielded values of R_g<5Ω from all the three equations (50) to (52). The earth grids were designed in three different arrangements, the first arrangement comprised of horizontal rows and columns of buried conductors only referred to as Grid A, while the second arrangement comprised of horizontal rows and columns of buried conductors and 3m long vertical earth rods installed at 3m intervals around the periphery of the grid which was labeled as Grid B. The third arrangement consisted of horizontal rows and columns of conductors, 3m long vertical earth rods installed at 3m intervals around the periphery of the grid and at all conductor intersections of and referred to as Grid C. Note that, for each grid dimension mentioned, Grids A, B and C have been constructed as shown in Figures 1, 2 and 3, respectively. The burial depth of all earth grids was 1.3m based on the soil model and the grid conductors and the earth rods were both made of hard dawn copper with radius 0.00535m and 0.008m, respectively according to the conductor sizes used in Malaysia for earth grid construction. The earth grid was energized by a current of magnitude of 3.125kA for duration of 0.3s.

$$R_g = \frac{\rho}{4}\sqrt{\frac{\pi}{A}} \quad (1)$$

$$R_g = \frac{\rho}{4}\sqrt{\frac{\pi}{A}} + \frac{\rho}{L_T} \quad (2)$$

$$R_g = \rho\left[\frac{1}{L_T} + \frac{1}{\sqrt{20A}}\left(1 + \frac{1}{1 + h\sqrt{20/A}}\right)\right] \quad (3)$$

Where, R_g is the grid resistance in (Ω), ρ is the soil resistivity in (Ω-m), A is the area occupied by the earth grid in m^2, h is the grid burial depth in m, and L_T is the total length of buried conductors in (m).

3. RESULTS AND DISCUSSION

Table 1 lists the measured apparent soil resistivity field data indicating apparent resistance and resistivity values which are average values of five measurements conducted for each probe spacing. The initial spacing between probes was 1m and was increased in steps of 1m up to 6m. To ensure accuracy of measurement, the spacing between probes was equally maintained and all probes were arranged in a straight line.

Table 1. Average values of measured soil resistivity field data

Probe Spacing (m)	Average Apparent Resistance (Ω)	Average Apparent Resistivity (Ω-m)
1.0	308.6	1,938
2.0	110.2	1,384
3.0	52.8	995
4.0	33.6	844
5.0	32.0	1,005
6.0	20.0	754

Table 2 depicts the soil model obtained after the RESAP run. It indicates that the soil at the proposed site comprises of two layers, where the first soil layer has a resistivity of 2231.9Ω-m and thickness of approximately 1.1m. And, the second soil layer is of resistivity 752.4Ω-m and infinite thickness. In other words, the soil model is made of two layers with high resistivity layer above a low resistivity layer of infinite thickness. For earth grid design, the grid would be buried in the second soil layer because it has a lower resistivity compared to the upper layer and the burial depth was taken to as 1.3m. Note that, the burial depth is normally varied between 0.5 to 1.5m as reported in [11].

Table 2. Soil structure parameters computed by RESAP

Layer Number	Resistivity (Ω-m)	Thickness (m)
1	2231.9	1.1
2	752.4	infinite

Table 3 lists variables that are required for calculations of earth grid resistance and the results obtained by substituting these variables into each of equations the IEEE equations (50) to (52) denoted by equations (1) to (3) in this paper. Note that, equations (2) and (3) contains the L_T term which defines the total length of buried conductors while equation (1) does not, regardless, all the three equations could be used to calculate value of R_g. Results indicated that, using equation (1), as the area occupied by the grid was increased from 25m^2 to 2,500m^2, the value of R_g decreased steadily from 66.65Ω to 6.66Ω. Observe that, when the grid area was increased to 4,900m^2 the value of R_g obtained was 4.76Ω, which is slightly lower than 5Ω recommended in [12] by IEEE Std. 142 as the maximum value of R_g for small distribution substations. This implies that, an increase of 2,400m^2 of grid area yielded a decrease of only 1.9Ω which is not economical from the design point of view.

Table 3 Calculated values of R_g using IEEE Std. 80-2000 equations 50, 51 and 52.

Grid Dimension (m)	Area (m^2)	No. of rows and columns (m)	L_T (m)	R_g eqtn. 50 (Ω)	R_g eqtn. 51 (Ω)	R_g eqtn. 52 (Ω)
5 x 5	25	2 x 2	20	66.65	104.36	71.88
10 x 10	100	3 x 3	80	33.32	45.89	30.00
20 x 20	400	6 x 6	280	16.66	19.80	12.36
30 x 30	900	11 x 11	660	11.11	12.25	7.60
40 x 40	1,600	11 x 11	880	8.33	9.19	5.95
50 x 50	2,500	11 x 11	1,100	6.66	7.35	4.95
60 x 60	3,600	21 x 21	2,520	5.55	5.85	4.02
70 x 70	4,900	15 x 15	2,100	4.76	5.12	3.69

Considering IEEE equation (51), it could be observed that, the value of R_g was initially computed as 104.36Ω when only 20m length of buried conductor was used. As the length, grid area and dimension were increased, the value of R_g drastically decreased until 7.35Ω was obtained utilizing 1,100m length of buried conductor. Further addition of conductor length from 1,100m to 2,520m, and increment of grid area from 2,500m^2 to 4,900m^2 and grid dimension from 50mx50m to 70mx70m resulted in the reduction of the value of R_g from 7.35Ω to 5.12Ω, respectively. Again, it could be noted that, an addition of 1,000m of buried conductor length yielded a decrease in the value of R_g by only 2.23Ω which is also considered uneconomical in grid design. Similarly, using IEEE equation (52), it could be seen that, the initial value of R_g was 71.88Ω with 20m length of buried conductor. As the length of buried conductor was increased as a result of the increase in dimension and area occupied by the grid, the value of R_g decreased to 4.95Ω utilizing 1,100m of buried conductor length. Note that, the value of R_g, i.e. 4.02Ω was obtained after the length of buried conductor was increased from 1,100m to 2,520m indicating a difference of 1,420m which is considered uneconomical for a reduction of less than 1Ω.

Comparing the three IEEE equations for calculating the value of R_g, it could be observed that equation (50) utilized more grid area, i.e. 4,900m^2 to yield a resistance of 4.76Ω as it does not contain any L_T term, while equation (51) which contains both the grid area and L_T terms used the same grid area and 2,100m length of buried conductor but could not yield a resistance value less than 5Ω which is slightly higher than the result obtained from equation (50). Considering equation (52) which also contains both the grid area and the L_T terms, it was found that, a grid area of 4,900m^2 and 2,100m of buried conductor length resulted to an R_g of 3.69Ω. Therefore, from economic point of view, IEEE equations (50) and (52) are recommended for estimating the initial values of R_g during substation earth grid design. Care must be exercised during design process to avoid uneconomic practice as the value of R_g gets lower since the addition of large size of conductor length does not contribute significantly to decrease the value of R_g.

Table 4 depicts the simulated values of R_g obtained using CDEGS for grids A, B and C containing different values of buried conductor length as a result of the addition of 3m long earth rods in Grid B and C arrangements. Considering the 50mx50m dimension with Grid A arrangement, the area occupied by the gird was 2,500m^2, and the total length of buried conductor was 2100m which yielded an R_g of 6.54Ω. In Grid B arrangement with the same dimension and area, the total length of buried conductors was increased to 2,340m as a result of the additional 3m long earth rods installed at the grid periphery, the value of R_g merely decreased to 6.20Ω indicating a difference of only 0.34Ω. In the same vein, when additional earth rods were installed at all the grid conductor crossings, the total length of buried conductors swelled to 3,423m but the value of R_g reduced by only 0.49Ω which could be considered negligible for 1,083m increase in buried conductor length.

Table 4. Summary of earth grid results after simulation using CDEGS

Grid dimension (m)	Grid Area (m^2)	Arrangement	Conductor length (m)	R_g (Ω)
50 x 50	2500	Grid A	2100	6.54
		Grid B	2340	6.20
		Grid C	3423	6.05
60 x 60	3600	Grid A	2520	5.48
		Grid B	2760	5.25
		Grid C	3843	5.14
70 x 70	4900	Grid A	2940	4.72
		Grid B	3180	4.56
		Grid C	4263	4.48

Considering the 60mx60m dimension and Grid A arrangement, the area occupied by the grid is 3600m^2 comprising of 2,520m length of buried conductors which produced an R_g of 5.48Ω. When the Grid B arrangement was installed, the total length of buried conductor increased from 2,520m to 2,760m yielding an R_g of 5.25Ω which seems to be slightly lower than the previous value with a difference of only 0.23Ω. Also, for Grid C arrangement, the total length of buried conductor swelled to 3,843m when earth rods were added at the grid intersections, however, the value of R_g obtained was barely 5.14Ω showing a difference of 0.34Ω only when compared with the initial value of R_g for 60mx60m grid dimension. In the same vein, considering the 70mx70m dimension Grid A arrangement, the grid covered an area of 4900m^2 with 2,940m length of buried copper conductor resulting in an R_g of 4.72Ω. The total lengths of buried conductor for Grid B and C arrangements were 3,180m and 4,263m which produced 4.56Ω and 4.48Ω of R_g, for a grid area of 4900m^2 respectively. Note that, the difference of buried conductor length between Grid B and C is 1,083m but resulted in the reduction of the value of R_g by only 0.08Ω which could be considered as negligible and uneconomical.

The results from the grid design and simulations have revealed that, for all the three grid dimensions, addition of earth rods at grid conductor crossings (all cases of Grid C) have negligible or precisely zero contribution to the reduction of the value of R_g and would certainly lead to huge increase in the overall cost of grid installation. This further indicate the saturation boundary beyond which further addition of buried conductor length does not lead to reduction of the value of R_g but incurs huge additional cost to the grid design. It could also be deduced from the results that, the area occupied by the grid plays a more significant role in reduction of the value of R_g as witnessed in the case of 70mx70m grid dimension. Furthermore, the results from the calculations using the IEEE Equations (50) to (52) and CDEGS simulations have good agreement for the three grid dimensions considered.

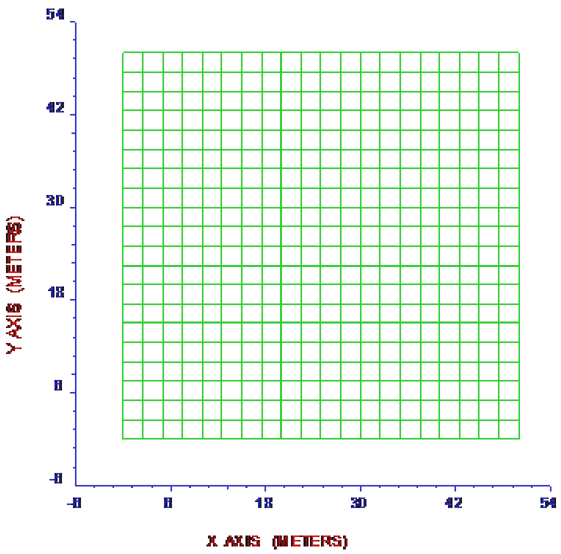

Figure 1c Top view of 50mx50m

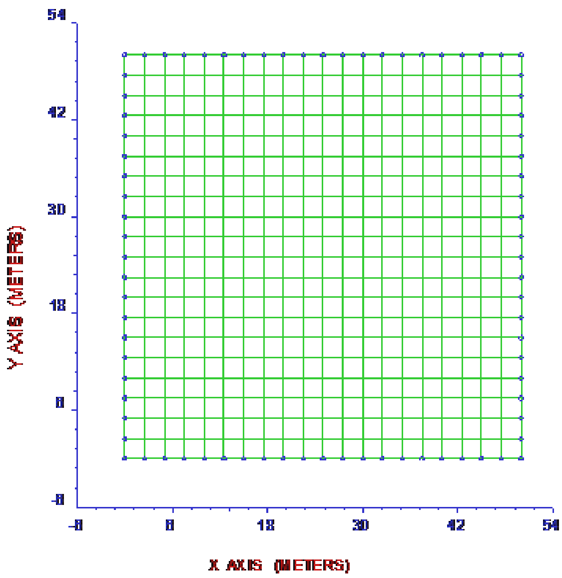

Figure 1b Top view of 50mx50m

Figures 1a, 1b and 1c shows the arrangement of Grid A, B and C for 50mx50m grid dimension, while Figures 2a, 2b and 2c illustrates the arrangement of Grid A, B and C for 60mx60m grid dimension. Similarly, Figures 3a, 3b and 3c depicts the arrangement of Grid A, B and C for 70mx70m grid.

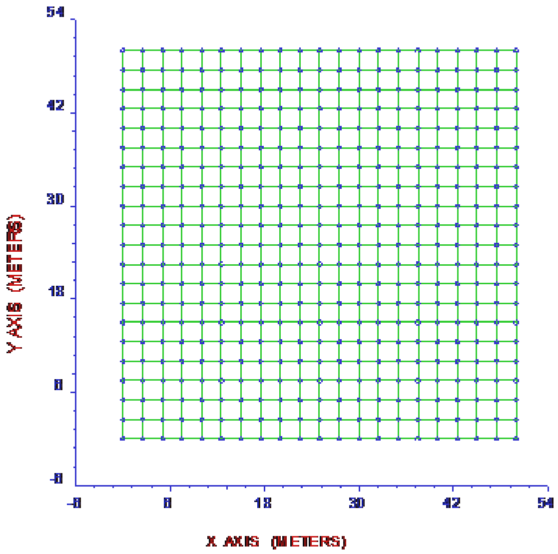

Figure 1a Top view of 50x50m Grid A

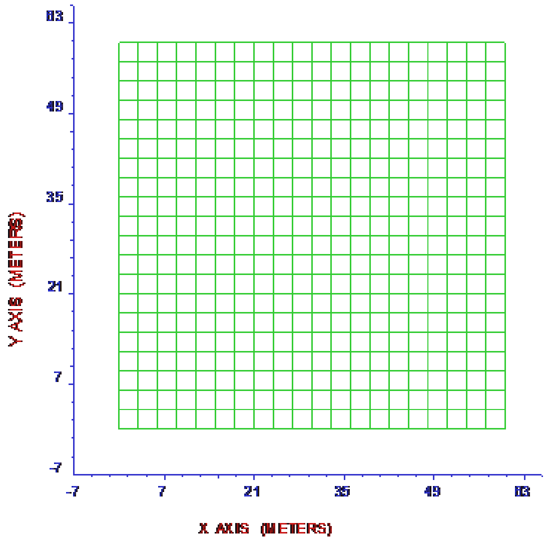

Figure 2a Top view of 60mx60mGrid A

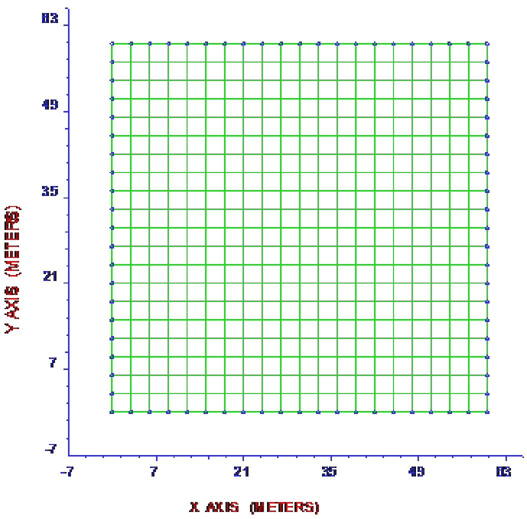

Figure 2b Top view of 60mx60m Grid B

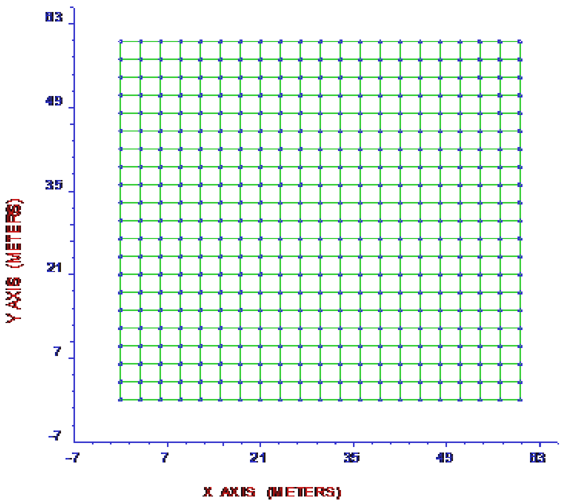

Figure 2c Top view of 60mx60m Grid C

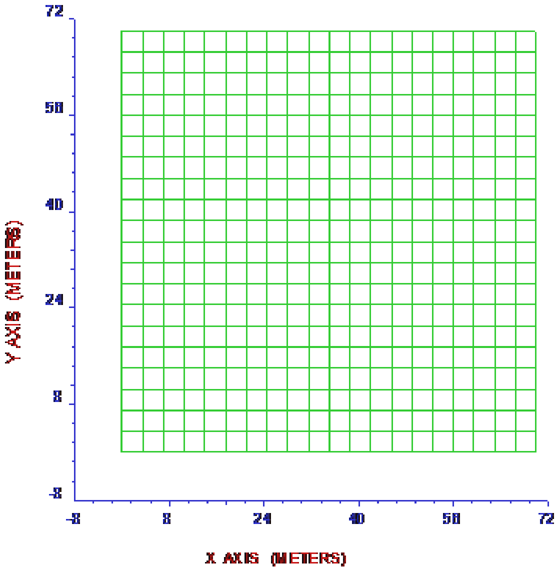

Figure 3a Top view of 70mx70m Grid A

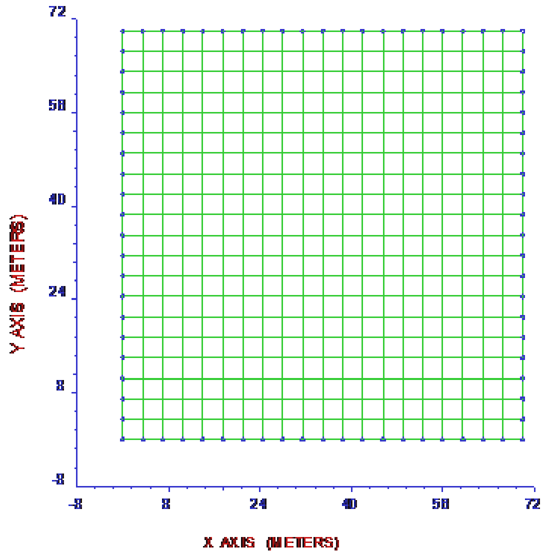

Figure 3b Top view of 70mx70m Grid B

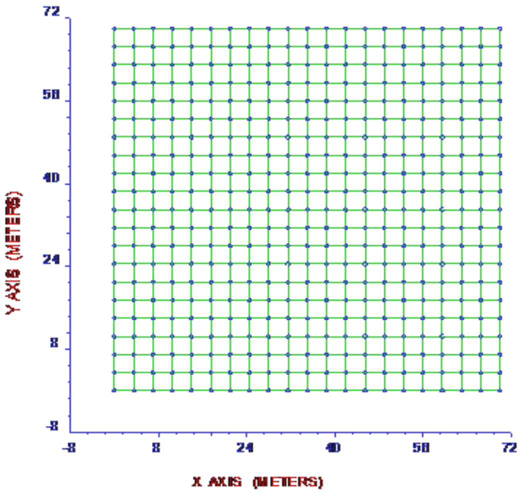

Figure 3c Top view of 70mx70m Grid C

Note that, the little dots at the grid periphery and conductor intersections in grid arrangements B and C for all dimensions 50mx50m, 60mx60m and 70mx70m indicates the earth rod positions which is distinctly absent in all cases of type A grid arrangements.

4. CONCLUSION

IEEE Standard 80:2000 equations 50, 51 and 52 have been evaluated to determine the contribution of buried conductor length in computation of the value of earth grid resistance. Three different dimensions and arrangements of earth grid have been designed by CDEGS to validate the impact of buried conductor length on the value of grid resistance. It was found that there is a saturation boundary (grid periphery) beyond which further addition of buried conductor length during earth grid design has negligible effect on the value of R_g and thus leads to uneconomical design. It was also revealed that equation (52) utilized much less grid area and buried conductor length to yield a lower value of R_g than equations (50) and (51). It could be concluded that, vertical earth rods are specifically useful for creating multiple paths for dissipation of fault currents into the soil, but their impact for reduction of grid resistance is limited beyond the grid periphery as seen in this study.

REFERENCES

[1] Y. Liu, "Transient Response of Grounding Systems Caused by Lightning: Modelling and Experiments," PhD Thesis, Uppsala University, 2004.
[2] J. D. McDonald, Electric Power Substation Engineering, 2nd Edition, CRC Press, New York, 2007, Ch. 11-1.
[3] *IEEE* Standard 80-2000, Recommended Guide for Safety in AC Substation Grounding, ANSI, 2000.
[4] V. L. Coelho, A. Piantini, R. A. Altafim, H. A. Almaguer, R. A. Coelho, M. R. de Lima, W. do C. Boaventura, J. O. S. Paulino, and P. L. Nosaki, International Symposium on Lightning Protection (XII SIPDA*)* 2013, Criciúma-Brazil.
[5] S. Ghoneim, H. Hirsch, A. Elmorshedy, and R. Amer, *"Improved Design of Square Grounding Grids,"* International Conference on Power System Technology, (PowerCon.) 2006, 22-26 Oct. 2006, Chongqing, China.
[6] A. A. El-Fergany, "Design and Optimize Substation Grounding Grid Based on *IEEE* Std. 80-2000 Using GUI And MATLAB Codes," International Journal of Engineering Science & Technology, vol. 3, No. 7, 2011.
[7] M. Mondal, D. K. Jarial, S. Ram, and G. Singh, "Design and Analysis of Substation Grounding Grid with and without Considering Seasonal Factors using EDSA Software." International Journal of Innovations in Engineering and Technology, Special Issue, ICAECE, 2013.
[8] S. Raju and P. Upadhyay, *"Design of Optimal Grounding Mats for High Voltage Substation,"* International Conference on Advances in Power Conversion and Energy Technologies (APCET) 2012, 2-4 Aug. 2012, Mylavaram, Andhra Pradesh, India.
[9] A. Ackerman, P. K. Sen, and C. Oertli, "Designing Safe and Reliable Grounding in AC Substations With Poor Soil Resistivity: An Interpretation of IEEE Std. 80," *IEEE* Transactions on Industry Applications, vol. 49, no. 4, pp. 1883–1889, Jul. 2013.
[10] K. D. Pham, "Design of a Safe Grounding System for Rural Electric Power Distribution Substations," Presented at the 34th Annual Conference on Rural Electric Power, (REPCON) 1990, 29 Apr-1 May 1990, Orlando, FL, U.S.A.
[11] Design Guide for Rural Substations, United States Department of Agriculture, Rural Utilities Service Bulletin 1724E-300, June 2001.
[12] *IEEE* Standard 142-2007, Recommended Practice for Grounding Industrial and Commercial Power Systems, ANSI, 2007.

BIOGRAPHIES OF AUTHORS

Sani D. Buba obtained National Diploma in Electrical and Electronic Engineering from the Federal Polytechnic Mubi in 1991. He proceeded to University of Maiduguri, Borno State, Nigeria, where he was awarded B. Eng. (Hons) Degree in Electrical and Electronic Engineering in 2002. He worked as a Tutor in the Department of Electrical and Electronic Engineering, Federal Polytechnic Mubi from November, 2002 until November, 2009. He enrolled for MSc Programme in the Department of Electrical and Electronic Engineering, Universiti Putra Malaysia (UPM) and obtained a Master of Science Degree in Electrical Power Engineering in August 2012. Mr. Buba is currently a PhD student in the Department of Electrical & Electronic Engineering at UPM. He is a Graduate Student Member of IEEE-PES, PELS and CIS. His research interests include, earthing systems, Solar PV systems, Lightning Protection Systems and Power System Analysis.

Wan F. Wan Ahmad (S'02, M'05) was born in Kelantan, Malaysia, on Sep. 6, 1978. She graduated from Universiti Kebangsaan Malaysia, Malaysia in 2000 with Bachelor in Electrical, Electronic and Systems Engineering with honours, and majoring in Electrical Power and Control Engineering. She received her PhD in Electrical and Electronic Engineering from University of Nottingham, Nottingham, U.K. in 2007, majoring in Lightning Protection System and Electromagnetic Compatibility for Electrical Power Engineering. She is currently with the Department of Electrical and Electronic Engineering, Faculty of Engineering, Universiti Putra Malaysia which she joined since 2000. She has tremendous experiences in teaching Bachelor of Engineering (Electrical and Electronics) with Honours students. At the moment she is Deputy Director (Research and Collaboration) at Centre of Excellence on Lightning Protection (CELP), Faculty of Engineering, Universiti Putra Malaysia, Malaysia. Through her career, she has won 3 Research awards and 4 non-research awards. Her research interests include electrical power engineering, grounding system, lightning protection system, Electromagnetic Compatibility (EMC), Transmission Line Modelling (TLM), Radio Frequency Electromagnetic Field (RF EM), Single Long Horizontal Ground Conductor and thin wire. Dr Wan Ahmad is member of IEEE APS, IEEE EMCS, AND IEEE MTTS, IEEE MS, IEEE SA AND MSSS.

Professor Mohd Zainal Abidin Ab Kadir graduated with B.Eng. Degree in Electrical and Electronic Engineering from Universiti Putra Malaysia in 2001, and obtained his PhD from the University of Manchester, United Kingdom in 2006 in High Voltage Engineering. Currently, he is the Head of Department of Electrical and Electronics Engineering, Faculty of Engineering, Universiti Putra Malaysia (UPM). He is also the Director of Scientific Committee at the Centre for Electromagnetic and Lightning Protection Research (CELP), UPM and a Member of International Board of Advisors for the National Lightning Safety Institute (NLSI), USA. Professor Zainal is a Professional Engineer (PEng) and a Chartered Engineer (CEng) from Board of Engineers, Malaysia and Engineering Council, UK, respectively. He is currently the Chair of IEEE-PES Malaysia Chapter, Working Group Member of IEEE-PES Lightning Performance on Overhead Lines, Senior Member of IEEE (PES, EMC, Insulation and Dielectric Societies) and IAENG. To date, he has authored and co-authored over 160 technical papers comprising of high impact journals and conference proceedings. He is also an Editorial Board Member for several international journals and Reviewer for many international journals and conference. His research interests include high voltage engineering, insulation coordination, lightning protection, EMC/EMI, keraunamedicine, renewable energy and power system transients.

Chandima Gomes was born in Colombo, Sri Lanka 0n 12th September 1966. He obtained his B.Sc. from University of Colombo, Sri Lanka, and PhD from Universities of Colombo/Uppsala, Sweden in 1999. He is a member of several professional bodies such as CEng (UK), CPhys (UK), MInstP (UK), MIET (UK), and MIP (SL). Currently, he is a Professor of Electrical Engineering in the department of Electrical & Electronic Engineering, Faculty of Engineering, Universiti Putra Malaysia and also the Head, Centre for Electromagnetic and Lightning Protection Research (CELP). In addition to his academic career, he is the Technical Director of ProMan Ship Builders Ltd., China, Chief Technical Advisor and Senior Consultant of Steelman Electro Mechanical Company LLC, Dubai, Chief Technical Advisor and Senior Consultant of Indus Resources Ltd., Pakistan, Senior Consultant of Capital Consultants Pvt Ltd., Pakistan, Director International Affairs of LP Consultants International Pvt Ltd., India, Director/ Technical Operations of SATRIC-M, Malaysia and Senior Consultant of LLAMPEC International Pvt Ltd., Sri Lanka during the last few years. Prof. Gomes has conducted over 80 training programs on lightning and transient protection technologies to the engineers in Saudi Arabia, Sweden, India, Sri Lanka, Bangladesh, Bhutan, Pakistan, Nepal, Indonesia, Malaysia and Colombia. Prof. Gomes has published over 80 research papers and several books on lightning protection. His research interests include, Lightning & Transient Protection of LV, MV, HV & Signal Systems, Grounding Systems & Backfill Materials EMI/EMC of Civil and Defense Systems and Electrical Safety.

Jasronita Jasni (M’01) graduated with a B Eng Degree in Electrical Engineering from Universiti Teknologi Malaysia, Malaysia in 1998 and received her Master Degree in Electrical Engineering from the same University in 2001. She obtained her PhD Degree from Universiti Putra Malaysia, Malaysia in May 2010. Currently she is a Senior lecturer in the Department of Electrical and Electronic Engineering, Faculty of Engineering, Universiti Putra Malaysia. Dr. Jasni is a member of IEEE. Her research interests include power system analysis for static and dynamics, load flow analysis, embedded generation and renewable energy.

Miszaina Osman received a Bachelor of Electrical Engineering Degree in 1999 and a PhD in Electrical Engineering in 2004 both from University of Southampton, United Kingdom. She is a member of many international professional bodies such as C.Eng. (UK), IET and IEEE. Currently, Dr. Miszaina is a Deputy Dean and Senior Lecturer in the Department of Electrical Power Engineering, College of Engineering, Universiti Tenaga Nasional (UNITEN), Malaysia. She is also a member under the Centre of Power System Simulation (CPSS) in UNITEN. Her research interest includes power system grounding, power system transients and engineering education.