الدار الدولية للهندسة
DAR ENGINEERING

PORTABLE GROUNDING SYSTEM Vs TRADITIONAL METHODS

This paper was presented at
GCC POWER 2016, Doha, Qatar

M. Tanveer Ahmad, *DAR Engineering Pakistan*

Portable Grounding System vs Traditional Methods

M. Tanveer Ahmad, DAR Engineering Pakistan

Abstract- This paper focuses on the comparison based analysis of grounding systems prepared by conventional rod method and a portable grounding system used for different electrical equipment, substation and portable machines. These two systems have been implemented and earth resistance of each grounding channel and cost of grounding channels prepared at same soil resistivity has been determined and discussed. Both of these systems are used at the same location having same resistivity. For first grounding channel, earthing blocks have been prepared and attached together to obtain the desired value of earthing resistance. Second grounding channel has been prepared by installing copper rods attached together with copper rope. Series of experiments have been performed for different combinations of portable blocks and rods for measuring resistances. Rocky soil has been selected for implementation of these grounding systems and resistivity of selected soil is 300 Ωm.

Keywords- Portable grounding system, Grounding blocks, Earthing channel, conventional rod method.

I. INTRODUCTION

A Grounding system with improper design can damage the electrical and electronic components installed in power system. Grounding system and ground fault protection should be taken into account while designing safe and healthy electrical system. High voltage spikes are produced due to lightning effect and other voltage stresses in the system which may lead to the failure of the equipment installed, Similarly, ground faults also occur in the system which produces high current stresses. In electrical power system, communication system and different electrical equipment, properly designed efficient grounding system is required to limit the voltage on the system and improve the performance of over current devices [2].The resistance of grounding system installed using conventional rod method mainly depends upon the nature of soil and length of grounding electrodes used to prepare grounding channel. Earth resistivity is one of the most important parameters that must be taken into consideration

while designing new grounding system and its value does not remain same within the small area of the soil. In addition, the earth resistance and the resistivity changes with moisture contents and chemical composition of the soil. This is important for design and implementation of efficient grounding systems to accurately measure the earth resistance and the soil resistivity. There are different methods to measure and simulate the earth resistance and research is in progress for new grounding systems. [3]

The grounding system prepared by adding grounding rods and connecting them with each other is effective and reduces the grounding resistance to very low level [4]. But this type of grounding system has limited applications; one of the important attributes of an efficient grounding system is its portability. Grounding system should be able to be shifted from one place to another as per requirement of users and portable electrical machines. This is impossible in rod method. Conventional rod method required long vertical earthing pits to place these rods in order to prepare grounding channel. The placement of these grounding rods is very hard, complex and costly, especially when grounding channel is required in hard rocky soil. After installation of rod method its resistance remains constant and another grounding channel is required to be installed if user needs lower resistance level.

The grounding system designed for EHV electrical substation (utilities) must have very low resistance level up to 1 Ω. Similarly, grounding system used for electromagnetic shielding to protect equipment from electromagnetic waves must have less than 4 Ohm grounding resistance. The recommended grounding resistance for industrial and commercial

electrical substation is 5 Ohms or less. This low resistance is required due to the high potential to earth of the electrical system. Many communication companies require grounding system having resistance of less than 3 Ohms and same value of resistance is for vender companies. Lightning arrestors used to protect the electrical equipment from lightning is 10 Ohm but this value should not exceed at any point [5].

The addition of long vertical rods in grounding channel with explosion grounding system technique has been used to decrease the earthing resistance in the actual grounding system engineering [6]. But if grounding system is required to be installed in rocky area having high value of soil resistivity, the placement of large number of vertical rod to obtained desired earth resistance is very complex and costly as compared to efficient portable grounding system [7].

II. IMPLEMENTATION OF PORTABLE GROUNDING SYSTEM

A novel method of grounding is developed by the author. Because that system is compared with the conventional rod based system, a review of the compact and portable grounding system is required to be presented here. This is an efficient method of preparing efficient grounding channel that is also cost effective. For installation of portable grounding system different grounding blocks having different dimensions have been constructed by mixing specific volume of salt, coal, sand, Crush and Cement (4:4:4:4:1) and desired amount of water is used to prepare sludge. Coal and salt are used in grounding channel to reduce the resistivity of soil. Sand, cement and crush are used to make these blocks compact which make them convenient to transport from one place to another. Construction of compact grounding blocks have been made possible to design portable grounding system of desired resistance which may be reusable. Twenty four portable grounding blocks having different dimensions have been prepared by the author. Different sizes of copper plates have been used in different blocks. Transportation problems may occur by increasing the size of blocks as their weight increases by increasing the size of blocks. The dimension of grounding blocks prepared and sizes of copper plates used in these blocks is given in table 1.

Table 1: Dimensions of grounding blocks and copper plate and respective weight of grounding block

Sr. No	Dimension of Block (Inches)	Dimension of plate (Inches)	Block Weight (kg)
1	18” x 18” x 12”	12" x 12" x 0.25"	96
2	14" x 12" x 14"	12" x 10" x 0.25"	75
3	14" x 10" x 14"	12" x 8" x 0.25"	67
4	12" x 10" x 14"	10" x 8" x 0.25"	44
5	10” x 10” x 14”	8" x 8" x 0.25"	42
6	10" x 8" x 14"	8" x 6" x 0.25"	38

The formation of a portable block involves preparation of a cage using angle iron and steel bar in which sludge is inserted to make it compact. The main purpose of using this cage is to make these blocks transferrable from one place to another. Heaving angle iron and steel bar provide more strength but weight of the block is increased. So a compromised value is used for preparing cage.

After sometime these blocks get dry and may be used for grounding system installed for electrical substation, electric machines and communication equipment. Copper plate placed inside grounding block is welded with two copper ropes having 70 mm diameter and length of 2 meter each. These ropes are used for connecting grounding blocks with each other and also with the equipment in order to obtain desired resistance level. Connection of blocks with each other create grounding channel. Portable grounding blocks prepared by author are shown in figure below.

Figure 1: Implementation of portable grounding system

Due to poor electrical conductivity of earth, large potential gradient occurs when high current flows through the ground and potential of earth rises which is known as earth potential. Earth potential rise is the difference of voltage between earthing system and

reference earth. The amount of earth fault currents is very high, and ground resistance required for EHV substations must be ranging from 0.05 □□to 1□□[8]. The design and implementation of earthing pits using low resistive material is very important in order to achieve low value of ground resistance. When such materials are used, it is important to reduce the pit dimensions in order to have an efficient and economical grounding system.

For the sake of comparison the portable blocks used for preparing grounding channel contains copper plate having same weight as that of copper rod used for preparing other grounding channel. Block having dimension of 10" x 10" x 14" has copper plate of dimension 8" x 8" x 0.25" having same weight as that of copper rod of length of 15 feet and diameter of 0.5". Grounding channel prepared using portable grounding block is shown in Fig. 3.

III. MEASUREMENT OF RESISTANCE FOR PORTABLE GROUNDING CHANNEL

The ground resistance can be measured using the fall-of- potential (FOP) method [9]. Two probes are used in this method. First probe is voltage probe and second probe is current probe. With the help of both potential and current measurements into the two surface probes, the material surface resistance between two probes can be calculated using formula:

Rtotal = Voltage(V)/Current(I) = 2Rc + 2Rsp + Rs [10]

The rocky soil having resistivity of 300 Ohm has been selected for performing these experiments. Four grounding blocks having dimension of 10" x 10" x 14" and plate size of 8" x 8" x 0.25" have been used in first phase to produce portable grounding system. These four blocks have been laid inside separate earth pits of dimension 4' x 4' x 2'. Clay is prepared inside these earth pits by providing specific amount of water. These blocks are connected with each other through already attached copper ropes with each block. These blocks have been attached with each other.

Figure 2: Implementation of grounding channel by combining four portable grounding blocks of dimension 10"x10"x14"

After attachment of these blocks with each other a grounding channel is formed. Different results obtained for different combination of blocks is shown in table 2.

Table 2: Resistance for different combination of blocks

Sr. No	Dimension of Block (Inches)	No. of Blocks	Resistance (Ω)
1	10" x 10" x 14"	1	4.5
2	10" x 10" x 14"	2	3.8
3	10" x 10" x 14"	3	3.3
4	10" x 10" x 14"	4	3.0
5	10" x 10" x 14"	5	2.8
6	10" x 10" x 14"	6	2.7

It can be observed that four grounding blocks having dimension of 10" x 10" x 14" connected with each other through copper conductor of 70 mm2. The weight of copper plate used in these blocks is similar to copper rod used in conventional rod method. Resistance of grounding channel decreases by connecting more grounding blocks with each

other and earth resistance of 2.7 Ω can be achieved in rocky areas where the soil resistivity is 300 Ωm by preparing grounding channel using six grounding blocks with each other.

IV. IMPLEMENTATION OF CONVENTIONAL ROD METHOD

For preparing grounding channel using rod method, long vertical copper rods have been placed inside earthing bores and low resistive material is used to reduce the soil resistivity. Four bores have been prepared at each corner of a square having sides of 5

meter. Copper rod of 13.5 feet in length along with perforated PVC pipe is inserted in each bore. Perforated PVC pipe is used to provide water to improve the performance of grounding system in future. Grounding bores are then filled with low resistive material in order to obtain low grounding resistance value. Coal and salt (4:4) are used as low resistive material and sludge is prepared using specific amount of water. Grounding bore is then filled with the sludge around the copper rod and perforated pipe. These four copper rods are connected with each other through copper conductor of 70 mm^2. Step wise preparation of grounding channel using four copper rods is shown in figure below.

Figure 3: Implementation of grounding channel using rod method

The material used to reduce the resistivity of soil is known as low resistive material (LRM). The volume of low resistive material used in grounding system totally depends upon the required resistance of grounding channel. Sometimes, this material is inserted partially inside grounding bore or grounding bore is filled with LRM to attain desired value of earth resistance. Grounding system without using such low resistive material can also be constructed. In these experiments salt and coal are used as LRM. The soil selected for performing this comparison has the same resistivity in both cases. Figure shows different grounding arrangements with different volume of LRM used in grounding bore.

It is difficult to obtain low earth resistance using conventional grounding techniques in hard rocky area where the earth resistivity is very high. Therefore, grounding pit must be designed by considering this factor and efficient grounding pit can be achieved by using low resistive material. But this is also important for efficient and economical grounding system that consumption of LRM should be minimum [4].

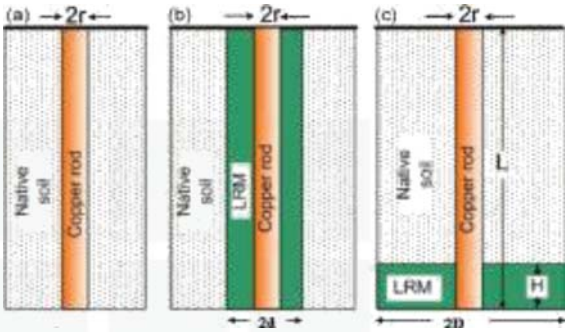

Figure 4: Rod grounding method [11].
(a) Grounding rod without using LRM,
(b) grounding rod with bore is completely filled with LRM and (c) grounding rod embedded partially in LRM at the bottom.

V. RESISTANCE MEASUREMENT FOR DIFFERENT NUMBER OF RODS

Experiments have been performed for different combination of grounding rods and resistance is measured in each experiment. The copper rod used in this method has the same weight as that of copper plate used in portable grounding system for better comparison. The soil selected in both cases has the same soil resistivity of 300 Ω.m. Soil resistivity is measured using four probe wenner method.

Two spikes are used for the measurement of grounding resistance. One spike is for current and other spike is used for voltage. These spikes are erected 5 meters and 10 meters away from test grounding channel in straight line. Earth resistance meter is now connected with channel and also with these spikes for resistance measurement.

The results obtained for different number of rods having 5 meter and 10 meter distance of potential and current spikes respectively is shown in table below. The distance between voltage spike and channel is 5 meters while the distance between current spike and channel is 10 meters in all of the cases discussed in the table 3.

Table 3: Measurement of resistance (Rod method)

Sr. No	No. of Rods	Resistance (Ω) (Rod method)	Resistance(Ω) (Rod method for large spacing)
1	1	5.2	5
2	2	4.8	4.6
3	3	4.2	3.9
4	4	3.7	3.5

It has been noticed that resistance of grounding channel is reduced by increasing the distance between potential and current probes and also with the grounding channel. This impact is reflected in the table 4 where the distance between voltage spike and channel is 7 meters while the distance between current spike and channel is 14 meters in all of the cases This reduction in earth resistance is due to increase in the area of grounding mesh under test.

VI. COMPARISON OF PORTABLE GROUNDING SYSTEM AND ROD METHOD

Grounding system has been installed using four portable blocks at soil having same resistivity of 300 Ωm as in case of grounding system installed using four rod method. Furthermore, the copper plate used in portable block has the same weight of 3.5 kg as that of copper rod used in rod method. The resistance and cost of material used in both grounding systems including labour charges have been compared. Total expenditures on preparing grounding system using four portable blocks having dimension earthing channel using four portable blocks having dimensions 10”x10”x14” is given in table 4 on the last page.

Weight of copper plate having dimension 8” x 8” x 0.25” used inside these blocks is 3.5 kg that is approximately similar to the weight of copper rod having length of 15 feet and 0.5” diameter used in conventional rod method. Total cost for constructing grounding system using four copper rods is given below in table 5 on the last page.

The comparison of resistance and cost for preparing both grounding system with different combination of portable blocks and grounding rods is given in table 6.

Table 6: Comparison of portable blocks and rod method

Number		Resistance (Ω)		Cost ($)	
Rod	Block	Rod	Block	Rod	Block
1	1	5.2	4.5	15880	13200
2	2	4.8	3.8	32830	29485
3	3	4.2	3.3	50400	45320
4	4	3.7	3.0	65660	58970

It has been analyzed that portable grounding system is more efficient and more economical as compared to conventional rod method.

VII. CONCLUSIONS AND FUTURE WORK

Portable grounding system and conventional grounding system using rod method have been constructed at same soil resistivity for comparison purpose. Different experiments have been performed on both grounding channels and comparison has been made. The portable grounding system has been proved less costly and highly efficient as compared to conventional rod method. In comparison with conventional rod method, the grounding resistance has been reduced to very low level using limited number of portable blocks prepared by author. Currently, these blocks are attached in the high voltage lab of UET Lahore, Pakistan. It has been observed that cost of preparing grounding system using portable blocks is approximately 90% of the cost of preparing grounding system using conventional rods. Similarly, grounding resistance observed for portable grounding system is 81% of the grounding resistance measured for conventional rod method. It can be concluded that portable grounding system is more efficient, compact, economical, semi prepared, reusable, and easy to install. The improved performance of portable grounding system can be obtained by using more efficient LRM and connecting more portable blocks. This grounding system can be further applied for developing portable electromagnetic shielding system for protecting Electrical and electronics equipment from Electromagnetic pulses.

REFERENCES

[1] Chow, M. A. R. K., Bowen, J., & Yu, L. (1995). Integrating safety, grounding, and ground fault protection in electrical system designs (No. CONF-9505342--). Inst. of Electrical and Electronics Engineers, Inc., Piscataway, NJ (United States).

[2] Ockuly, G. J. (1989, October). Equipment grounding conductors and bonding-a vital link in electrical system protection. In Industry Applications Society Annual Meeting, 1989., Conference Record of the 1989 IEEE (pp. 1651-1655). IEEE.

[3] Salam, M. A., Ang, S. P., & Aj, C. (2012, September). Simulation of grounding resistance with 70 by 70 feet grid. In Universities Power Engineering Conference (UPEC), 2012 47th International (pp. 1-5). IEEE.

[4] Al-Arainy, A. A., Khan, Y., Qureshi, M. I., Malik, N. H., & Pazheri, F. R. (2011, April). Optimized pit configuration for efficient grounding of the power system in high resistivity soils using low resistivity materials. In Modeling, Simulation and Applied Optimization (ICMSAO), 2011 4th International Conference on (pp. 1-5). IEEE.

[5] Recommended Practice for Grounding, ANSI/IEEE Standard 142-1982

[6] Zeng, R., He, J., Wang, Z., Gao, Y., Sun, W., & Su, Q. (2000). Analysis on influence of long vertical grounding electrodes on grounding system for substation. In Power System Technology, 2000. Proceedings. PowerCon 2000. International Conference on (Vol. 3, pp. 1475-1480). IEEE.

[7]Hassan, W., Akmal, M., & Kamran, M. (2013, September). Portable and compact grounding system. In Power Engineering Conference (UPEC), 2013 48th International Universities' (pp. 1-6). IEEE.

[8] Abdel-Salam, M. (2000). High-Voltage Engineering: Theory and Practice, Revised and Expanded. CRC Press.

[9] Bouchard, M., Dawalibi, F., & Mukhedkar, D. (1977, January). Survey on ground resistance and earth resistivity measurements. In IEEE Transactions on Power Apparatus and Systems (Vol. 96, No. 4, pp. 1076-1076). 345 E 47TH ST, NEW YORK, NY 10017-2394: IEEE-INST ELECTRICAL ELECTRONICS ENGINEERS INC. [10] Schroder, D. K. (2006). Semiconductor material and device characterization. John Wiley & Sons.

[11] Al-Arainy, A. A., Khan, Y., Qureshi, M. I., Malik, N. H., & Pazheri, F.

R. (2011, April). Optimized pit configuration for efficient grounding of the power system in high resistivity soils using low resistivity materials. In Modeling, Simulation and Applied Optimization (ICMSAO), 2011 4th International Conference on (pp. 1-5). IEEE.

Table 4: Total expenditures on grounding system prepared using four portable blocks having size 10”x10”x14”

Sr. No.	Description	Unit	Qty	Unit Price (PKR)	Total Value (PKR)
1	Copper Plate 8"x 8"x0.25"	numbers	4	6500	26000
2	Copper Conductor 70 mm²	Feet	60	270	16200
3	Coal	Kg	30	260	7800
4	Salt	Kg	30	20	600
5	Cement	Bag (40 Kg)	3	500	1500
6	Crush (zero size)	Cft	10	40	400
7	Sand	Cft	10	40	400
8	Angle Iron 2"x2"x0.118"	Kg	5	130	650
9	Steel Bar 1/2"	Kg	4	110	440
10	Labor cast for preparing block and four pits having dimension 4"x4"x2"				4980
Total Cost on Portable grounding system using four blocks having dimensions 10” x 10" x 14"					**58970**

Table 5: Total expenditures on grounding system prepared using four copper rods having 15 feet length and 0.5" diameter

Sr. No	Description	Unit	Qty	Unit Price (PKR)	Total value (PKR)
1	Copper rod 15 ft x 1/2"	Nos	4	5400	21600
2	UPVC pipe 1/2" dia (perforated)	Ft	60	30	1800
3	Coal	kg	30	260	7800
4	Salt	Kg	30	20	600
5	Cement	Bag (40Kg)	3	500	1500
5	Copper conductor 70 mm²	Feet	60	270	16200
6	Thimble 70 mm²	Nos	4	90	360
7	Cotton rags	Kg	20	400	8000
8	Labor cast for preparing earth bore having depth of 15 feet and 5" diameter				7800
Total Cost on channel prepared by rod method using four copper rods					**65660**

مؤتمر كهرباء الخليج 2016
GCC POWER 2016
8-10 NOVEMBER 2016,DOHA

2016 مؤتمر ومعرض كهرباء الخليج
GCC POWER 2016
8-10 November 2016
Doha - State of Qatar
THE 12TH GCC CIGRE INTERNATIONAL CONFERENCE & THE 21ST EXHIBITION FOR ELECTRICAL EQUIPMENT

تحقيق الكفاءة في استخدام الطاقة
Towards Energy Efficiency

Certificate of Appreciation

For the invaluable support to

THE 12th GCC CIGRE INTERNATIONAL CONFERENCE &
THE 21st EXHIBITION FOR ELECTRICAL EQUIPMENT

8 - 10 November 2016 | Doha | State of Qatar

EVENT MANAGER
GCC cigre الخليج سيجري

مؤتمر كهرباء الخليج 2016
GCC POWER 2016
8-10 NOVEMBER 2016,DOHA

2016 مؤتمر ومعرض كهرباء الخليج
GCC POWER 2016
8-10 November 2016
Doha - State of Qatar
THE 12TH GCC CIGRE INTERNATIONAL CONFERENCE & THE 21ST EXHIBITION FOR ELECTRICAL EQUIPMENT

تحقيق الكفاءة في استخدام الطاقة
Towards Energy Efficiency

Certificate of Participation

The GCC Regional Committee For Large Electric Systems
"GCC-Cigre", is proud to award this certificate to:

Muhammad Tanveer Ahmad

To honor his/her participation in

THE 12th GCC CIGRE INTERNATIONAL CONFERENCE &
THE 21st EXHIBITION FOR ELECTRICAL EQUIPMENT

8 - 10 November 2016 | Doha | State of Qatar

With his/her paper titled:

Portable Grounding System vs Traditional Methods

Eng Abdulaziz Ahmed Al-Hammadi
GCC CIGRE Secretary General

EVENT MANAGER
GCC cigre الخليج سيجري