Grounding System for High Resistivity Limited Area Substations in Hilly Region of Himachal Pradesh

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***Abstract*--This paper proposes a method of grounding system analysis in the presence of satellite electrode for hilly region where soil resistivity is quite high and area available for grounding system is also limited. The impacts of lateral variation of soil resistivity called vertical fault has also been studied for ground resistance, safe and touch potentials. An experimental analysis has been carried out at Baddi Himachal Pradesh. Computer program has been developed to verify the experimental results of an experimental grounding system located in hilly region of Baddi of Himachal Preadsh, India.**

***Index Terms*—Ground resistance, ground potential rise, step and touch potential, satellite electrode.**

I. Introduction

A safe design of grounding system has two main objectives: To carry and distribute currents into earth under normal and fault conditions without exceeding operating and equipments limits or adversely affecting continuity of service and to ensure that person in the vicinity of grounded facilities is not exposed to the danger of electric shock.

The performance analysis of a grounding system essentially consists of determination of its ground resistance and earth surface potential distribution due to current dissipated by it during a ground fault. IEEE standard 80 [1] Emperical formulae have been widely used by the design engineers for a long time. These formulae have number of limitations and are suitable for only square or nearly square grids placed in homogeneous soil [2-4]. In the last decade, techniques for grounding grid analysis based on Average Potential Method (APM) have been developed. A new boundary element approach that includes the technique of APM has been presented in [5-6]. Recently number of algorithms has been reported in literature [7-8] for analysis and design of grounding systems. These algorithms are applicable for practical shapes of ground electrodes placed in homogeneous soil and stratified soil medium. However lateral variation of soil resistivity cannot be accounted in these algorithms.

Only a limited work related with analysis of grounding system with lateral variation of soil resistivity has been reported. Tagg [9] has analysed a single vertical rod in the presence of vertical fault (a vertical plane separating the soils of two different resisitivities). Legace et al. [10] have published a method for computing a performance of a ring electrode in the presence of vertical fault. However, methods of Tagg and Legace et al. are not applicable for the practical combinations of ground electrodes used in generating station or a substation. Their methods are not applicable for the ground electrodes lying in both sides of a vertical fault. Hydroelectric power plants are located in rocky beds where the moisture content in the soil is very low and due to rocks soil resistivity is very high. The area available for grounding system is also very limited. Under such limited area and high resistivity soil conditions, it becomes quite difficult to design grounding system with low grounding resistance and safe touch and step potentials.

In the present work, an experimental analysis has been carried out with the collaboration of PSEB on a grounding system with square electrodes placed in a homogeneous soil and connected through underground tie wire with different depths in the soil. Another experimental analysis has also been carried out on two ring and rod electrodes placed at two different locations separated by a vertical fault located at Baddi, Himachal Predesh. The computer program has been developed and tested by applying it to an experimental grounding system. The computer model developed in this work is of practical use for the design of the grounding system with additional electrode for high resistivity limited area substations. A parametric study has also been carried out for two grids located in different soil resistivities joined by overhead tie wire.

II. Design of Grounding Systems for Limited Area High Resistivity Stations

The design of grounding system for rocky areas requires special measures to obtain safe step and touch potentials for grounding system. Some of the measures to reduce the grounding resistance can be adopted in such situations.

A. Use of Vertical Ground Rods

A grounding system at a power station often requires the form of a horizontal grid supplemented by number of vertical rods. The ground rods are of particular value when the upper layer of soil in which grid is buried is of much higher

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resistivity than that of the soil beneath [1,11]. The information about the soil stratas can be obtained from the interpretation of the measured soil resisitivity data. A number of computer algorithms have been developed in [12, 14] for interpretation of soil resistivity data obtained by Wenner method or driven rod method [13]. If the analysis of measured soil resistivity data suggests lower resisitivity medium at shallow depth, use of vertical rods can be very helpful and convenient to obtain safe design of the grounding system.

B. Use of Counterpoise Mesh

A counterpoise mesh is a closely spaced mesh of horizontal conductors placed at a shallow depth above main grounding system. If this additional mesh could be placed to occupy area otrher than occupied by the main grid, its contribution would have been higher. Punjab state Electricity Board has carried out scale model studies on counterpoise mesh placed above the main square grid in an electrolytic tank. The main and counterpoise mesh has no electric connection and a considerable improvement by the use of mesh has been reported in [15].

C. Chemical treatment of Soil and use of bentonite

Chemical treatment or backfilling of the soil in a close proximity of a ground electrode is very effective method of improving the performance of a grounding system [1, 16]. Addition of common salt, charcoal, and soft coke around the ground electrode has been traditionally used for lowering the ground resistance. This treatment requires regular watering in order to keep ground resistance low. In the high resistivity soil area, bentonite clay can be used to decrease the grounding resistance effectively. It consists of hydrous aluminium silicate and acts as an excellent backfill if sufficient amount of water is added to it. It has been observed [17] that fly ash disposal poses serious problem in thermal power plants and since ash possesses similar characteristics as of bentonite, it can be used as a backfill to reduce ground resistance.

D. Use of Penstock as an earthing system element

At many hydroelectric stations, long penstocks are necessary to carry water to the turbines. If the penstoch liner is buried in the earth, it can be made part of the station earthing systems [18].

E. Current diversion by overhead earth wires

The overhead earth wires, when connected to the station grounding system, divert substantial portion of the ground current away from the station ground [1, 19]. The ground potential rise (GPR) of the grounding system is substantially reduced.

F. Use of Satellite Electrode

In this work, a satellite electrode to design the safe grounding system has been proposed. An extra ground electrode in an adjoining area of lower soil resistivity and connected to the station grounding system is called a satellite electrode. The satellite electrode is an effective way to reduce ground resistance and potential gradients. The grounding system of station and satellite electrode can be connected by an overhead wire or an underground wire. When an underground wire is used, the tie wire also becomes a part of the grounding system and is effective compared to overhead interconnection. However, with underground tie wire, potential gradients around the tie wire must also be determined in order to safeguard the living beings moving around the tie wire. For computation of ground resistance and earth surface potentials, the grounding system placed in two different areas of different soil resistivity has to be represented by suitable mathematical model. In this work, computer model has also been obtained for interconnected grounding system with overhead and underground tie wire. The results for ground resistance have been obtained with computation as well as experimental investigation at Baddi, Himachal Preadesh

III. Computational Methodology

The performance analysis of a grounding system essentially consists of determination of its grounding resistance and earth surface potentials. From knowledge of these parameters, step and touch potentials can be obtained [1]. For computational purpose, the grounding system can be divided into linear conductor segments. It is assumed that the current dissipation to earth is uniform over the finite length of the segment and it varies from segment to segment. The current dissipation from the electrode surface with equi-potential boundary conditions is known to be non-uniform [18]. The validity of the constant current dissipation along the segment length increases as the size of the segment is made shorter with respect to the total length of the conductor in the grounding system.

The grounding system formed by interconnection of the main and the satellite electrode is modeled as an interconnection of linear conductors located in tow soil mediums of resistivities ρ_1 and ρ_2. The linear conductors are divided into number of segments. The total current I is dissipated by the grounding system to the earth from the surface of these segments. The potential of any segment depends on the current dissipated by it and the current dissipated to the earth by the neighboring segments [19]. The potential of the any i^{th} segment is written as [5]:

$$V_i = \sum_{j=1}^{N} R_{ij} * I_j, i = 1,2,.......N \qquad (1)$$

Where,

V_i is the potential of the i^{th} segment

R_{ij} is mutual resistance between i^{th} and j^{th} segment.

N is the number of segments into which the grounding system is divided.

The mutual resistance R_{ij} is the potential of the i^{th} segment due to unit current dissipated by the j^{th} segment with all other segment currents equal to zero. For *i-j*, R_{ii} represents the self resistance of the i^{th} segment. It is the potential of the segment due to unit current dissipated by the i^{th} segment itself with all other segment currents equal to zero. By taking potential of earth segment equal to 1.0 V, N simultaneous equations can be obtained from (1) and the solution of these equations gives the value of segment currents corresponding to 1 volt potential of the grounding system. The ground resistance R_g of the grounding system is equal to the reciprocal of the sum of these segment currents. The potential of the grounding system V_g known as ground potential rise (GPR) is given as:

$$V_g = R_g * I_g \qquad (2)$$

Where I_g is the current dissipated by the grounding system. A segment current corresponding to 1.0 V potential when multiplied by Vg gives the actual current for a grounding system dissipating current I_g. The potential on earth surface is computed by summing the potential contribution due to currents dissipated by all the segments. For implementation, it is necessary to develop:

(i) The expression for self resistance and mutual resistance between any two segments located in two soil media separated by vertical fault.

(ii) The expression for the potential at any point due to current dissipated by a segment located on either side of vertical fault.

A. A Linear Conductor Segment in an Unbound Homogeneous Medium

A linear conductor segment *j* dissipating current I_j located in unbound homogeneous medium of resistively of ρ. The potential at any point located in a surrounding medium can be obtained as [21]:

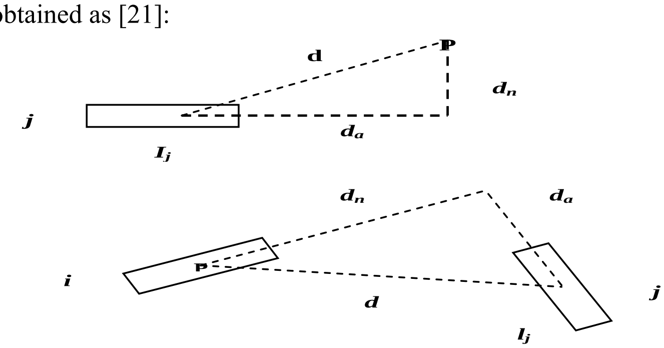


Fig.1. Linear conductor segments located in unbound homogeneous medium

$$V_P = \frac{\rho I_j}{4\pi l_j} h(d_a, d_n, l_j) \qquad (3)$$

where

$$h(d_a, d_n, l_j) = \ln \frac{\sqrt{\left(d_a + \frac{l_j}{2}\right)^2 + d_n^2} + \left(d_a + \frac{l_j}{2}\right)}{\sqrt{\left(d_a - \frac{l_j}{2}\right)^2 + d_n^2} + \left(d_a - \frac{l_j}{2}\right)} \qquad (4)$$

l_j is the length of the segment

d_a,d_n= Components of the distance of point P from the centre of the segment, along the segment axis and the perpendicular to the segment axis respectively.

The expression (3) is also applicable for obtaining the potential at any point on the surface of the conductor. The potential computed by (3) at different points along the length of the conductor would not be equal because for conductor to be equi-potential, the current dissipation along its length can not be uniform. The potential of the segment due to current I_j dissipated by it is approximated as the average of the potentials computed along the length assuming uniform current dissipation. This method is known as average potential method (A.P.M.). The average potential Vs of the segment obtained by integrating (3) along the length of the conductor is obtained as [21]:

$$V_S = \frac{I_j \rho}{2\pi l_j} \ln\left[\frac{l_j}{a}\left(l + \sqrt{\left(l + \frac{a}{l_j}\right)^2} + \frac{a}{l_j} - \sqrt{\left(l + \frac{a}{l_j}\right)^2}\right)\right] \qquad (5)$$

where

a is the radius of the conductor segment

When l_j is very large than *a*, (5) can be written as:

$$V_S = \frac{I_j \rho}{2\pi l_j} \ln\left[\frac{2l_j}{a} - 1\right] \qquad (6)$$

Thus the self resistance of the segment is:

$$R_{jj} = \frac{\rho}{2\pi l_j} \ln\left[\frac{2l_j}{a} - 1\right] \qquad (7)$$

B. Mutual Resistance between two Segments in Unbound Homogeneous Medium

Two segments *i* and *j* located in a homogeneous medium of resistivity ρ and dissipating current *Ij* is shown in Fig. 1. The potential at point P located at centre of segment *i* due to current *I* dissipated by *j* is given by (3). The average potential of segment *i* because of current I_j dissipated by segment *j* can be found by integration of (3) along the segment *i*. It has been shown by Dawalibi [22] that instead of finding average potential at segment I, it is sufficiently accurate to determine the potential at the center of the segment i. Thus, the potential given by (3) at point P on segment I may be regarded as the average potential of segment *I* due to current I_j dissipated by segment *j*. Thus, the mutual resistance is equal to:

$$R_{ij} = \frac{\rho}{4\pi l_j} h(d_a, d_n, l_j) \qquad (8)$$

The problem of finding potential at any point due to the current dissipated by a segment *j* located near a vertical fault can be transformed by the method of images into a problem of finding potential due to multiple sources in an unbound homogeneous medium [23]. The image system for a line source can be obtained by the extension of the image system for a point source as a linear current source is a succession of point current sources arranged along the line [24]. Thus, the linear conductor segment near a vertical fault can be replaced by an image system located in a homogeneous soil of resistivity equal to the resistivity of the region in which segment is located.

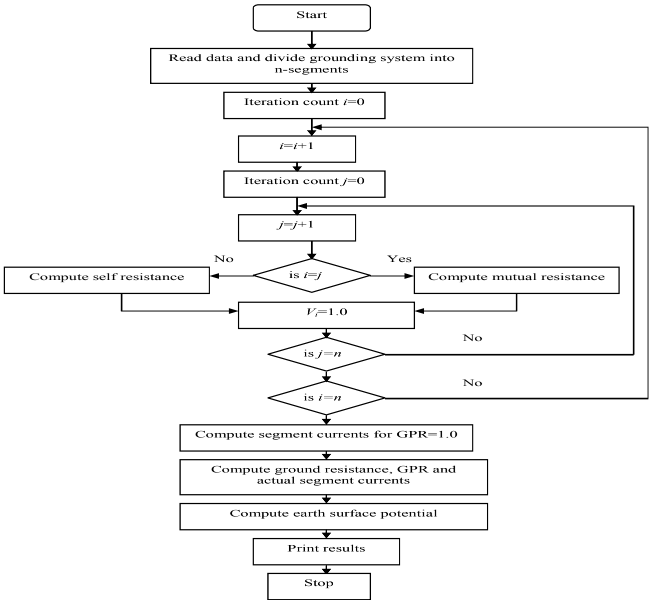


Fig. 4. Flow chart of the computer program developed

IV. PROGRAM EVALUATION AND APPLICATION FOR EXPERIMENTAL GROUNDING SYSTEM UNDER STUDY

The program compute ground resistance and earth surface potentials distribution of a grounding system placed in a soil with vertical fault. The program has been utilized for an experimental grounding system with a vertical fault and connected with a satellite electrode of Punjab State Electricity Board (PSEB) located in a high resistivity hillock at Baddi, Himachal Pradesh. The measured results are compared with the computed results to determine the applicability of the program.

A. Experimental Grounding set up at Baddi, Himachal Pradesh

The experimental study relates to the following:

(i) Two intertied square grids connected by tie wire are placed in the uniform soils of same resistivity

(ii) Two ring electrodes with vertical rods placed in the soil of different resisitvities.

The results for the above cases have been made use of establishing practical utility of the computer program.

(a) Interconnected Square Grids in Uniform Soil

Two square grids each of side 1m are buried in the rocky soil on a hillock at baddi at a depth of 0.5m. The configuration of the grids is shown in the Fig. 3. The soil resistivity is 2465 ohm-m. Tow sets of studies are carried out with interconnection through intertie wire of radius 0.001041 (14 SWG). N one study, the tie aire is laid underground and in second case it is overhead. The tie line is run along the shortest path between the two grids measuring 154 m. The depth of the wire is taken as 0.1m. 0.25m, and 0.5m in the soil. The ground resistance of the individual grids, tie wire and the complete interconnected system with different modes of interconnection has been measured.

Case 1: Grid A alone
Case 2: Grid A and B joined by tie wire at depth 0.1 m
Case 3: Grid A and B joined by tie wire at depth 0.25 m
Case 4: Grid A and B joined by tie wire at depth 0.5 m
Case 5: Grid A and B joined by insulated wire
Case 6: Tie wire at depth of 0.1 m
Case 7: Tie wire at depth of 0.25 m
Case 8: Tie wire at depth of 0.5 m

The measured and computed values of ground resistances for different cases are shown in Fig. 4.

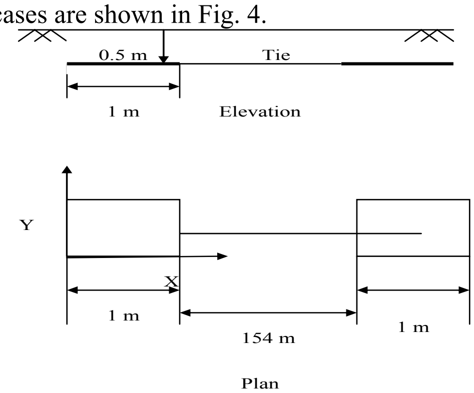
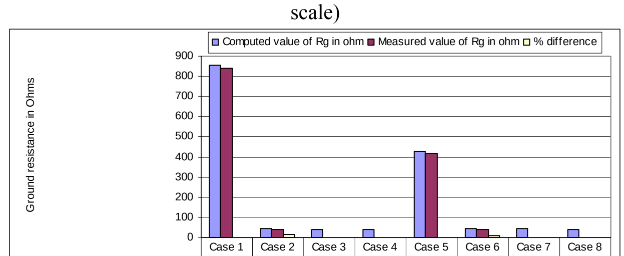


Fig.3. Plan and Elevation showing the intertied Square grids at Baddi (Not to scale)



	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8
Computed value of Rg in ohm	856.7	43.3	41.4	39.8	429.6	45.6	43.6	41.7
Measured value of Rg in ohm	840	38			420	42		
% difference	1.949	12.44			2.23	8.49		

Fig.4. Measured and computed values of ground resistance for different cases

It is observed from the Figure that ground resistance of two grids joined by over head wire is about half of the one grid. The computed values of the ground resistance are slightly larger due to the mutual effect between the grids.

Ground surface potentials over the grids and the tie wire are shown in Fig. 5 along with the computed data. The origin of X-Y axis is located at the lower left hand corner of the grid A. With underground tie wire the earth surface potentials are obtained along the length of the tie wire also. It is observed that earth surface potentials are more uniform with underground tie along the length of the tie wire than when insulated tie is used. Further the wire becomes more effective when depth is increased. In case of grid alone, the maximum touch voltage is obtained at point (0, 1.0), the maximum step voltage voltage is obtained at point (1.0, 1.0). In case when underground tie wire is used, maximum touch voltage over the grid is at (0, 1.0) and maximum step voltage occurs at (1.0, 1.0). Also it is found that maximum step voltage occurs at point (78, 0.5) and (78, -0.5). The maximum step and touch voltages are reduced by using the inter-tie with two grids because GPR is reduced. The maximum step and touch voltages in percent of GPR for interconnected square grids are shown in Fig.6. It is observed that maximum step is obtained at middle of the wire when tie wire is buried at depth of 0.1 m. The reduction in step and touch voltages are considerable when depth of tie wire is increased.

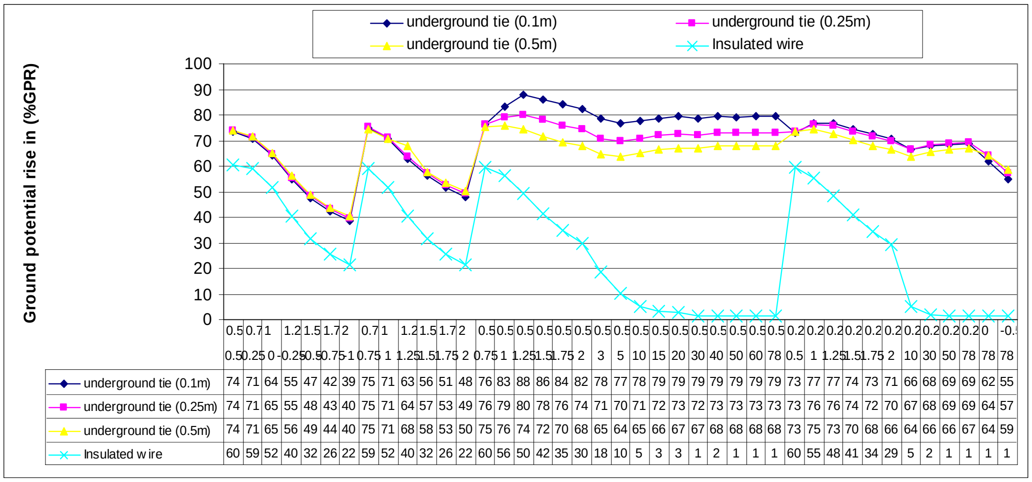


Fig. 5. Ground potential profile

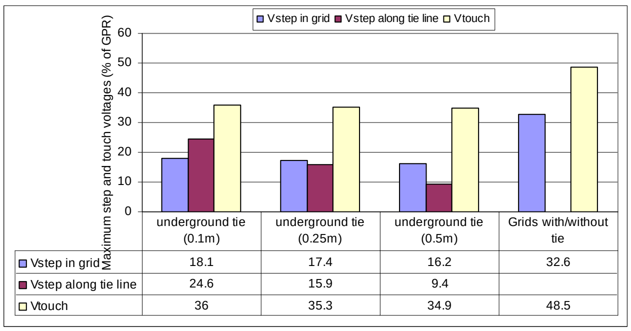


Fig.6. Maximum step and touch voltages

(b) Ring and Rod Electrodes in Two Different Resistivity Soils with Vertical Fault and connected with over-head tie wire

Two copper ring electrodes each of diameter 1m along with two vertical rods each of 1m length are buried in the soils of different resistvities. The plan of the experimental set up is shown in Fig.7.

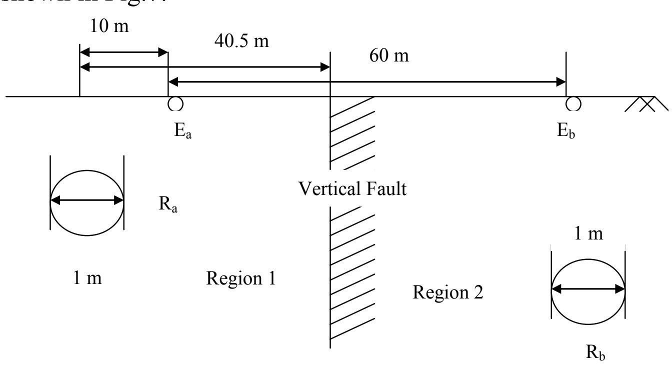


Fig.7. Arrangement of ring and rod electrodes used in experimental set up at Baddi, Himachal Preadesh (not to scale)

One ring electrode (R_a) and vertical rod (R_a) are buried in a flat trait of a hillock and another ring electrode (*R_b*) and rod *E_b* are buried at a lower level in a nearly cultivated land. The soil resistivity of flat portion at a hillock is 2465 ohm-m and soil resistivity of lower level is 837ohm-m. Radius of each vertical rod is 0.001041m and depth of burial of upper end of vertical rod and ring electrode is 0.05m. The resistivity changes abruptly at a distance of 40.5 meter from the centre of the ring electrode located in region 1. Thus, the two regions are separated by a vertical faulty with Yv=40.5 m. Since the program GSVF is applicable for grounding system which can be split into linear conductor segments. Therefore ring electrodes are represented by an equivalent square with each side equal to 0.9m. The ground resistance has been measured for various combinations of R_a, E_a, R_b and E_b and experimental results have been compared with those obtained from computation. The results for 15 different cases with measured and computed values and the percent differences are shown in Fig.8.

The possible combinations taken are:

Configuration 1: Grid R_a alone
Configuration 2: Grid R_b alone
Configuration 3: Vertical rod E_a alone
Configuration 4: Vertical rod E_b alone
Configuration 5: Vertical rods E_a and E_b
Configuration 6: Grid R_a and vertical rod E_a
Configuration 7: Grid R_a and vertical rod E_b
Configuration 8: Grid R_a and vertical rods E_a and E_b
Configuration 9: Grid R_b and vertical rod E_a
Configuration 10: Grid R_b and vertical rod E_b
Configuration 11: Grid R_b and vertical rods E_a and E_b
Configuration 12: Grid R_a and grid R_b
Configuration 13: Grid R_a and R_b with vertical rods Ea and E_b
Configuration 14: Grid R_a and R_b with vertical rod E_a
Configuration 15: Grid R_a and R_b with vertical rod E_b

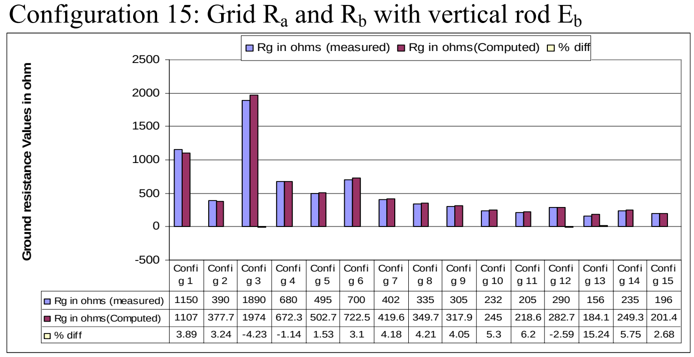


Fig.8. Ground resistance for different combinations with measured and computed values

It is observed that minimum ground resistance is obtained for the case with both ring electrodes and ground rods. The computed and experimental values match closely.

(C) Parametric Study

In this section, a parametric study has been carried out on two 30m by 30m square grids located in soils of resisitivities 1000ohm-m and 100 ohm-m. The two soil areas are separated by a vertical fault. The centre to centre distance between two grids has been taken as 330m. Depth of burial of grids has been taken as 0.5m with radius of conductor as 0.01m. The ground resistance and ground surface potentials have been determined for different distances of vertical fault as Yv=130m, 180m, 230m, and 280m considering overhead insulated tie wire. The plan of the intertied square grids for parametric study is shown in Fig. 9. The earth surface potentials have been determined along AB and CD.

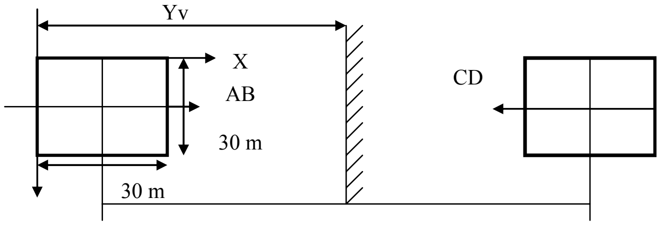


Fig. 9. Square grids located in two different soil resistivities intertied with overhead tie wire

The computed values of ground resistance of the interconnected grids with overhead tie wire are shown in Fig. 10. It is observed that ground resistance of the grids tied with overhead conductor changes by only 1.82% (from 1.632 to 1.682 ohm) when the distance of the vertical fault is changed by more than 100% (130m to 270 m). Thus, there is only a small variation in the ground resistance of the grids intertied with insulated wire when the location of vertical fault is varied.

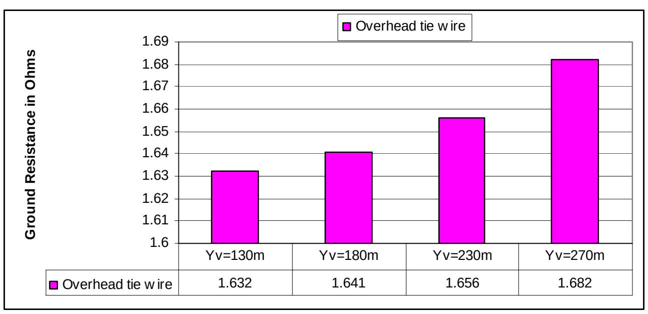


Fig. 10. Ground resistance in ohm for intertied square grids with overhead tie wire

Ground resistance in homogeneous soil of 100 ohm-m has also been determined for a single grid, two grids joined by insulated wire. These values obtained are 1.755 ohm for a single grid and 0.9028 ohm for two grids with insulated wire. The ground resistance of the inter-tied grids is only slightly greater than the parallel combination of ground resistance of grid A of soil resistivity 1000 ohm and grid B in soil resistivity of 100 ohm-m. The resistance higher than that obtained for parallel combination is due to the mutual resistance between the two grids.

(d) Earth Surface Potentials

Earth surface potentials have been computed for a unit current injected into the grounding system for different cases. For a comparison, the potentials for a case with homogeneous soil are also computed. The profile axis along which potentials are computed are represented as AB and CD in Fig. 6. To generalize the results, the potentials have been expressed as percent of the ground potential rise (GPR). The GPR being equal to the ground resistance multiplied by the total current dissipated by the grounding system is equal to the ground resistance itself for a unit current. The earth surface potentials computed for different case are:

Case 1: Single grid in homogeneous soil

Case 2: Two grids joined by an overhead tie wire

Case 3: Two grids joined by an overhead tie wire with vertical fault and its variation in distance (Yv=130m, 180m, 230m 270m)

It is observed that the earth surface potentials expressed as % of GPR for grids joined by an overhead tie aire for different locations of vertical fault are practically same as those for the case of homogeneous soil. But the absoluter values of the potentials would differ in various cases depending on the values of the ground resistance. The earth surface potential variation for Case 1 is plotted in Fig.11. The earth surface potentials for case 2 and Case 3 are given in Fig. 12. It is observed from the Figs. that touch and step voltages of interconnected grids when expressed as % of GPR are approximately equal to the corresponding values of the single grid in homogeneous soil. Thus for an interconnection by an overhead wire, the absolute values of step and touch voltages are reduced in the same proportion as the reduction in the ground resistance. For a single grid located in soil of resisitvity 1000 ohm-m, the ground resistance is 17.54 ohm. When this grid is tied to a similar grid located in a soil of 100 ohm-m by an overhead tie wire, the ground resistance is reduced to 1.632 ohm for Yv=130m.

The step and touch voltages would thus only be 1.632/17.54=0.093 times the values for the single grid in 1000 ohm-m resisitvity. Thus, a considerably reduction in step and touch voltages is obtained by the additional grid in lower soil resistivity soil. The reduction in step and touch voltage would be of the same order as the reduction in the ground resistance. If the area enclosed by satellite electrode is of the same order as the main grid in the high resistivity soil, the maximum step and touch voltages in the main grid area when the two grids are joined by an overhead tie wire would get reduced by the factor approximately equal to the ratio of soil resisitivity of the area where satellite grid is placed to the resistivity of the area where main grid is placed.

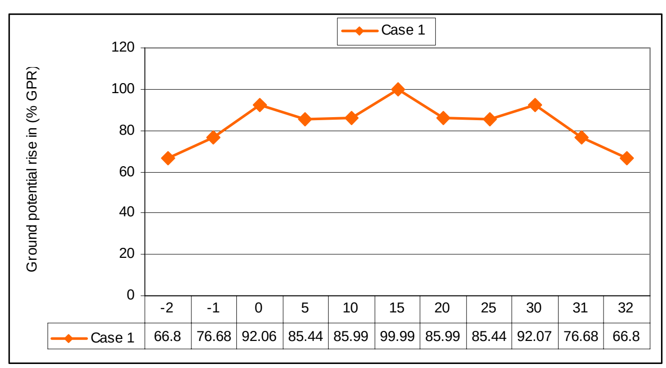
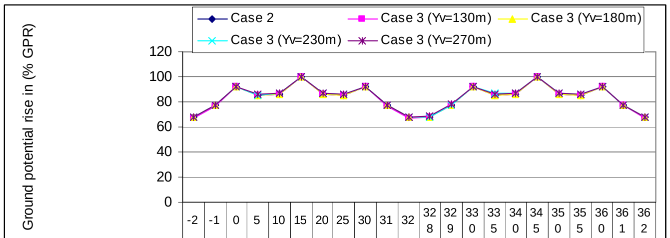


Fig. 11. Ground surface potential near grid along axis AB



	-2	-1	0	5	10	15	20	25	30	31	32	328	329	330	335	340	345	350	355	360	361	362
Case 2	67	77	92	86	86	100	86	86	92	77	68	68	77	92	86	86	100	86	86	92	77	67
Case 3 (Yv=130m)	67	77	92	85	86	100	86	85	92	77	67	67	77	92	86	86	100	86	86	92	77	67
Case 3 (Yv=180m)	67	77	92	86	86	100	86	86	92	77	68	68	77	92	86	86	100	86	86	92	77	67
Case 3 (Yv=230m)	68	77	92	86	87	100	87	86	92	77	68	68	77	92	87	87	100	87	86	92	77	68
Case 3 (Yv=270m)	68	77	92	86	87	100	87	86	92	77	68	69	78	92	86	87	100	87	86	92	78	68

Fig. 12. Ground surface potential for grids joined with an overhead tie wire

V. Conclusions

In this work, an experimental analysis has been carried out on grounding systems located at Baddi Himachal Pradesh. A computational methodology for analyzing performance of a grounding system with a satellite electrode in the neighboring area of lower soil resisitivity has also been developed. The computational methodology has been utilized for evaluating the performance of an experimental grounding system located at Baddi in Himachal Pradesh. Based on the results, the following conclusions have been drawn:

(i) A satellite electrode in the neighboring area of lower soil resistivity is an effective method of lowering ground resistance and potential gradients in and around the station area.
(ii) Experimental and computed values of ground resistances match closely.
(iii) The ground resistance decreases with increase in depth of tie wire in the ground and also with the shift of vertical fault towards soil of lower resistivity.
(iv) The step and touch potentials reduces with additional satellite grid placed in the soil of lower resistivity.

VI. Acknowledgements

Authors gratefully acknowledges the research cell of Punjab State Electricity Board to collaborate and provide the facility to conduct experimental analysis of grounding system located at Baddi, Himachal Pradesh.

VII. References

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VIII. Biographies

Ashwani Kumar graduated from GBPUA&T, Pant Nagar in 1988. He did his masters in Power systems from PEC Chandigarh in 1994 in honors. He did his Ph.D. in Electrical Enginerring Dept at IIT Kanpur in 2003. He published numerous papers in national and international journals. He has interest in grounding systems, power systems restructuring, power system operation, demand side management, distributed generation, load and price forecasting. He is a life member of ISTE and IEI, India and member IEEE and IEEE/PES.

Hans. R. Seedhar graduated from Punjab University Chandigarh in honors. He did his masters in Power Systems from Punjab University with distinction and also did his Ph.D. from Punjab University Chandigarh.. He published many papers in national and international journals and won numerous awards. He is consultant to grounding systems for Punjab, Haryana, and Himachal presdesh. He is actively involved in research in the area of grounding systems and with Punjab State Electricity Board Research Cell, PEC Chandigarh. He worked on many key positions in his service career. He retired as a Prof. from Punjab Enginering College, Chandigarh. He is a life member of ISTE and fellow IEI, India and senior member IEEE.