CHAPTER VI

TESTS WITH GROUNDING RODS

It is apparent from last section that the characteristics of the grounding grid are largely dependent on the medium in which it is buried. The lower medium even with large value of $-0.9$ for $K$ does not influence the grounding resistance, mesh and step potential to a great extent. To make full use of the higher conductivity of the lower medium, it is essential that the grounding system penetrates into this medium. Therefore, in case of situations where the lower layer has lower resistivity, it is advantageous to use vertical grounding rods that should reach the lower medium. The vertical rods may be placed and connected to the grid at junction points. Since more current dissipates from the periphery of the grid, the rods may be better utilized by concentrating them on the periphery.

In the model, the rods can be represented by vertical wires connected to the grid. If the length of the rod is less than the depth of the upper layer minus the depth at which the grid is placed, the rod will remain entirely in the upper medium and there is no difficulty in representing it in the model. However, if the length of the rod is more, it has to enter the lower layer. To
represent it in the model, the vertical wire from the grid was connected to the nearest copper pin in the acrylic sheet. A vertical wire was connected to the lower end of the same pin to make up the complete length of the rod. The length of the pin itself was not included in the measurement of the length of the vertical wire. This pin was covered with an insulating sleeve. The joints of the vertical wire with the grid and the pin were made by soldering without any difficulty.

Model studies with vertical rods were made with the following variation of parameters:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grid Size</td>
<td>30 cm x 30 cm</td>
</tr>
<tr>
<td>No. of meshes</td>
<td>9, 25</td>
</tr>
<tr>
<td>No. of vertical rods</td>
<td>(i) At all junctions of the grid.</td>
</tr>
<tr>
<td></td>
<td>(ii) At all junctions on the periphery.</td>
</tr>
<tr>
<td>Size of conductor for the grid and the rods</td>
<td>0.26 mm</td>
</tr>
<tr>
<td>$\rho_1$</td>
<td>20 ohm-m (normalised)</td>
</tr>
<tr>
<td>$K$</td>
<td>0.0, -0.6, -0.8, -0.9</td>
</tr>
<tr>
<td>Length of vertical rods</td>
<td>2.5, 5.0, 7.5 cm</td>
</tr>
<tr>
<td>Depth of upper layer</td>
<td>2.5, 5.0 cm</td>
</tr>
<tr>
<td>Depth of burial of the grid</td>
<td>0.5 cm</td>
</tr>
</tbody>
</table>

The quarter of the model grids with rods that were
(a) 9 MESHES, RODS AT ALL JUNCTIONS
(b) 25 MESHES, RODS AT ALL JUNCTIONS
(c) 9 MESHES, RODS AT PERIPHERAL JUNCTIONS
(d) 25 MESHES, RODS AT PERIPHERAL JUNCTIONS

FIG. 6-1. QUARTER GRIDS WITH RODS TESTED
studied are shown in Figure 6.1.

From the measurements made, the graphs given in Figures 6.2 to 6.9 are developed. Figure 6.2 to 6.5 show the grounding resistance and Figures 6.6 to 6.9 show the percentage mesh potential for various values of k, h, number of meshes and number of rods. The graphs for percentage mesh potential are drawn for only two values of K viz K = 0 and K = -0.6.

When the length of the vertical rod is about the same as the depth of the upper medium minus the depth at which the grid is buried the model does not give accurate results, since the tip of the wire representing the rod comes close to the pin. Hence there is a gap in all the graphs for which interval the curves are not drawn.

**Observations**

The following observations are made from the test data:

1. **Grounding Resistance**

   (a) Presence of vertical rods decreases the grounding resistance. Their effect becomes significant when they penetrate in the lower layer of lower resistivity. Ratio of the ground resistance of a grid having r/h less than 7.0 without vertical
FIG. 6.2. GRID RESISTANCE VERSUS LENGTH OF GROUND RODS 30 cm x 30 cm 9 MESH GRID, HEIGHT OF UPPER LAYER = 2.5 cm, DEPTH = 0.5 cm, (ν1 = 20.Ω·m)
FIG. 6-3 GRID RESISTANCE VERSUS LENGTH OF GROUND RODS 30 cm x 30 cm 9 MESH GRID, HEIGHT OF UPPER LAYER = 5.0 cm, DEPTH = 0.5 cm ($\gamma_1 = 20 \Omega \cdot m$)
FIG. 6.4. GRID RESISTANCE VERSUS LENGTH OF GROUND RODS 30 cm x 30 cm, 25 MESH GRID, HEIGHT OF UPPER LAYER = 2.5 cm, DEPTH = 0.5 cm, (ρ₁ = 20 Ω·m)
FIG. 6.5. GRID RESISTANCE VERSUS LENGTH OF GROUND RODS 30 cm x 30 cm, 25 MESH GRID, HEIGHT OF UPPER LAYER = 5.0 cm, DEPTH = 0.5 cm, ($\rho_1 = 20 \Omega \cdot \text{M}$)
FIG. 6.6. MESH POTENTIAL VERSUS LENGTH OF GROUND RODS FOR A 30 cm X 30 cm 9 MESH GRID, HEIGHT OF UPPER LAYER = 2.5 cm, DEPTH = 0.5 cm, ($\rho = 20 \Omega \cdot m$)
FIG. 6.7. MESH POTENTIAL VERSUS LENGTH OF GROUND RODS FOR A 30 cm X 30 cm 9 MESH GRID, HEIGHT OF UPPER LAYER = 5.0 cm, DEPTH = 0.5 cm, \( \varepsilon_1 = 20 \Omega \cdot m \)
FIG. 6.8. MESH POTENTIAL VERSUS LENGTH OF GROUND RODS
FOR A 30 cm $ \times $ 30 cm 25 MESH GRID, HEIGHT OF UPPER
LAYER = 2.5 cm, DEPTH = 0.5 cm, $\gamma_1$ = 20 $\Omega \cdot$ m
FIG. 6.9. MESH POTENTIAL VERSUS LENGTH OF GROUND RODS FOR A 30cm×30cm 25 MESH GRID, HEIGHT OF UPPER LAYER = 5.0 cm, DEPTH = 0.5, (ρ₁ = 20 Ω·m)
rods to the grounding resistance of the same grid with vertical rod electrodes penetrating about 2 cm in the lower medium (of the model) is of the order of $\sqrt{R_1/R_2}$.

(b) In uniform soil vertical rods at the periphery are important. Addition of extra rods to cover all the junctions reduces the grounding resistance by less than 10%. However, when lower layer of lower resistivity is present, the extra rods used to cover all the junctions become more effective and they may reduce the grounding resistance by about 20%.

2. **Mesh Potential**

The presence of vertical rods always reduces the mesh potential. In some cases, the percentage mesh potential increases with the increase in the length of the rods. Since the rate at which the grounding resistance in these cases decreases is more, the absolute value of the mesh potential always decreases with increase in the length of the rods and it falls considerably when the rods penetrate the lower medium of lower resistivity.