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Studying the Properties of Sounding Curve in Electric Sounding Measurement

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Abstract: This paper presents a study of the properties of sounding curves equivalent to the different electrode arrays by means of simulations for numerical modeling. Following this, the authors proposed a calculation for the synthetical apparent resistivity values in effort to gain higher-resolution sounding curves in electric sounding measurement.

Keywords: Electric sounding, resistivity surveys, apparent resistivity, focusing array.

1. Introduction

For a long time the Petrovski apparent resistivity ρ_P has been usually calculated and applied to the Schlumberger arrays with the distance between the electrodes is not equal. In this paper, this Petrovski apparent resistivity ρ_P is applied to calculate with the distance between the electrodes is equal by synthesizing the possible apparent resistivity values.

In this study, present a method to calculate extension Petrovski apparent resistivity ρ_P. Following this, the average values of the apparent resistivity values with Wenner arrays and the apparent resistivity values with dipole-pole arrays (also known as apparent resistivity values of half-Schlumberger arrays) would be instead of the apparent resistivity values with four symmetric electrodes ρ_S, in which the distance from the one pole to the other poles is equal, so the signal strength is higher accuracy.

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2. Theory

In1932, Petrovski gave a variant of sounding curve (namedPetrovski curve) which can be obtained by means of derivativeof apparent resistivity with four symmetrical electrodes (also known as apparent resistivity of Schlumberger array) with high density of information in electric sounding measurement [1]. The Petrovski apparent resistivity is calculated as:

$$\rho_P = \frac{\rho_S}{1 - \frac{r}{\rho_S}\frac{\partial \rho_S}{\partial r}} \qquad (1)$$

where ρ_S is the apparent resistivity valuesof Schlumberger arrayscalculated asfollowing function :

$$\rho_S(r) = \rho_1 r^2 \int_0^{\infty} \overline{R}(m) m J_1(mr) dm \quad ; \qquad r = \frac{AB}{2} \qquad (2)$$

Electrodes of the Schlumberger array are presented in Fig.1.

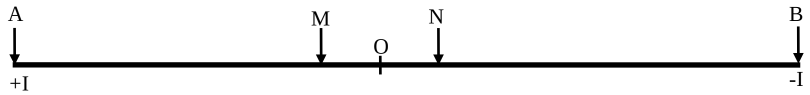

Fig. 1. Schlumberger electrode arrays used in resistivity surveys.

When conducting measurement of Schlumberger array, the distance MN between the two potential electrodes (M and N) and the distance AB between the two current electrodes (A and B) must satisfy the conditions: $MN \leq \frac{1}{5} AB$.Therefore, the calculated apparent resistivity value ρ_s doesn't give a fully-exacted result because the signal voltage difference ΔU_{MN} (between M and N) is relatively low.

We study the properties of sounding curves equivalent to the different electrode arrays by means of simulations for numerical modeling. Following this, we propose a calculation of the apparent resistivity values to receive properly sounding curves not only for Schlumberger arrays butalso for another arrays in electric sounding measurement [2-4].The extension Petrovskiapparent resistivity is calculated as follows:

- When conducting measurements of Wenner array, the distance from one pole to others is equal. Six sequential poles in a row are shown in Fig. 2.The electrodes M_1, A, B,N_1 are constituted Wenner arrays and the electrodes M_2, A, B and A, B, N_2 are constituted Half-Schlumberger arrays.

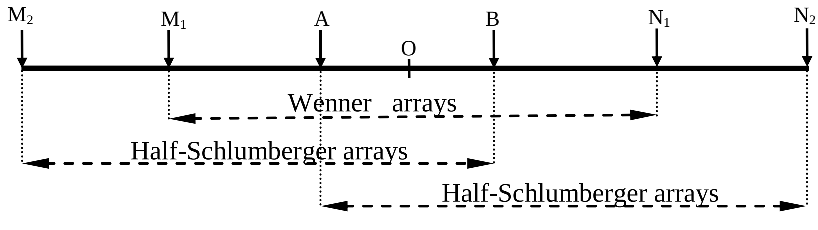

Fig. 2. Wenner electrode arrays used in resistivity surveys

- The average values of the apparent resistivity with Wenner and Half-Schlumberger arrays would be instead of the apparent resistivity values with four symmetric electrodesρ_s, the extension Petrovski apparent resistivity ρ_p is:

$$\rho_P = \frac{\rho_a}{1 - \frac{r}{\rho_a}\frac{\partial \rho_a}{\partial r}} \; ; \; \rho_a = \frac{(\rho_w + \rho_{3S})}{2} \quad (3)$$

$$\rho_w(a) = \int_0^\infty \overline{R}(m)[J_0(ma) - J_0(2ma)]dm \;\; \rho_{3S}(r) = \rho_1 r^2 \int_0^\infty \overline{R}(m) m J_1(mr) dm \; ; \quad (4)$$

Besides that, the Werner arrays were also used in multi-electrodes electrical sounding, so the data of these measurements were also calculated as test for this method.

The calculated results are compared to the results in the cases of previous research.

To obtain an accurate calculation, we calculate the sounding curves of the extension Petrovski apparent resistivity of three different models:

a) A 1-D model consists of horizontal layers:

It is normally assumed that the 1-D model consists of horizontal layers. The subsurface resistivity changes only with depth but does not change in the horizontal direction. This model is a basic proble min the geo-electrical curriculum and its solution is exactly. It is possible to test this calculation.

A 1-D model of four layersis shown in Fig. 3.1. The upper layer has a resistivity of 1.0Ωm and thickness of 1.0 m. While the first mid layer has a resistivity of 0.1Ωm and thickness of 6.0 m, the second mid layer has a resistivity of 10.0 Ωm and thickness of 50.0 m and the lower layer has a resistivity of 0.5Ωm. The sounding curve and pseudosection of the extension Petrovski apparent resistivity $\rho_p^*$of four-layer model are calculated shown in Fig. 3.

The results show that, the sounding curve of the extension Petrovski apparent resistivity ρ_p^* has a higher resolution than the sounding curves of the apparent resistivity ρ_w with Werner arrays. The shape of the curve of the extension Petrovski apparent resistivity ρ_p^* is similar to thecurve of the Petrovski apparent resistivityρ_p, reflects the model selected (Fig. 3.2).

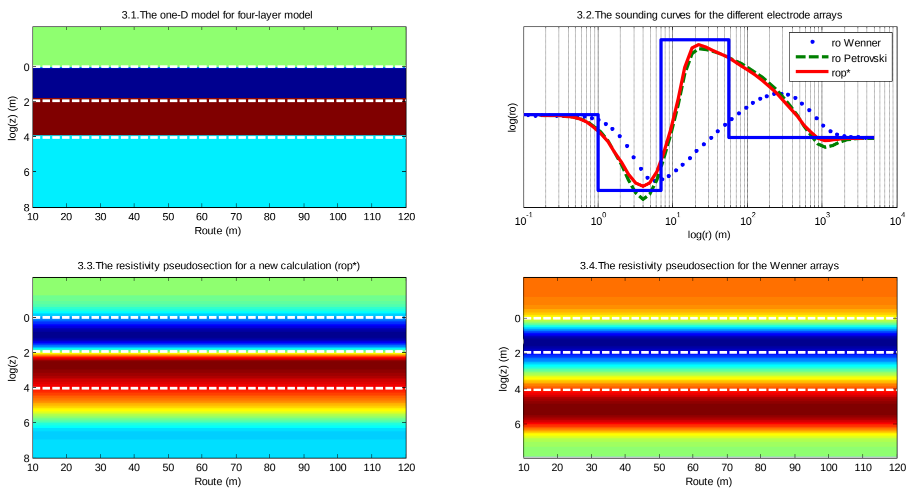

Figure 3. The result forfour-layer model allows the sounding curves and the apparent resistivity pseudosection.

b) A 2-D model consists of multi-layers:

The subsurface resistivity of 2-D model changesboth in the vertical and the horizontal direction. The 2-D resistivitymodel is shown in Fig. 4.1.Layer resistivities areρ_i = 1.0, 0.1, 0.3, 0.5, 3.0, 10.0Ωmvaried for each position along the route. Thecalculated sounding curves and the apparent resistivity pseudosectionsare plotted in Fig. 4.

The advantages of the two dimensional calculated pseudosections over the resistivity pseudosection for Werner arrays can be clearly seen by comparing the corresponding results shown in Figs. 4.4 and 4.3.

The extension Petrovskiapparent resistivity pseudosectioncalculated (Fig. 4.5) is compared with the Petrovskiapparentpseudosection(Fig. 4.2), results obtained are equivalent to each other.

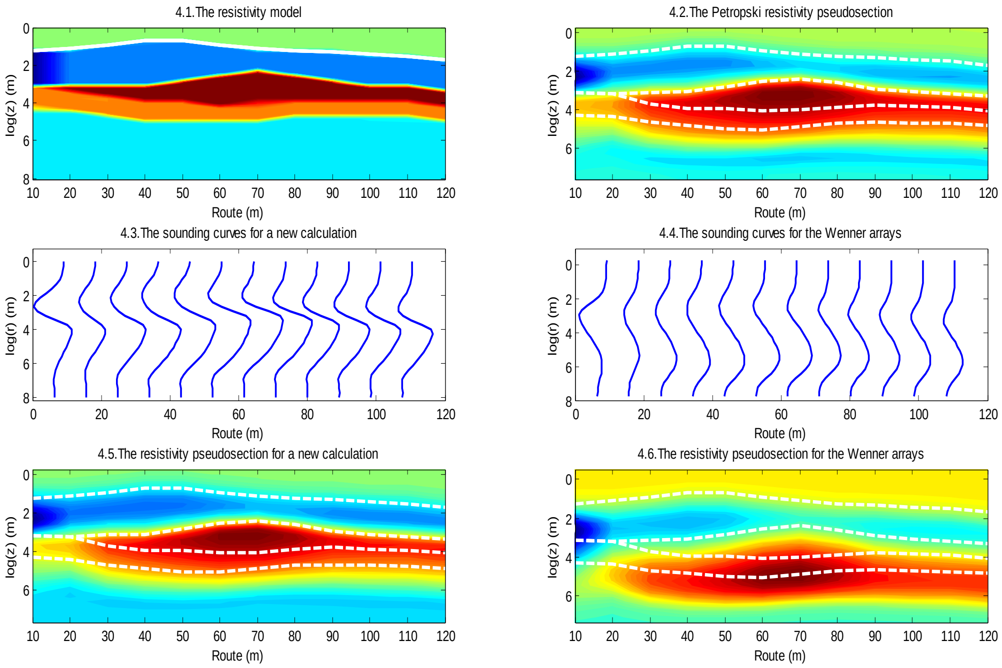

Figure 4. A 2D resistivity model of multi-layers used in interpretation of the sounding curves and the apparent resistivity pseudosection for different electrode arrays.

c)A block with low resistivity in a homogeneous half-space:

The resistivity model of the subsurface used to interpret the sounding curves and the apparent resistivity pseudosection is shown in Fig. 5.1. Resistivity of environment and the blockare 100 Ωm, 10Ωm, respectively. The calculated apparent resistivity pseudo sections are plotted in Figs. 5.2, 5.3 and 5.4.

Just as well the second model, the advantages of the two dimensional calculated pseudo sections over the resistivity pseudosection for Wenner arrays can be clearly seen by comparing the corresponding results shown in Figs. 5.3 and 5.4.

The extension Petrovski apparent resistivity pseudo section calculated (Fig. 5.3) is compared with the Petrovski apparent pseudo section (Fig. 5.4), results obtained are equivalent to each other.

Besides that, the Werner arrays were also used in multi-electrodes electrical sounding, so the data of these measurements were also calculated as test for this method.

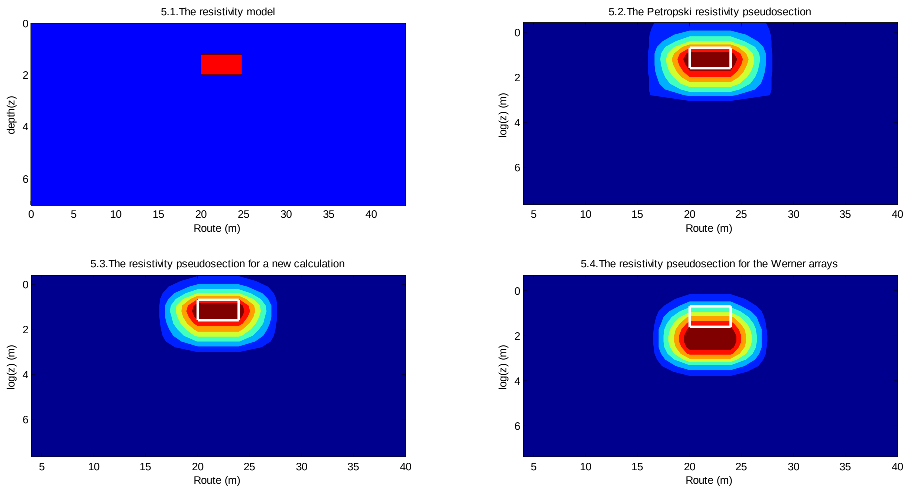

Figure.5. The result forthe survey model allows the apparent resistivity pseudosection.

4. Conclusion

The calculated result of the extension Petrovski apparent resistivity shows that: the sounding curves had higher density of information and the apparent resistivity pseudo sections reflected properly resistivity model with the true values selected resistivity.

These results are going to give a first idea about an in homogeneous medium where the subsurface resistivity has a 2-D distribution. It can also be used to obtain an initial guess for inversion.

Because of the advantages in calculating of the extension Petrovski apparent resistivity and compared to conventional difference electrode arrays, it is worthily to take the reading of this calculation in field work.

Acknowledgments

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