Armenian Journal of Physics, 2018, vol. 11, issue 3, pp.135-140

Features of The Distribution of Electric Fields of Multipoint Grounding and Their Application In Hydrogeology

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Received 27 August 2018

Abstract. In order to solve a number of engineering and hydrogeological problems, it is important to discern between the investigated incision horizons (layers) that are aquiferous or with shifting landslide surface. In geophysics, the method of vertical electrical sounding is the most commonly employed to solve such problems. However, the practical solution of problem becomes difficult or impossible if the horizons sought are low-powered or located in considerable depths. It is shown that in engineering-hydrogeological conditions of the Armenian Volcanic Highland type of territory it is effective to use the well-known multi-electrode sounding by the method of subtraction of fields (SMSF). However, its practical application requires examination of the features of the distribution of the electric field of multipoint grounding electrodes and determining the way of quantitative processing of the observed graphs. The examples given show the effectiveness of the proposed methodology in the solution of targeted engineering hydrogeological problems.

Keywords: Electrical resistivity, electric field, vertical electrical sounding, aquiferous horizons

1. Introduction

Recently geophysical electrical exploration methods, in particular modification of vertical electrical sounding (VES), are widely used in geological practice to solve important practical problems: in hydrogeology – to research underground water resources, in engineering geology – mainly to study landslide appearances [1,2]. At the same time in lesser degree applies the modification of sounding by the method of subtraction of fields (SMSF), although it is considered as differential method of the electrical exploration. The essence of the method is that in field conditions determines the difference of electric potentials (ΔU) which is the result of imposition of two electric fields (ΔU_1 and ΔU_2), which are created in earth by two supplying lines with oppositely directed constant electric currents. Such way of measurement has an increased sensitivity to local geological heterogeneities and low-powered interlayers in section [3-5]. These possibilities of the method attract attention of specialists while using it on purpose to identify, countering and follow-up low-powered aquiferous horizons especially in such difficult by structure volcanic regions as Central Armenian Volcanic Highland [6,7]. Herewith the practical solution of supplied problems required, firstly, obtaining representations about the features of distribution of the electric fields in earth at multipoint grounding and determining the way of interpretation of observed field data. The solution of these difficult problems is subject of our research.

2. Study of the distribution of the electric field at multipoint grounding

The basis of the observed field subtraction method is laid the formula of Petrovskiy to re-count field curves of VES [3]

$$\rho_t = \frac{\rho_a^{\ 2}}{\rho_a - \ell \dfrac{\partial \rho_a}{\partial t}} = \frac{\rho_a}{1-t}, \quad (1)$$

when ρ_t – apparent electrical resistivity accepted in the method of subtraction of fields, which depends on the parameters of the explored section and the sizes of measuring field installation, ρ_a – apparent electrical resistivity measured with VES method, t – angular coefficient tangential to the curve of VES, which is constructed in bilogarithmic scale. At the significant differentiation of the cut by the specific electrical resistivity (SER) it is also recommended transformation of the curve ρ_a of VES to the curve ρ_t recounting by the formula

$$\rho_t = \frac{\ell_2 - \ell_1}{\dfrac{\ell_2}{\rho_{a2}} - \dfrac{\ell_1}{\rho_{a1}}}, \quad (2)$$

where l_1 and l_2 – semi-openings of the measuring installation for the following and the previous current lines, ρ_{a1} and ρ_{a2} – relevant apparent electrical resistivity.

The practical application of the method of SMSF and interpretation of the obtained data, firstly required studies of the distribution of the electric field of multipoint grounding in uniform space and in the presence of the local (differing by the electrical resistivity) low-powered horizons. In this purpose it is realized by us the modeling using the electrical conductive papers and the modeling in hydraulic tank [8]. Below is the relevant analyze of the obtained data.

The mutual influence of the fields, which arises from autonomously and oppositely directed electrical circuits A^+B^- and A^-B^+ leads to form relevant positive and negative charges. As a result of their mutual attraction within separate layers of the section observes increasing of the density of the secondary (subtraction) electric field compared with primary fields which are created by current of separate circuits $A^+B'^-$ and $A'^-B'^+$. In particular, according to the modeling, in the structure of the uniform field observes "curvature" attracting to each other the power lines in the average part of the area (fig.1 (a), (b)). At the same time the second couple of the contra-lateral electrodes, with the lesser spacing, ($A'^-B'^+$) pushes out the power lines of the primary electric field (A^+ B^-) to the lower horizons which leads to the comparatively increase of the current density.

For the uniform environment the comparison of the distribution of current and equipotential lines of the electric fields VES and SMSF methods show that on the same cuts SMSF observes increased density of the current compared with VES.

Within the solution of the practical problems by the method of sounding the models highlighting the separate low-powered layers represent special interest. On the fig. 2 and 3 it is shown the comparative character of the distribution of electric fields for the methods of VES and SMSF in the presence of a low-powered conductive and a relatively high-resistance electric layers. Generally, the analyze of the distribution of electric fields shows at the same deep cuts the density of the current at the scheme of SMSF is more than at the VES. Mainly, just this circumstance makes to supply the method of SMSF more effective in field conditions to highlighting relatively low-powered aquiferous horizons.

The important task for the practical application of the SMSF method, as it was indicated, is the determination of the way of interpretation of observed data. Particularly, in the special methodical instructions for these purposes it is recommended to spend the interpretation using calculated pallets, of which album is composed on the basis of recounting three-layer theoretical curves of VES [1,9]. Herewith, in a basis of ordering the same type curves ρ_t is laid the principle of constancy of the relations of powers of layers. It is considered often changeable just that parameter within the small areas at the relatively constancy of the SER of the layers forming the cut [10]. However, this condition is not always occurred in practice and the obtained curves often have "sharp bends" and it is practically impossible to collate with the calculated theoretical curves.

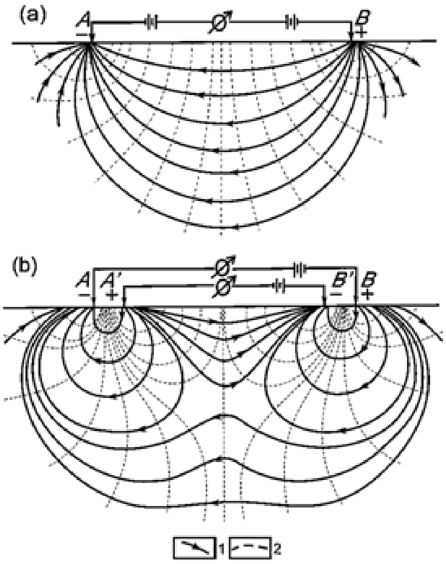

Fig.1. Distribution of the electric fields in uniform environment by the methods of (a) –VES and (b) sounding by SMSF; 1 – power lines, 2 – equipotential lines.

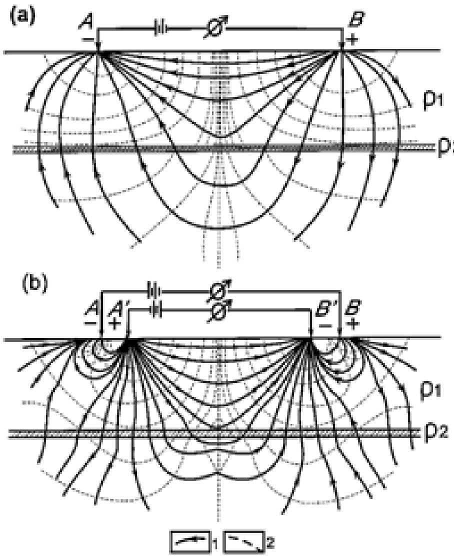

Fig.2. Distribution of the electric fields in presence of a low-powered conductive horizon in environment by the methods of (a)–VES and (b) sounding by SMSF; 1–power lines, 2–equipotential lines.

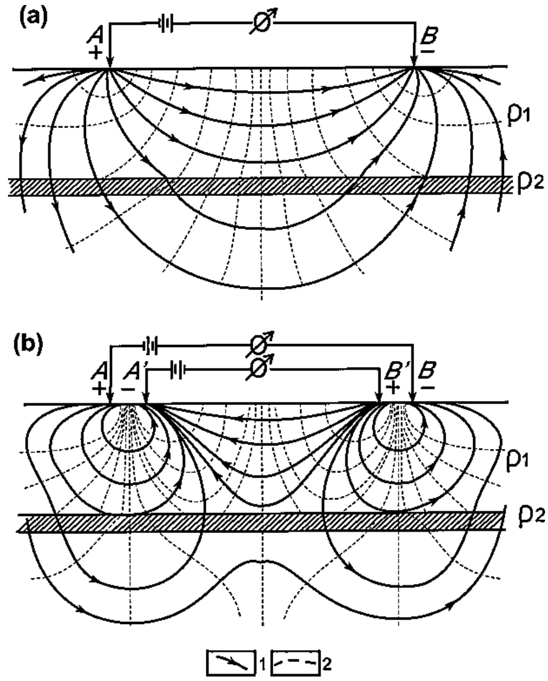

Fig.3. Distribution of the electric fields in presence of a relatively high-resistance horizon by the methods of (a) – vertical electrical sounding (VES) and (b) sounding by the method of subtraction of fields (SMSF); 1 – power lines, 2 – equipotential lines.

We recommend to use the method of Tagg for the quantitative interpretation which already has been used at the quantitative processing of the field curves of VES [11]. With the field measurements ρ_t it is formed cumulative graphics. The ordinates of the graphic are obtained by the summation of all the values ρ_t for the previous measurement including the measurement of the pending point. So, for instance, for the successive initial measurements 1, 2 and 3, the ordinates of points will be $p_{t1}, p_{t1} + p_{t2}$ and $p_{t1} + p_{t2} + p_{t3}$. The recalculated points are united with the minimal number of direct segments. The points of the fracture of curves allow to identify the depth of layers.

3. Discussion of the results of the practical application of the sounding by the method of subtraction of fields

Examples of the effective application of the SMSF method are the results of the research works which are implemented on the northern part of the Gegham Volcanic Highlands where is expected the existence of the paleochannel of the Hrazdan river which flows from Sevan lake. In connection with the spatial mapping of the specified paleochannel and the establishing its associations with the underground waters of the lake it was studied the hydrogeological conditions of the coastal territory with the highlighting here aquiferous horizons.

The study was accomplished by the VES and SMSF methods. The comparative results are given in fig.4. As it seen from the picture on the curve of VES (fig.4 (a)) stands out the following geoelectric horizons: $\rho_1 < \rho_2 < \rho_3 > \rho_4$, i.e. it is four-layered, where h_1 – recent boulder-pebble sediments, h_2 – tuffs, h_3 – relatively "dry" lava, h_4 – aquiferous basalts. According to the data of SMSF, the geo-electric cut is more differentiated. Instead of four layers there is stand out six geo-electric layers. The high practical interest represent the low-powered horizons h_3 and h_5 (fig.4 (c)), because they are conditioned with the interlaid aquiferous horizons which is connected with the filtration waters of Sevan lake.

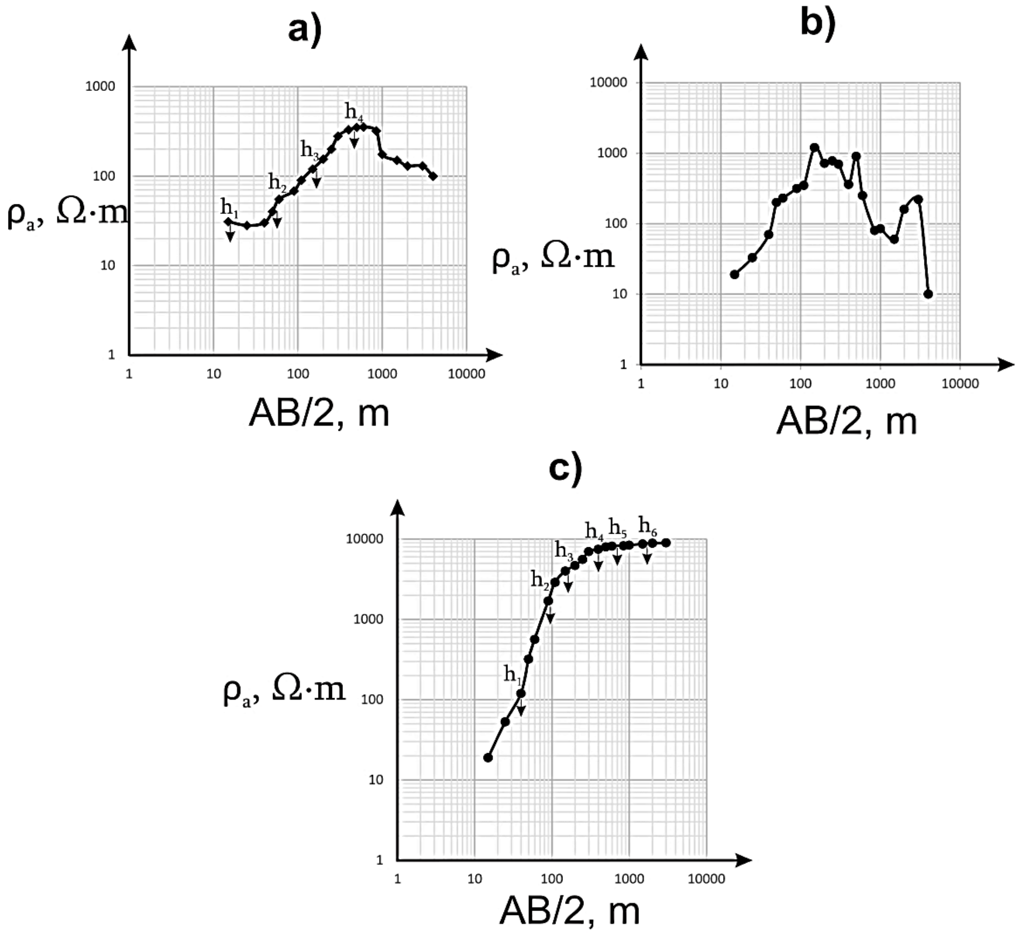

Fig.4. Comparison of the results of quantitative interpretation of the curves of a) VES and b) SMSF to highlight the low-powered aquiferous lava formations: a) – observed curve of VES, b) – observed curve of SMSF c) – cumulative curve of SMSF.

4. Conclusion

Thus, in the study of hydrogeological and engineering geological conditions of the territory (detection of low-powered aquiferous horizons, determination of shear surfaces of landslides etc.) by the electromagnetic methods arise significant difficulties connected with the highlighting the low-powered horizons or the slight differentiation of the studying cut by conductivity which is characteristically, for instance, for the volcanic regions (including Armenia). For such territory as effective research method proposed the sounding by the method of subtraction of field (SMSF). The distribution of an electric field of multipoint grounding for characteristic geo-electric cuts was investigated. It is offered to widely use the method of SMSF in volcanic areas at the solution of practical problems in hydro- and engineering geology.

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