Indonesian Journal of Physics
Vol. 34. No.2, 25 December 2023
Journal homepage: http://ijphysics.com

Magnetoteluric Modelling in High Noise of Low Frequency Signal

Agus Laesanpura[1*], Nindia Ekasuci Larasati[1], Asep Sugianto[2], Eko Junian[1]
[1]*Geophysics Department,Jl. Ganesha 10,Bandung 40191, Indonesia*
[2]*PSDMPB, Jl. Soekarno Hatta 444, Bandung 40254,Indonesia*

(Received: 10 October 2023, Revised: 24 December 2023, Accepted: 03 January 2024)

Abstract

Magnetoteluric(MT) modelling geophysics in high noise areas is a challenging task. One component comprises valuable data crucial for subsurface reconstruction, while the other component, characterized by inherent noise, has the potential to adversely impact the outcome. This paper will investigate these two phenomena through simulation and illustrate their dynamics with a real-world example in the field. The simulation will propose the ideal model without and with noise, running on the Bostick inversion. Noise varies several schemes in two types of curves. Occam and Bostick algorithms will be used to run the inversion scheme. The trade of the advantages and disadvantages is then compared to a prior model in the field where MT data and geologic cross section are available. Two scenarios are available, one is to use data with treatment using an available scheme, and the other is to use data by cutting off the noise contaminant segment, and finally to see the result through 2D modelling process. The resultant shows the model use the ideal signal without noise through inversion resulting is a better than the other with a noisy signal experiencing treatment, notably in level shallow part. The geologic cross section and gravity model is available to support these results.

Keywords: Magnetoteluric, Modelling, noise

INTRODUCTION

Magnetoteluric(MT) is a potential method for geophysics to utilize subsurface structure. It is less ambiguous than gravity methods. For geological models, electromagnetic output is resistive value.
The layer may have a common similarity with the density generated by gravity. For instance, this case can be found on the Caprock of geothermal. Bostick and Occam [1] or [2] are aiming to analyse the subsurface layer, which is geologically important [3]. They are connected to each other.

Noise reduction schemes are being proposed to reduce noise, which is a significant issue for modelling. Based on the data and inversion scheme, we recognize 1D inversion (similar to Rho in resistivity) and 2-D or even 3-D inversion. The 1-D inversion has been assumed for the ideal homogenic layer, while the 2D and 3D inversions have been used for varieties with heterogeneity.

The modelling in 2-D is influenced by the initial conditions and data. We start by modelling in 1D and then process the result to generate the initial model in 2D. Hence, our objective is to select the data, and continue to initialize, and finally the 2-D resistivity result.

Geological interpretation and gravity model available will affect the result. Therefore, the initial consideration is the geological data and gravity interpretations that are compatible with MT data. To support MT, it is important to consider the impact of noise on the quality of result.

METHODS

The observation suggests that the data at low frequencies is characterized by noise, so we apply the following methods to be used to solve this problem:

- Synthetic model to simulate the initial condition and model.

1* Corresponding author. E-mail address: laesanpu@itb.ac.id

- Treatment data should be treated as a whole (and smoothed before inversion) or data should be cut off from the noise.
- Modelization geometry based on the gravity or geology model, resistivity based on Sounding.
- Modelization based on layering model and put constrain on the resistivity range for the layers.
  An iterative method is used to invert using the model and data described elsewhere. Example in [1][2], and for gravity data on [4].

The initial model reference, β, was formulated to include optimization error and value.

$$\emptyset(m) = \emptyset_d(m) + \beta\emptyset_m(m) \qquad (1)$$

The optimization of the entire optimization model m depends on optimizing parameter of misfit $\emptyset_d$, and improving the optimization model $\emptyset_m$, which involves involving the initial reference and trade-Off, β. To obtain the optimal Rho apparent and geometry subsurface, the parameter is adjusted iteratively.

SYNTHETIC MODEL

A synthetic model is meant to understand the behavior of an initial model that evolves into the final model through an iteration process. The final model is optimized by minimizing error between the data and the calculated model. Optimization typically uses a Gauss or Newton iterative scheme, and some references can be found in [5].

The model of field data will become more understandable once we have satisfied the initial model's scheme. It is based on geological hypotheses and MT data. To accomplish this, we start with a layer cake model and simulate the sounding point in various segments.

Three schemes are used to develop a satisfactory model, two of which are synthetic models, for the horizontal model (figure 1-3) and the perturbation model (figure 4-6). The field model is depicted in figure 9 as an inclined model.

Two things are introduced in horizontal models such as figure 1: homogenous with single guess Rho apparent and layering with nearly true value. The result of a homogenous model with a single initial condition is close to the average true value. Although there is a small discrepancy in depth. See figure 2.

The result is quassia-equal when compared to the true model value shown in figure 1.

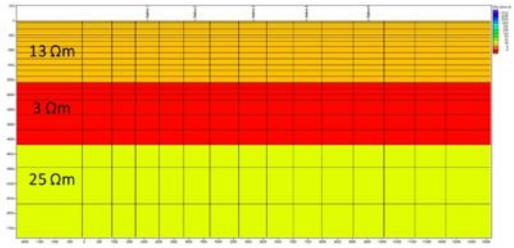

Fig. 1. The MT horizontal model

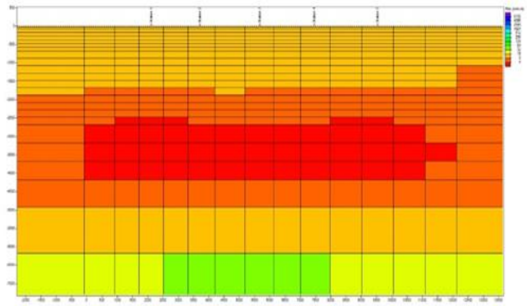

Fig. 2. An average value was initially set for the horizontal inverse result.

We are now changing to initial value beyond the average value and become 100 Ohm.m. In figure 3, the result of initial model of single rho apparent is also tested. In the initial model, a horizontal layer with homogeneous material is introduced with a single RHO apparent value of 100 Ohm.m, which is greater than the average value. Despite being roughly horizontal, the value of apparent resistivity begins to fluctuate compared to the MT horizontal model.

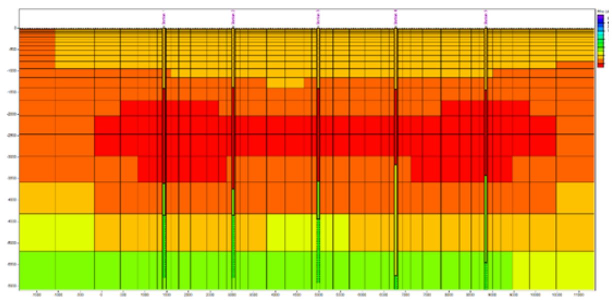

Fig. 3. Horizontal model inversion result for rho initial 100 Ohm.m

The second scheme discuss about perturbing model. The first case uses initial rho homogenous and model layers. In the second case use rho differs for every layer.

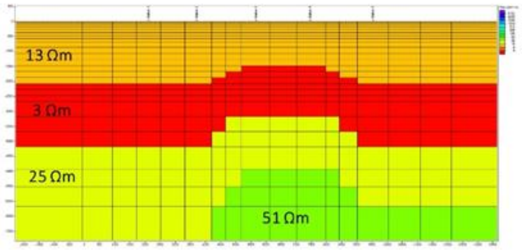

Fig. 4. The MT perturbation model

In the perturbation model in figure 4, the inversion uses an initial model with horizontal layer with rho value closed to average and constant, and the result in figure 5. It is close to perturbation model in figure 4. Although the artefacts exist in multiple parts (right corner), which may result in interpretation failure.

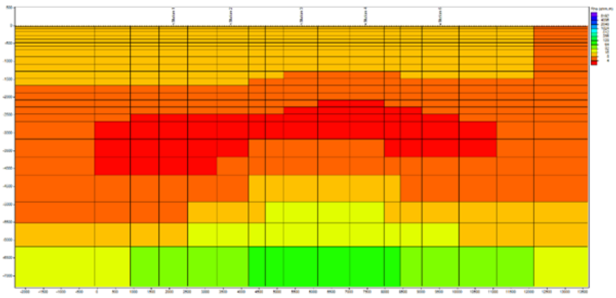

Fig. 5. The model perturbation has an initial value that is close to an average value. It is resembling the ideal model

For the case model perturbation, the initial model of single rho apparent applied to the homogenous layer is set to 1000 Ohm. The average value is significantly less than this. The result model is almost unrecognizeable in figure 6. The inversion result is become worst. Compare the result of figure 6, to model ideal in figure 4, and compare the result with better one in figure 5.

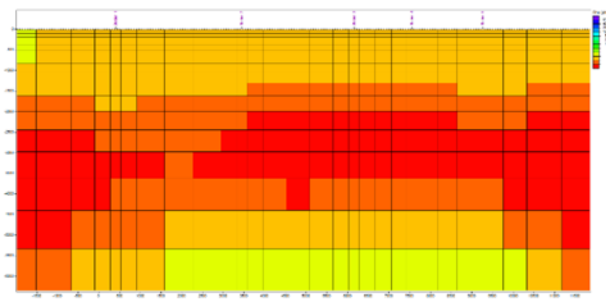

Fig. 6. The result perturbation layer for initial rho 100 Ohm. m

The inversion results proven that it will be reliable for the single rho apparent in previous experiments to be close to the true value. The initial model with layers similar to the final model is also pushing the model to be more realistic, as well as filling the unmeasured zone, which will be present geologically.

Thus, a good initial model will guide us towards a more realistic end model that will be straightforward to interpret.

GEOLOGY AND GEOPHYSICS MODEL

The data on MT has been converted from the time domain to the frequency domain. The amplitude and Responds are illustrated in (figure 7). The low frequency area has a subtle high noise. We use a whole data set and smooth it uses the D+ [6] technique, considering two factors.

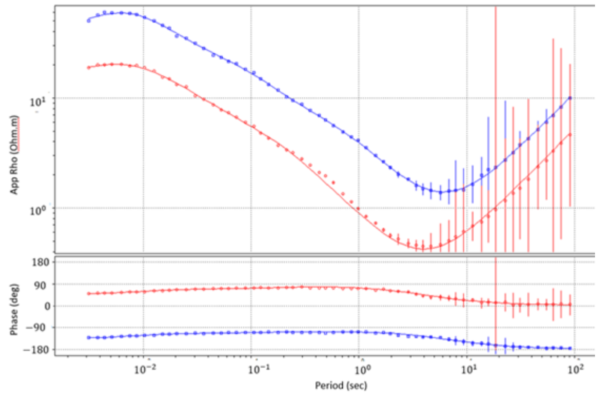

Fig. 7. The MT data with high noise in low frequency zone

The second choice is to reduce and make use of data until the one second period.

Figure 8, shows the result of 1-D an inversion process using a simple layer model, applying a whole data with smoothing to the noisy signal. The software ©WinGlink facilitates the inversion process.

In the case of using a whole data with smoothing, the inversion result (figure 9) shows multiple spot height resistivity layers (green and yellow) among the lowest ones. The geology model in the field indicates that it won't be feasible due to the layers of volcanic deposits.

The primer data is limited to a maximum of one second period for the following models. We use a Homogenic model with an initial rho apparent of 60 Ohm.m. Iteration is done on the system until there are tolerable errors. The profile on figure 10 reveals the results and logical geological explanations for volcanic deposits on the flanks.

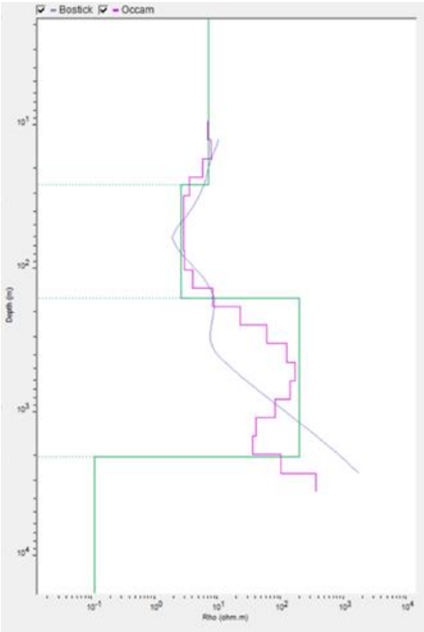

Fig. 8. Typical 1-D Inversion

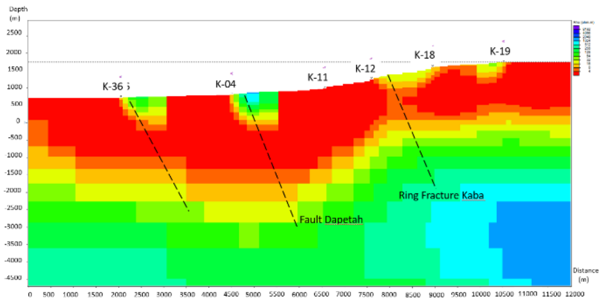

Fig. 9. The result is inversion with smoothing noise of data

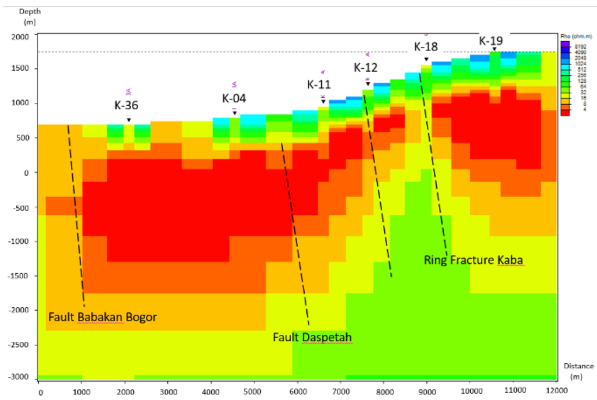

Fig. 10. The result is an inversion that eliminates data noise

By comparing it to the figures from the resulting inversion (figures 9 and 10). The figure 10 is resulting of signal cutting off after one second, which is more advantageous than using a complete data set in noise one (figure 9).

The results and the synthetic model, which depict the perturbation with misposition in figure (3,6), have a significant impact on the decision. Moreover, when it comes to the case data displayed in figure (9,10) selecting the relevant data can lead to the best outcome.

The final model is depicted in figure 11. The coherence between the geological model and gravity data is the basis for it [7]. The gravity also needs to be adjusted. Both the MT model, gravity model, and geology model have been developed to be consistent.

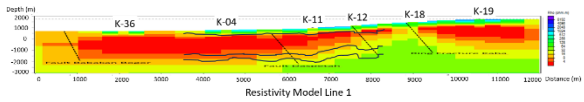

Fig. 11. The final model considers the initial model from the gravity model. The black line shows the plot of the gravity model superposed on the MT Result.

CONCLUSION

To achieve the best results, it is important to have quality data and strategies when interpreting MT. Regarding the quality data in an area with high noise in the low frequency signal through geology facts and interpretation, it is better to cut off after a period of one second. This study showed that the curve model and modelling results didn't have a significant impact on the deeper layer, despite the assumption that it would.

It can be concluded that the initial model contributes due to modelling constraints in synthetic models and the importance of the geological model in creating the final model. A prior model can help achieve the most desirable results when the initial model is close to the true model or geology model during the iteration inversion process.

REFERENCES

[1] S. Constable, R. Parker, and C. Constable, Occam's Inversion: A Practical Algorithm for Generating Smooth Models from Electromagnetic Sounding Data, *Geophysics*, **52**(3), 289,1987.

[2] W. Rodi and R. Mackie, Nonlinear conjugate gradients algorithm for 2-D magneto- telluric inversion, *Geophysics*, **66** (1), 174, 2001.

[3] A. G. Jones and X. Garcia, Okak Bay AMT data-set case study: Lessons in dimensionality and scale, Geophysics, **68**(1), 70,2003.

[4] D. Pratt, A. Foss, and S. Roberts, User Guided Inversion & Visualization of Interpretation Confidence, Melbourne AESEC, 2006.

[5] G. Newman and G. Hoversten, Solution strategies for two and three dimensional electromagnetic inverse problems, *Inverse Problems*, **16**(5), 1357, 2000.
[6] D. Beammish and J.Travassos, The use of the D+ solution in magnetoteluric interpretation, *Journal of Applied Geophysics*, **29**, 1,1992.
[7] A. Laesanpura et al., Proc. Int. J. Phys. conf Ser. (Oct. 5-6, 2021, Bandung, Indonesia), **2243,** 012016

IJP Volume 34, Number 2, 2023

If you find difficulties in placing figures or table in the text above, please insert them in this page!