DATA ANALYSIS OF VLF (VERY LOW FREQUENCY) TO DETERMINED CONTINUUM UNDERGROUND GAS PIPELINES AT GRESIK, EAST JAVA

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ABSTRACT

Survey Very Low Frequency (VLF) to predict continuously of gas pipe at subsurface, carried out. The gas pipe’s belongs PT Pertamina locate at Gresik beach, West of Java. Some part of the pipe go down at under sea water. The VLF survey use 2 set T-VLF BRGM (sensor+monitor-T) equipment, GPS Trimble 4600S and Theodolit Topcorn to fixe the measure points. T-VLF Iris Instrumens operate with one or two frequency simultaneously. The transmitter involve the use of Turkey (26700Hz) and JJF4 (22200Hz) Ebino Japan.

The parameters measured from VLF methods are tilt (%) and elliptisity (%). The VLF data processed with tilt angle Fraser derivative result that frequency as a function of tilt angle on a graph, the fraser derivative versus distance and current intensity contour. The current intensity contour tilt at 2 frequency (22200 and 26700 Hz) resulted in order to fraser derivative: Horizontally pipe cross section lies at central corridor, at 4 up to 6 meters at each measuring corridor. The shape of pipe are shallow at left side from 60 m distance. The right side from 150 meter corridor distance, with 1 up to 2 meters depth at rise of tide sea water. The central corridor at 60 till 150 meters distance, the pipes pattern curve relatively with 3,5 up to 4,5 meters depth at rise of tide. The pipes oblige 34,06° at northwest 60-65 corridor and 20,00° at southeast 140-150 corridor.

Keyword: vlf, gas pipe, Fraser derivative, tilt.

SARI

Telah dilakukan survey metode VLF (Very Low Frequency) untuk mengetahui kemenerusan saluran pipa gas yang terletak dibawah permukaan. Pipa yang mengalirkan gas milik PT Pertamina terletak di pantai Gresik Jawa Timur, beberapa rusnya terletak di bawah permukaan air di pantai. Survey VLF menggunakan 2 set alat T-VLF BRGM (sensor+monitor-T) dengan perlengkapan GPS Trimble 4600S dan Theodolit Topcorn untuk menentukan posisi titik ukur. T-VLF Iris Instrumens ini beroperasi dengan satu atau dua frekuensi sekaligus. Pemancar yang digunakan adalah Turki (26700Hz) dan pemancar JJF4 (22200Hz) di Ebino Jepang. Jumlah lintasan pengukuran sebanyak 63, dimana 41 lintasan dengan spasii antar lintasan 5 m dan 22 lintasan dengan spasii antar lintasan 1m. Spasi titik pengukuran 1m dan panjang lintasan 10 m.

Parameter yang diperoleh dari pengukuran VLF adalah tilt (%) dan elliptisitas (%). Data VLF diolah dengan membuat fraser derivatif dari tilt angle, sehingga diperoleh grafik frekuensi sebagai fungsi tilt angle dan fraser derivatif versus jarak serta kontur rapat arus. Kontur rapat arus untuk data tilt pada dua frekuensi, yaitu 22200Hz dan 26700 Hz diperoleh dari pembuatan fraser derivatif tersebut. Penampang pipa pada arah horizontal berada pada tengah koridor yaitu pada jarak 4 hingga 6 m di setiap koridor pengukuran. Bentuk pipa pada arah vertikal dangkal pada sisii kiri dari jarak koridor 60 m dan kanan dari jarak koridor 150 m dengan kedalaman yaitu 1 m hingga 2 m pada kondisi pasang. Pada posisi di tengah koridor yaitu pada jarak 60 m hingga 150 m pola pipa cenderung melengkung dengan kedalaman berkisar antara 3,5 m hingga 4,5 m pada kondisi pasang. Kemiringan pipa pada busur Barat Laut adalah 34,06° pada koridor 60-65 dan pada busur Tenggara adalah 20,00° pada koridor 140-150.

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INTRODUCTION

VLF method is one method of electromagnetic (EM) which aims to measure the electrical conductivity of rocks by acknowledging the properties of the secondary EM waves. These secondary waves resulting from the induction field is the primary EM. EM wave frequency is very low from 10 to 30 KHz. Given the low value of frequencies used, the frequency range are grouped into VLF (Very Low Frequency) groups.

 Generally T-VLF measurement is to measure the electromagnetic fields in the path above the target. Electromagnetic waves emitted by the antenna communication (transmitter) that lay in various countries (places) in the world. Waves are then induced rock (target) so the target will bring up a secondary electromagnetic waves. The resulting field is then measured by means T-VLF. The secondary EM field strength is proportional to the magnitude of the electrical conductivity of rocks (σ). By measuring the field strength in a certain direction, indirectly we can detect the electrical conductivity of rocks beneath it. The depth penetration of the VLF method is to tens of meters.

The pipeline, which transports gas owned by PT Pertamina is located on the coast of Gresik, some segment lies under the water surface at the beach. If the condition mainly tidal immersed in water, but if some portions of the visible from the surface of the water receded. This condition leads to a deviation or a curved form of the original straight pipe. If unchecked, it will disrupt the flow of gas through it. This will cause many problems in the future.

In this study tried to determined of pipecurve. Some methods are applied, one of which is the VLF electromagnetic method. Interpretation of tilt and ellipticity, results good enough continuum pipeline

OBJECTIVE THE STUDY

This study aims to determine the distribution of resistivity anomaly based on pseudo resistivity obtained on the surface. It also compares the measurement results obtained i.e. ellipticity and conductivity parameters for two frequency domain, so that the known geometry of the anomaly. The objective of this study was to determine the shape continuum gas pipe which lies below sea water surface.

BACKGROUND THEORIES

VLF method utilizing a carrier wave (carrier wave) of the transmitter is made by the military actually for underwater communication. This wave has a deep enough penetration as the frequency is low enough. VLF waves spread throughout the world with little attenuation in the waveguide between the earth’s surface and the ionosphere.

Because the induction of primary wave, medium-induced currents will occur (Eddy current) figure (1). Induced current that causes the secondary field can be captured and measured on the surface. The secondary EM field strength is proportional to the electrical conductivity of rocks (σ), so by measuring the field strength in a certain direction, can be detected indirectly electrical rocks conductivity beneath it.

![Figure 1: Induction of Electromagnetic fields on object at subsurface, which raises Eddy currents.](image)

Electromagnetic field is expressed in the four-vector field. That is: $E = \text{electric field intensity}$ (V/m), $H = \text{intensity of magnetization field}$ (A/m), $B = \text{magnetic induction, or flux intensity}$ (Wb/m2 or Tesla) and $D = \text{electric shift}$ (C/m2).

The four equations are Maxwell equations.

$$\nabla \times E = -\frac{\partial B}{\partial t}$$

$$\nabla \times H = i + \frac{\partial D}{\partial t}$$

$$\nabla \cdot B = 0$$

$$\nabla \cdot D = \rho_c$$

(1)

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With the additional tensor reduction relations will be obtained an equation that simply relates to the field \(E\) and \(H\) (Grant and West, 1965, p.496). If \(E\) and \(H\) fields are assumed only as an exponential function of time, we obtained

\[
\nabla^2 E = i\omega \mu \sigma E - \epsilon \omega^2 E \\
\nabla^2 H = i\omega \mu \sigma H - \epsilon \omega^2 E
\]

\(\epsilon\) dielectric permittivity (F/m), \(\mu\) magnetic permeability (H/m), dan \(\sigma\) electric conductivity (S/m).

At the low frequencies (<100 kHz), the current change is less than the conduction current. The average dielectric permeability is small enough (about \(10\epsilon_0\) and \(\epsilon_0 9\times10^{-12}\) F/m) and VLF conductivity is usually \(10^{-2}\) S/m. This means that the effect of field due to conduction currents play an important role when the conductivity of the medium changes (Sharma, 1997).

Plane wave propagating in the media with conductivity \(\sigma\), where the \(E\) oscillates in the \(x\) axis and \(y\)-axis \(H\) will provide the solution.

\[
E_x = E_0 e^{-ikx} = E_0 e^{-i(\beta + i\alpha)z}
\]

(3)

\(k\) is waves number \((k^2 = - i\omega \mu (\sigma + i\omega \epsilon))\). The real \(\beta\) shows the phase factor (rad / m) and imaginary \(\alpha\) shows the wave attenuation (db/m). Considering the value of electrical conductivity and permittivity divided by the frequency angular greater than one for the rock media, then the phase factor and damping factor of the same value (Kaikkonen, 1979).

Depth at the amplitude to \(1/e\) (approximately 37%) known as the skin depth \((\delta)\). It is deep in the EM method is often suspected as the depth of penetration of the wave, which is implemented in Table I.

\[
\delta = 1/\alpha = \sqrt{\frac{2}{\mu_0 \sigma}} \approx 504.5 \sqrt{\frac{\rho}{f}}
\]

(4)

**METHODOLOGIES**

Lines measurements carried out in a grid with 63 tracks, 41 tracks with 5 m spacing and 22 track with 1 m. Measurement points spaced 1 m and a length of 10 lines. A study area at north coastal Gresik, East Java (fig.1).
Equipment used in the survey were two sets of tools T-VLF BRGM (sensor + monitor-T) with the completeness of the figure (3): Cable connector 2 pieces @ 20 meters and supporting equipment (6 pcs 1.5 volt batteries, one 9 volt battery, rollmeter 100 meters or more, Trimble GPS and theodolite Topcon 4600S).

EM wave field consists of the component fields H and E. To a place far from the transmitter and the ground conductive media are considered, then the components of the field H will have a horizontal direction perpendicular to the direction of the transmitter. While the E wave will have a horizontal direction in the transmitter direction (the direction of propagation). Because the secondary wave field direction H and E field will change. The equipment used is Iris Instruments T-VLF which can operate with one or two frequencies at the same time. The transmitter used is a transmitter Turkey (26,700Hz) and transmitter JF4 (22,200Hz) in Ebino Japan. Parameters measured resistivity Mode, Tilt Angle and Ellipticity mode.

Field measurements with the T-VLF is a measure on the trajectory perpendicular above the target (pipe), with 1m spacing at line 10m distance. Length of pipe is 200m. Because the transition zone where targets (pipes) in the condition survey is always submerged in water is usually done by walking on the target zone will be slightly modified. Modifications made by performing measurements on a boat is pushed along the track. To maintain the balance of the boat so that the sensor on the tool does not moving the boat will be held on both sides so that the boat was in stable condition.

DATA PROCESSING

The parameters obtained from measurement of VLF is tilt (%) and ellipticity (%). Several steps must be done in the VLF data processing. The first, make Fraser derivatif of tilt angles is by applying the formula \( Y(a) = X(a-1) + X(a) - X(a +1) - X(a +2) \) on the tilt series in a profile. The Y ordinat is the result of the derivative which is located in space \((a + \frac{1}{2})\), and a moving from station to station-2 data into the data to n-2. Then, create a chart of each frequency in each path. The chart are tilt angles and Fraser derivatif versus distances, and create current dendity contour with calculate tilt.
mode. The next step, make apparent resistivity versus distance at resistivity mode. Furthermore, from each of the graphs in the previous step, then made each contour (tilt contour, elliptical, Fraser, and the contours of apparent resistivity) for each frequency. By making section on the tilt contour and the elliptical contours and operated a linear filter (Karous & Hjelt, 1983).

![Image](image_url)

Figure (6): Current density profile at 27,600Hz frequency (top) and 22,200Hz (bottom)

The next, Fraser then be derived from the slope and create the contour of the input current density equivalent to the tilt profiles. Examples of profile at figure (6) in the lines KR 50 for frequency of 27,600 Hz and 22,200 Hz. The red color indicates the density of current high values and low blue.

**INTERPRETATION**

By looking at the pattern of tilt, elliptical, and Fraser was then obtained peak the depth of the conductor. Conductivity value x thickness can be resulted by looking at peak to peak maximum tilt angle (α_{max}) in % and the maximum peak to peak elliptisitas (ε_{max}) in % of the targets which are conductive anomaly (Saydam, 1981)

VLF data interpretation results of the position and depth of the target pipe. To find pipe position, the Fraser derivative graphs used of tilt measurement data. The pipe depth determined from Linear Filter program. From both analysis can be derived continuum pipeline targets.

The field data i.e. tilt (%) used in the processing of VLF. From the field measurements are also frequently constraints found. The constraint in the form of noise barriers tend close to conductive objects locations and measurements of objects that emit electromagnetic waves. The sensor moves due to the measurement carried out on the boat is also a factor that can affect the data. To get better results then first performed on an applied filter to eliminate the trend/value of the influence of other objects around the measurement location. Data is already in the filter is then used in a linear filter process that will result current density contour in lower measurement path. Fraser derivatives is also made to clarify the position of the target object. Both arc used as data analysis VLF interpretation.

The value of higher current density indicates the existence of the target pipe. The depth and position of the pipe can be obtained from the contours of each track measurement supported by the analysis of Fraser derivatives. For each point tilt data the two taken from different sources i.e. from Japan with a frequency of 22,200 Hz and 26,700 Hz frequency Turkey.

The results of data analysis and interpretation of each section (corridor) for the different sources show different positions and depths (table I). Interpretation of each corridor, the approach that made the pipe on horizontal and vertical position. Pipe section approach made with doing smoothing interpretation of each corridor.
n pipeline targets. i.e. tilt (%) using VLF. From the field study, the targets are frequently constrained in the form of non-conductive objects that exist in the area. The sensor moves deep down in the boat to get the data. To get better results, a 1-meter filter is used on applied filtering. The influence of the measurement location is then used in a line to get current density in the measurement path. Fraser derivatives are used to clarify the position of the target pipe. The target pipe can be obtained by track measurement results of Fraser derivatives at the two taken for the different sources (26,700 Hz and 22,200 Hz) frequency Turkey and interpretation of the results indicate the positions and different depths. Interpretation of each trajectory approach made pipe in a horizontal and vertical cross-sectional figure (7) and (8). Table II displays the comparison of results interpretation at the frequency 26,700 Hz and 22,200 Hz.

**Table II**

<table>
<thead>
<tr>
<th>Corridor</th>
<th>Frekuensi 26700Hz</th>
<th>Frekuensi 22200Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Horizontal Position (meter)</td>
<td>Depth (meter)</td>
</tr>
<tr>
<td>0</td>
<td>4.10</td>
<td>-1.16</td>
</tr>
<tr>
<td>5</td>
<td>4.19</td>
<td>-1.17</td>
</tr>
<tr>
<td>10</td>
<td>4.40</td>
<td>-1.18</td>
</tr>
<tr>
<td>15</td>
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<td>-1.33</td>
</tr>
<tr>
<td>30</td>
<td>4.85</td>
<td>-1.37</td>
</tr>
<tr>
<td>35</td>
<td>4.89</td>
<td>-1.38</td>
</tr>
<tr>
<td>60</td>
<td>4.85</td>
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</tr>
<tr>
<td>200</td>
<td>5.40</td>
<td>-1.80</td>
</tr>
</tbody>
</table>

In the horizontal section, position of the pipe is not straight northwest-southeast there is reflection or distortion. At distances of 0 to 60 meters, the position of the pipe relative to the north. At a distance of 140-200 meters, the pipe relative to the south. In the vertical cross section, below a distance of 60 meters and 150 meters the pipe curve underneath with a fairly significant. This place is expected to generate more precise, by creating a space measuring 1

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meter. By calculating the slope of the pipe in position, result 34.06° in the northwest corridor 60-65 meters. While in the southeastern 20° in 140-150 meter corridors.

Figure (8): The pipe target position at horizontal section (top) and vertical (bottom) from the tilt data with a frequency of 26,700 Hz (Turkey). A red dot is the result of interpretation of the corridor with a spacing of 1 meter.

By looking at the results as figure (7), (8) and (9) as well as quality measurement data, the results of data analysis and interpretation of the slope with a frequency of 22,200 Hz better than 22,700 Hz.

Figure (9): Comparison the result of the pipe targets at the frequency 22,200Hz (red) and 26,700 Hz (black), at horizontal (top) dan vertical section (bottom).

CONCLUSIONS

From the results of data processing, interpretation and analysis in this study, it can take several conclusions:

1. The pipe in the horizontal direction tends to be in the middle of the corridor at a distance of 4 to 6 m in each measurement corridor.
2. The pipes shape in the vertical direction is shallow on the left side of the corridor 60 meter, and right side is 150 m corridor. The depth are 1 m to 2 m in tidal conditions. At the middle of the corridor at a distance of 60 to 150 m, the pipe curve underneath with depth ranges between 3.5 m to 4.5 m tide conditions.
3. The slope of the pipe is 34.06° West part at 60-65 meters corridor and the South East part is 20° at 140-150 meters.

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REFERENCE


Gharibi M., and Pedersen, L.B., 1999, Transformation of VLF data into apparent resistivities and phases, Geophysics, p 1393-1402


Raditya, F., 2002, Penyebaran Mineral sulfida dari data VLF-EM di daerah Keloran Wonogiri, Jateng, Skripsi S1 Geofisika FMIPA UGM


Sharma, P.V., 1997, Environmental and engineering geophysics, Cambridge University Press