ELECTROMAGNETIC COMMUNICATION CHANNEL FOR INFORMATION TRANSMISSION ON ABYSSAL PARAMETERS OF THE DRILLING WELL

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In several areas of national economics there is a need to address the issue of the field calculation's particulars in order to determine the current distribution laws and the potential along the stretched metallic construction on its longitudinal resistance, situated in the conducting medium. The similar issues are solved by distribution of potential along the metallic construction in order to protect them electrochemically from corrosion, by means of using the electric communication channel in order to measure the abyssal parameters during the oil well drilling, in the case of the great current leakages (mist, raining etc) in the underwater pipelines and the conducting telemechanical communication lines. Calculations of the electric communication channel are the most common and complex of all these cases. Here, the system exciting the electromagnetic field consists of the different sectors and each of these sectors has its certain influence on the current and potential distribution. Moreover, in order to get the expressions connecting the event all over the system, it is necessary to take into consideration the parameters of the abyssal source of the electric energy.

During the drilling process the operating mechanism for disintegrating rock is located in the oil well bottom distant from its mouth. Due to the lack of a reliable communication channel between the oil well's bottom and mouth, there are no instrument on mouth to measure and control the drilling process. The data obtained do not reflect the real values of the parameters, and this does not allow the drilling process to be carried out in optimal manner. In order to control the oil well's true parameters (a curvature, an azimuth, an angle of the vertical line's deviation, etc.) one is forced to stop the drilling process and to take the measurements by lowering all tools/instruments to the oil well on a cable.

The necessity of using surface-based control instruments for the drilling process increases when drilling deep and slopped oil wells. This leads to the prolonged stops and increased costs. Therefore there is an acute need for an uninterrupted flow of information on the drilling parameters to be received by operators on the surface to control the oil well's installation. This would also help to establish optimal conditions for the drilling process.

This work is devoted to the establishment of the electromagnetic communication channel for data transfer. The system works like an antenna for information transmission during drilling from the bottom of the well to its surface.

Let us consider the case where the simultaneous sea drilling of several neighbouring oil wells from the same base is in progress and the parameters control is carried out by wireless channel. Here the solution to the problem of electromagnetic compatibility for removing the mutual influence of the neighbouring wells' signals becomes critical.

The common case of information transmission from the underground depth to the surface during the oil well's drilling is shown in fig.1.

Here the signal's entrance into the communication channel is provided with the assistance of the scheme possessing the electrode – bush and the retranslator. The transmitted information in the state of electric voltage enters into the communication channel by connecting the generator to the column of the drilling tubes and to the electrode – bush isolated from the column.

The difference of potentials (modulated according to transmitted information) between two points of the surface is being measured. The signal's retranslation can be done by the retranslator (RT). The information transmitting system consists of the underground antenna [1] possessing the particular construction and the waves' propagation specific conditions. Under all other equal conditions of vibrations propagation the largest concentration of the electromagnetic field energy in a given direction can be reached by changes to the geometric and electric values in the transmitting part of the system and by the choice of optimal energies.

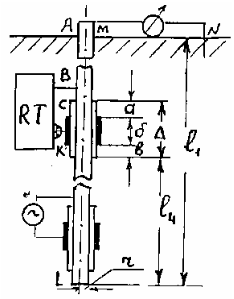

Fig.1 Scheme of underground antenna.

A distinctive feature of the problem under consideration is that the transmitter and receiver simultaneously have the galvanic and electromagnetic communication through a prolonged metallic pipeline and the field in the conducting medium. These two phenomena are connected and mutually reinforcing each other. We are unaware of any information in the literature on setting and solving of such a problem that takes into account the influence of the method of the signal's being transmitted into the communication channel.

Questions of theoretical and experimental investigations concerning the information transmission system through wireless electric communication channel are discussed in this paper. We have achieved corresponding expressions allowing an increase in the signal's transmission depth by varying the system parameters and providing electromagnetic compatibility between neighbouring wells channels.

Because of the drilling tube's own resistance (i.e., because the tube column's surface) is not equipotential, the field created around the column is not flat – parallel but flat – meridional. So the extra members reflecting the flat – meridionality of the electromagnetic field must be added to Maxwell's equation for system calculation:

$$d\dot{U}_1(\eta) = Z_{01}\dot{I}_1(\eta)d\eta$$
$$d\dot{I}_1(\eta) = Y_{01}^1\left[\dot{U}_1(\eta) - \dot{U}_{N1}(\eta)\right]d\eta$$

$$\dot{U}_2(\eta) = const = \dot{U}_D; \quad \dot{I}_D = \frac{\dot{U}_D}{Z_3}$$

$$d\dot{U}_3(\eta) = -Z_{01}\dot{I}_3(\eta)d\eta$$
$$d\dot{I}_3(\eta) = -Y_{01}\left[\dot{U}_3(\eta) - \dot{U}_{N3}(\eta)\right]d\eta$$

Here $\dot{U}_1(\eta), \dot{U}_2(\eta), \dot{U}_3(\eta), \dot{I}_1(\eta), \dot{I}_2(\eta)$ are the potentials and currents of AB KL and CE sectors, $\dot{U}_{N1}(\eta)$ and $\dot{U}_{N3}(\eta)$ are the additional potentials reflecting the field's flat – meridionality.

$$\dot{U}_{N1}(\eta)=\frac{Y_{01}\rho}{4\pi}\int_{0}^{l1}\left(\frac{e^{-\gamma_c\sqrt{(x-\eta)^2+r^2}}}{\sqrt{(x-\eta)^2+r^2}}+\frac{e^{-\gamma_c\sqrt{(x-\eta)^2+r^2}}}{\sqrt{(x+\eta)^2+r^2}}\right)\dot{U}_1(x)dx-$$

$$-\frac{Y_{02}\rho}{4\pi}U_D\left[E_i\{-\gamma_c(S_2-\eta)\}+E_i\{-\gamma_c(S_2+\eta)\}-E_i\{-\gamma_c(S_1-\eta)\}-E_i\{-\gamma_c(S_1+\eta)\}_i\right]+$$

$$+\frac{Y_{01}\rho}{4\pi}\int_{S_3}^{S_4}\left(\frac{e^{-\gamma_c\sqrt{(x-\eta)^2+r^2}}}{\sqrt{(x-\eta)^2+r^2}}+\frac{e^{-\gamma_c\sqrt{(x-\eta)^2+r^2}}}{\sqrt{(x+\eta)^2+r^2}}\right)\dot{U}_3(x)dx$$

$$\dot{U}_{N3}(\eta)=\frac{Y_{01}\rho}{4\pi}\int_{0}^{l1}\left(\frac{e^{-\gamma_c\sqrt{(x-\eta)^2+r^2}}}{\sqrt{(x-\eta)^2+r^2}}+\frac{e^{-\gamma_c\sqrt{(x-\eta)^2+r^2}}}{\sqrt{(x+\eta)^2+r^2}}\right)\dot{U}_1(x)dx+$$

$$+\frac{Y_{02}\rho}{4\pi}U_D\left[E_i\{-\gamma_c(\eta-S_2)\}+E_i\{-\gamma_c(\eta+S_2)\}+E_i\{-\gamma_c(\eta-S_1)\}-E_i\{-\gamma_c(\eta+S_1)\}_i\right]-$$

$$-\frac{Y_{01}\rho}{4\pi}\int_{S_3}^{S_4}\left(\frac{e^{-\gamma_c\sqrt{(x-\eta)^2+r^2}}}{\sqrt{(x-\eta)^2+r^2}}-\frac{e^{-\gamma_c\sqrt{(x-\eta)^2+r^2}}}{\sqrt{(x+\eta)^2+r^2}}\right)\dot{U}_3(x)dx$$

These equations enable us to determine the distributed potential along the surface of the drilling tubes. The use of these equations makes it possible to determine the optimal values of the directivity of the underground antenna. Concentration of the field's power lines close to the drilling column makes it possible to get the maximal signal and to provide electromagnetic compatibility. It has been found that in the actual conditions of drilling on Apsheron Peninsula, i.e. in the case of low – resistant rocks, the distance between the second electrode and the removal interchannel interference could be taken as 100 metres. The equations' system is solved by the iteration method with a margin of error of about 8 percent.

Theoretical and experimental research supporting the idea of the creation of wireless electric communication channel and the possibility of electromagnetic compatibilities in the case of simultaneous operation of neighbouring oil wells have been carried out.

This paper presents the results of the system calculation under alternative geometric and electric parameters that are illustrated in the figures.

Dependence of the signal value obtained on the well surface on the length of insulated "a" site of the tube $\lg U_s = f(a)$ at various current electrode δ lengths is shown in fig.2.

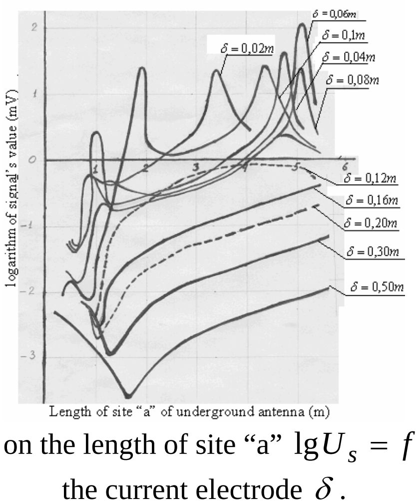

Fig. 2. Dependence of signal on the length of site "a" $\lg U_s = f(a)$ at the various lengths of the current electrode δ.

Here we take $\Delta = 3m; \delta = 0{,}18m; \rho = 5ohm; f = 20$ hertz. The figure shows that the signal level might be increased up to 1,000 times by changing the "a" value. We point out that all geometric dimensions of the abyssal antenna system have their influence on the following fact that by changing geometric dimensions of the system its total resistance also changes, the field's power lines are directing to the earth, and the coordination between the external load and the internal resistance of the abyssal generator is realised.

It is proved by the graphs of the whole resistance of transmission system dependence on the "a" site length at various δ shown in figure 3.

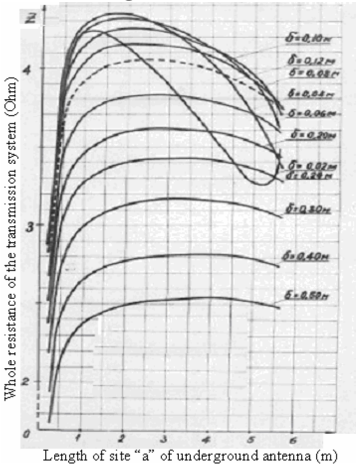

Fig 3. Dependence of the whole resistance of the transmission system on the length of "a" of various δ, $z = f(a)$, $\delta = \text{var}$.

It can be seen that the changes in these values lead to significant change in the resistance of the entire system.

Figure 4 shows the dependence of signal value at the surface on the current electrode length of underground antenna $\lg U_S = f(\delta)$.

The values of "a" parameter shown on the graph correspond to maximal values of the signal U_S. The given graph illustrates that in order to increase the signal and therefore to increase the distance of its transmission, one also needs to select the optimal dimensions of the current electrode.

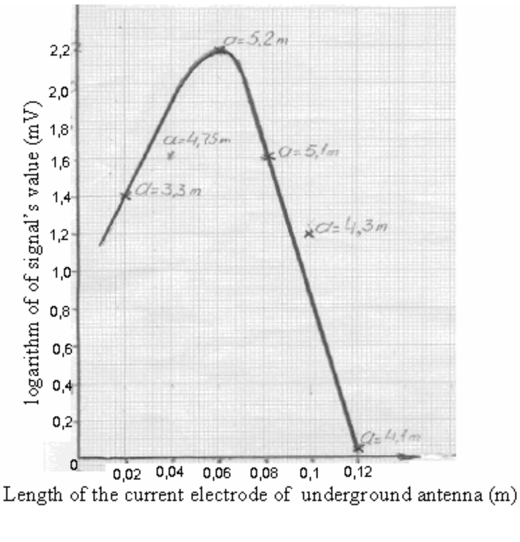

Fig. 4. Dependence of signal value on the length of current electrode δ, $\lg U_S = f(\delta)$.

The influence of the frequency on the obtained signal value has been researched.

The fig.5 shows the dependence of the signal changing interval on the "a" sector length for the different frequencies and $l_1 = 3{,}000\,\text{m}$. It has been observed that at comparatively low frequencies the signal's value is higher.

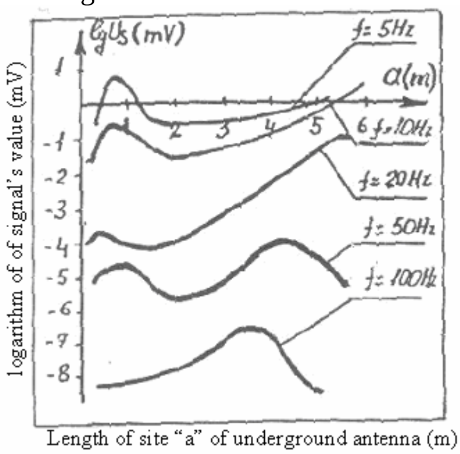

Fig. 5. Dependence of signal value on the length of site "a" at the various frequencies

$$\lg U_S = f(a)\,,\ f = \text{var}\,.$$

Thus it makes sense to ensure a signal transmission on the lower frequencies.

As above graphs illustrate the whole resistance that is the load for the system's transmission part changes dramatically as geometric parameters of underground antenna change. Furthermore, the graphs contain sharp peaks.

In the given system it is possible to change the active and reactive resistances of the communication channel by changing the different elements' dimensions. This allows the external load to be coordinated with the interval resistance of the generator. It also provides the directiveness of energy to the well's mouth. This helps to increase the transmission distance and eliminates the interference of the neighbouring wells' channels.

It is clear from these figures that changes in the parameters of antenna and environment cause significant changes of the surface signal's values.

These figures confirm the influence of linear dimensions of the underground antenna on the signal's value.

Analysis of these dependencies reveals that it is feasible to significantly expand signal transmission depth to over 5,000 meters via selection of system parameters.

The developed system allows field power lines to be concentrated close to the drilling column; it enables to direct the transmission of the measured signal's electromagnetic energy. This permits the second measuring electrode to be placed close to the well; furthermore, it provides electromagnetic compatibility with simultaneous operation of several information transmissions along the given communication channel in the neighbouring wells.

The system enabling wireless communication channel for transmission of information on abyssal parameters during the drilling process discussed in this paper has been created. It has stood the test directly in drilling conditions at these depths up to 5,000 metres. The obtained results confirm a great potential / opportunity to use this system / communication channel for information transmission.

References

1. Underground antenna for information transfer from the earth depth. Proceedings of theoretical and practical conference of Azerbaijan Technical University, part II, Baku 2003.