Development of a method for wireless information transmission in wells equipped with sucker rod pump units

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Abstract. Oil lifting via sucker rod pump units is the most widespread way to extract oil reservoir products. Complications adversely affecting the operation of downhole equipment and entailing increased wear and premature failure of sucker rod pump units arise in the process of high-viscosity oil production. The pressure and temperature of the well fluid are the main parameters for assessing changes in the properties of the extracted products and for determining the static level of the liquid column. It is possible to control pressure and temperature using sensors located in the immediate vicinity of the well pump. Today, a wired channel is the main way of transmitting the measured data to the well mouth. The present work proposes a new technical solution for a wireless communication channel along tubing strings and rods. The columns are separated by asphaltenes deposits on the surface of the columns and centralizers mounted on the rods. The rod string isolation from the tubing string at the wellhead is carried out through suspension modernization. Columns are closed inside the pump, specifically, on the cylinder-plunger contact. Information is transmitted from the bottom by means of a submersible module, consisting of an electrical separator and electronic circuit. The latter controls the separator closure and opening. The results of measurements of the resistance between the columns indicate the possibility of implementing a communication channel.

1. Introduction

The sucker rod method holds a specific place among the various methods of artificial oil lift since it has a wide scope. The proportion of sucker rod pumping units at some enterprises makes two thirds of the total artificial lift well stock. These units are often used in wells with the low flow rates and high-viscosity oil lifting. Most subsoil users with a production decline transfer wells to periodic pumping. In this case, a change in the technological parameters of a well is possible. However, it requires adjustment of the operating mode [1,2].

The parameters of the multiphase formation fluid produced by sucker rod pumping units vary throughout the entire well operation and depend on various factors, including wellwork, water cut, gas factor, paraffin content, etc. [3]. Based on the actual values of pressure and temperature of the well fluid measured in the immediate vicinity of a shelf it is possible to assess changes in the properties of the extracted product and the influence of the above factors [4]. In addition, control of bottomhole pressure is necessary to determine the static level of the liquid column while lifting by means of
sucker rod pumping units and it is the main indicator that determines the required pumping rate of the well fluid, which is realized either by the periodic pumping mode or by changing the well pump’s plunger strokes number [5, 6]. Pressure and temperature are monitored using sensors located in close proximity to a bottomhole. Measured information is mainly transmitted from the bottom to the surface via a wired communication channel.

2. Methods and materials
This work was carried out in the framework of the Federal Target Program “Research and Development in Priority Directions for the Development of the Russian Science and Technology Complex during the years 2014 – 2020” under the Agreement on granting the subsidy No. 14.610.21.0019 dated 10.23.17 on the topic “Creating a set of technological solutions for increasing oil recovery containing highly viscous oil”, a unique identifier for the work is RFMEFI61017X0019.

3. Results and Discussion
Almetyevsk State Petroleum Institute (AGNI) is developing a wireless communication channel between a wellhead and a bottomhole for wells equipped with sucker rod pumping units. Information from the bottom is supposed to be transmitted along the flow strings and rods. These columns can be considered as conductors separated by a layer of asphaltene deposits and centralizers installed on rods. In order to prevent a short circuit between the columns at the wellhead, it is proposed to use a galvanic isolation unit. Columns (ground surfaces with a large contact area) are closed at the bottomhole inside a sinking pump at the plunger case contact. Information is transmitted from the bottom using a submersible module, which includes an electric separator and circuit [7] that controls the separator’s closure and opening. Information transmitted through the columns enters the ground control and management unit (ground receiver) via a wired line.

The submersible module is located in close proximity to the suction of a well pump (Figure 1) and is equipped with sensors for measuring pressure, temperature and with a transmitter of information via a galvanic communication channel. An electric separator disconnects upper and lower parts of a column and transmits the signal via a voice channel.

The electrical resistance of a chain consisting of a string of rods, a deep well pump and a tubing is evaluated under the assumption that the circuit consists of homogeneous, electrically insulated rods and production tubing with a constant cross-section (1):

$$R = R_R + R_{TUB} + R_H = \rho \frac{L}{S_R} + \rho \frac{L}{S_{TUB}} + R_H,$$

where $\rho$ is specific resistivity of the conductor substance;
L is conductor length;
$S_R$ is rod cross-sectional area;
$S_{TUB}$ is tubing cross-sectional area;
$R_H$ is electrical resistance occurring in a submersible pump.

The electrical resistance arising in the deep pump is taken to be zero, since the distance between the plunger and the cylinder is small, and the interaction area is large. At the same time, the calculated electrical resistance of the circuit consisting of a string of rods ($S_R = 380 \text{ mm}^2$), a well pump ($R_H = 0 \text{ Ohm}$), tubing string ($S_{TUB} = 243 \text{ mm}^2$) for a well with a pumping depth of 1500 m and $\rho = 0.14 \text{ Ohm m}$ was 1.41 Ohm.

When calculating the open circuit electrical resistance, the following assumptions were made: the medium filling of the tubing is homogeneous and a stem in the tubing string is concentric [8-10]. The resistance of cylindrical grounding was determined according to [4] by the formula (2):
The resistance of cylindrical grounding was determined according to [4] by the formula (2):

\[ R_G = 0.367 \cdot \frac{\rho}{L} \log \left( \frac{L}{d_R} \right), \]  

(2)

where \( \rho \) is medium resistivity;
\( L \) is the length of cylindrical grounding (rods);
\( d_R \) is the diameter of cylindrical grounding (rods).

According to the presented field data the estimated resistance of the medium between the rods and tubing was equal to 200 Ohms [4].

A general view of the submersible module is shown in Figure 2.
The submersible module consists of an electric separator with a dielectric loading, an electronic unit with power batteries as well as temperature and pressure measurement sensors, an electronic board with the units processing memory and information transfer to the ground control station via GCS. The electronic unit conducts sessions of pressure and temperature measurements, records the measured parameters in the internal memory and transmits them at a set frequency to the surface of the earth via a voice channel [11-14].

The electrical splitter contains:
- housing elements (nipple and coupling) in the form of an adaptor with a connecting thread;
- a dielectric insulating layer between the housing elements;
- an electronic unit that provides pressure and temperature measurement and information transfer through a galvanic communication channel.

The ground-based information receiver contains a power source connected by one contact to the ground part of the metal rod string and by another contact to the metal tubing string, in which
the metal rod is concentrically mounted with scratchalizers of dielectric material.

The design of the galvanic isolation unit with insulating bushings providing electrical disconnection of the polished rod with the rod string from the remaining parts of the sucker rod pump drive is shown in Figure 3.

Bushings 2 made of insulating material are installed in the central holes of the upper and lower traverses 4 and 5. A plug 1 with a contact ring 3 providing an electrical contact between the wire communication line 7 and the polished rod (rod string) is screwed into the threaded end of a polished rod coupling. The second wire of the communication line provides the contact with the tubing string, using the slip ring and is mounted on the wellhead.

4. Conclusion

A tubing string represents an electrically open conductor due to an electric separator having a dielectric loading in its design. A submersible module in conjunction with a tubing string, boom string and galvanic isolation unit represents a system for transmitting borehole information through the galvanic communication channel with the modulation of a valid signal by switching the electrical separator with regards to a predetermined algorithm.

The developed galvanic communication channel will enable to measure downhole parameters avoiding down taking a cable into the well.

References

[1] Karimov L F, Ponikarov S I, Kalimullin N I 2017 Bulletin of the University of Technology 20 3.
[2] Bikbulatova G I, Galeev A S, Boltneva Yu A, Larin P A, Suleymanov R N, Filimonov O V 2019 Optimization of pumping fixed volume of liquid on two directions Bulletin of the Tomsk Polytechnic University, Geo Assets Engineering 330 (1) 134-144.
[3] Khabibullin M Ya 2019 Development of the design of the sucker-rod pump for sandy wells IOP Conference Series: Materials Science and Engineering 560 (1) 012065. DOI: 10.1088/1757-899X/560/1/012065.
[4] Urazakov K R, Nurgaliev R Z, Latypov B M, Bikbulatova G I, Boltneva Yu A 2018 Selection of the design of the weighted bottom of the pump rod column for high-viscosity oil production. Oil industry 10 111-113.
[5] Bikbulatova G I, Isaev A A, Boltneva Yu A 2018 Investigation of the influence of complicating factors on the efficiency of screw rod pumps Proceedings of Tomsk Polytechnic University. Geo-resource engineering 329 4 21-29.
[6] Shakirov A A 2018 Informativity of transient processes accompanying hydrodynamic well survey Advances in Engineering Research (AER) 157 558-561.
[7] Galeev A S, Filimonov O V, Suleymanov R N 2019 Development of a laser beam to the line in measuring systems IOP Conf. Series: Materials Science and Engineering 560 012125 doi:10.1088/1757-899X/560/1/0121251.
[8] Wang Z H, Lv X, Sun Y, Dai X, Li Y P 2012 A simple approach for load identification in a current-powered inductive power transmission system In Proc. IEEE Int. Conf. Power Syst. Technol (pp. 1-5).
[9] Zheng P, Lei W, Liu F, Li R, Lv C 2018 Primary control strategy of magnetic resonant wireless power transfer based on steady-state load identification method In Proc. of 2018 IEEE International Power Electronics and Application Conference and Exposition. DOI: 10.1109/PEAC.2018.8590563
[10] Urazakov K R, Nurgaliev R Z, Belov A E, Bikbulatova G I, Davletshin F F 2019 Investigation of complications in the operation of downhole rod pumps during simultaneous and separate operation Oil industry 7 114-117.
[11] Kominami D, Sugano M, Murata M, Hatauchi T, Fukuyama Yu 2009 Evaluating the effectiveness of intermittent data transmission through wireless sensor receivers In
Proceedings of the 6th International Symposium on wireless communication systems (pp. 141-145).

[12] Tutunkuoglu K, Yener A 2012 Optimal transmission policies for battery nodes with limited energy consumption IEEE Trans. Wireless communication March 11 (3) 1180-89.

[13] Tutunkuoglu K, Yener A 2012 Total speed optimum power policy for interference channel power collection transmitters J. Commun. Netw 14 (2) 151-161.

[14] Arafa A, Ulukus S 2015 Optimal policies for wireless networks with energy collection transmitters and receivers: the impact of decoding costs IEEE J. Sel. Community Areas 33 (12) 2611-25.