Implementation of wireless data transmission method on wells equipped with sucker-rod pumping units

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Abstract. When operating wells equipped with SRP units, the parameters of the products are monitored mainly via a wired communication channel in close proximity to the bottom by means of sensors. In the course of the work, it was found that, despite the large number of proposed scientific and engineering solutions, the objective of creating a reliable wireless electromagnetic channel connecting to the well bottom along with a configuration for its implementation is urgent, especially as far as the practical implementation is concerned. A distinguishing feature of the engineering solution proposed is data transmission via a galvanic communication channel in the course of well operation, involving the electric current excitation in the metal string in a well using the ground generator with one terminal connected to the ground part of the metal string and the other one to the pickup electrode on the well surface; switching dielectric loading, splitting the metal string in the downhole into the top and bottom parts, and data receipt from the well bottom depending on the ripple caused by the switching of the dielectric loading, where the data transfer phase synchronized with the upward lift of the rod string providing the possibility to use the feedback in order to track the cycle duration with a constant voltage on the dielectric splitter.

1. Introduction

The most commonly used method of artificial oil lift in brownfields that are characterized by a low production rate of most wells and the presence of viscous oils is the sucker-rod lift method. Two thirds of the total producing well stock is operated using sucker-rod pumping units (SRPU).

In the course of the SRPU operation, its technical condition and basic parameters are subject to inevitable changes. Corrosion, abrasive and mechanical wear, as well as various deposits have a negative impact on the performance of pumping units, while leaks that increase as the pump components wear out result in lower pump delivery rate. The speed of changes depends on the properties of the multiphase fluid extracted, operating modes, design peculiarities and quality of equipment. The simultaneous impact of all these factors makes it much more difficult to identify causes and patterns when analysing the causes of unit component failures [1].

The reservoir fluid parameters also change throughout the well's life cycle, since they in turn depend on various changing factors, such as injection of contour water flood of reservoir pressure maintenance (RPM) systems, water content, as well as gas, salts, paraffin content, etc. [2].
2. Problem statement

Some parameters of the products are evaluated in the immediate vicinity of the reservoir using sensors connected to the receiving station via a cable. Depending on what information is required, various sensors can be placed at the pump suction, such as density, temperature, or pressure sensors. The latter is required for measuring the static level of the fluid column during the sucker-rod pump operation, since it is the main indicator which determines the required borehole fluid pumping rate. It is implemented either by the cyclic pumping method, or by adjusting the number of strokes of the SRPU plunger.

The transmission of measurement data from the bottom to the mouth via a wired communication channel is complicated by a narrowing cross-section of the tubing as well as cable breakdowns caused by the movement of rods and paraffin deposits [2]. Patent studies carried out within the framework of implementing the monitoring of the SRPU technical condition and the reservoir fluid parameters at the bottom of the well to adjust the production process have shown that the development trends tend towards the use of cheaper and more reliable data transmission channels.

3. Engineering solution

In the course of performing the applied R&D works, a monitoring system was developed for SRPU with a submersible module and the downhole data transmission via a galvanic communication channel. The system which includes a ground station, a galvanic communication channel and a submersible module, analyses the technical condition of the drive and the sucker-rod pump, monitors the main well parameters, and transmits information to the relevant departments of the enterprise.

Each of the stages is controlled by software installed on controllers of the system’s downhole and ground modules. Software, which is based on a mathematical model of the SRPU drive with a transforming mechanism in the form of a lever of the 1st kind, is designed to calculate the correlation between the phase of the rod string movement and time and establish the relationship between wattmetrogrammes and dynamogrammes. The system's SM-SRPU Monitoring software is designed for collecting, storing, processing and interpreting sensor measurement data, evaluating their levels against the limit set points, and is installed on a personal computer. Built-in algorithms for detecting defects in the technical condition provide the possibility to issue and distribute among the subscribers of the relevant services diagnoses of the condition, forecasts of trouble-free operation and recommendations concerning the timing of repair and preventive actions.

A general layout of the SRPU monitoring system with a submersible module and a galvanic communication channel for transmitting downhole data is shown in Fig. 1.

The submersible module of the monitoring station transmits downhole measurements via a galvanic communication channel (GC) represented by a tubing and rod string. The galvanic isolation unit isolates the communication line from the grounded ground equipment of the sucker-rod pumping unit. Further, data from downhole and ground sensors is transmitted to the ground monitoring and control module (ground station) via a wired line or radio communication [4].

The submersible module is located in the immediate vicinity of the downhole pump suction (see Figure 1) and may be equipped with various sensors, in this case, pressure and temperature sensors and the device transmitting the measured information via a galvanic communication channel.

The electrical resistance of the circuit consisting of a rod string, a downhole pump, and tubing is estimated assuming that the circuit consists of homogeneous, electrically isolated rods and tubing with a uniform cross section. The electrical resistance is calculated as follows:

\[ R = R_{SH} + R_{NKT} + R_H = \rho \cdot \frac{L}{S_{SH}} + \rho \cdot \frac{L}{S_{NKT}} + R_H, \]

where \( \rho \) is the resistivity of the conductor substance, 
\( L \) - conductor length, 
\( S_{SH} \) - rods cross section area, 
\( S_{NKT} \) - tubing cross section area,
R_{H} - electrical resistance that occurs in the downhole pump.

Figure 1. SRPU monitoring system with galvanic communication channel and submersible module.

Given that the distance between the plunger and the cylinder is small and the contact area is large, the electrical resistance that occurs in the pump can be taken as zero. For a well with a pump running depth of 1,500 m, specific resistance $\rho = 0.14 \text{ Ohms} \cdot \text{mm}^2/\text{m}$, and rod and tubing cross-sectional areas equal to 380 mm$^2$ and 243 mm$^2$, respectively, the calculated circuit electrical resistance was 1.41 Ohms.

The electric resistance of an open circuit was calculated on the assumption that the tubing is filled with homogeneous medium, and the rod string in the tubing is positioned concentrically. For calculations, the formula for finding the resistance of the cylindrical grounding electrode was used. According to [3], the cylindrical grounding resistance is calculated as:

$$R = 0.367 \cdot \frac{\rho}{L} \log \left( \frac{L}{d_m} \right)$$

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

In experimental tests conducted on a well with medium resistivity of 106 Ohms·m, a pump running depth of 1,770 m, and a rod string diameter of 22 mm, the calculated resistance of the medium between the rods and the tubing was 200 Ohms. The general layout of the submersible module is shown in Figure 2.

Figure 2. Submersible module
The submersible module (SM) consists of an electric splitter with dielectric loading, an electronic module with batteries, sensors for measuring the downhole fluid parameters, an electronic board with units processing and transmitting data to the ground control station via the GC. The electronic module performs parameter measurement sessions, records the results of measurements in the internal memory and transmits them to the earth's surface at a set frequency via the GC.

To enable the data transmission from the pump to the well mouth, the submersible module is equipped with an electric splitter for the upper and lower parts of the strings, and an electrical key transmitting a signal via the GC.

The electric splitter of the submersible module contains:
- housing elements - a nipple and a coupling made in the form of adapter subs with connecting threads that fit the tubing;
- dielectric insulation layer between housing elements;
- electronic module, which measures parameters and transmits the data via a galvanic communication channel.

The ground-based data receiver comprises a power source with one terminal connected to the ground part of the rod string and the other terminal - to the tubing, in which a metal rod string is installed concentrically with dielectric scratchalisers.

![Galvanic isolation unit](image)

**Figure 3.** Galvanic isolation unit: 1 - plug; 2 - insulation bushing; 3 - slip ring; 4 - upper cross-arm; 5 - lower cross-arm; 6 - washer; 7 - connecting wire

To ensure the electrical isolation of the polished rod and the rod string from the rest of the ground equipment of the sucker-rod pumping unit, a galvanic isolation unit with insulation bushings has been developed, its design shown in Figure 4. Bushings 2 made of insulating material are installed in the central holes of the upper and lower cross-arms 4 and 5. The threaded end of the polished rod coupling contains a plug 1 with a slip ring 3 in order to establish an electrical contact of the wire connection line 7 with the polished rod (rod string). The second wire connection line, which provides contact with the tubing string by means of the slip ring 3, is fixed to the well mouth.

Equipped with an electric splitter, which contains a dielectric loading, the tubing string is an electrically open conductor. The submersible module, together with the tubing string, the rod column...
and the galvanic isolation unit, transmits borehole data via the galvanic communication channel with the modulation of the useful signal by switching the electric splitter according to a specified algorithm.

4. Results and Discussion
The submersible module and other elements of the monitoring system were successfully tested in the laboratory and on the test bench.

Pilot tests of the monitoring station with a galvanic communication channel were performed in accordance with the approved SM-SRPU acceptance test program and procedures that involved the system installation activities and the start of software, including SM-SRPU Monitoring.

During the tests, data was transmitted and registered in the client's software with the indication of the e-mail address, the parameter and the type of mailing. The SRPU technical condition data viewing by date and time was tested along with saving incoming reports and viewing the data received.

When testing the submersible module parameters, large interference was detected in the control station's static power supply unit, obscuring the signal from the submersible module in the course of a communication session when measurements data was transmitted via the galvanic communication channel to the monitoring and control unit.

The acceptance tests of the monitoring station with a galvanic communication channel were interrupted and the submersible module was lifted. When analysing the reasons for the lack of a stable signal and the connection between the submersible module and the monitoring and control unit, it was found that the production string contacted the rod and tubing strings.

To prevent contact between the rods and the production string, it was decided to equip the rod strings with centralizers, and the tubing with rubber insulation elements (Figure 4.)

![Figure 4. Flow diagram of the downhole pumping equipment configuration](image)
5. Summary and conclusions
The submersible module and other elements of the monitoring system with a galvanic communication channel were successfully tested in the laboratory and on the test bench. Some changes were made based on the first results of pilot tests. So far, tests have continued on PJSC TATNEFT oil field with high-viscosity oil.

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References
[1] Polygin V V and Lekomtsev A V 2011 The dynamics of wear of sucker rod pumps during well operation *The journal "Oil industry"* 9 27-312
[2] Urazakov K R, Bogomolny E I, Seytpagambetov Zh S and Gazarov A G 2003 *Pump production of highly viscous oil from deviated and flooded wells* (M.: Nedra-Business Center LLC)
[3] Galeev A S, Arslanov R I, Ermilov P P and Kuzmin I A 2012 Monitoring the technical condition of the SHSNU during periodic operation *Electronic scientific journal oil and gas business* 1 24-29
[4] Stepanov V S 2010 A non-generator method for transmitting downhole telemetry data *TUSUR Reports* 2 22