Metrological support of an automated control system for a rocking machine

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Abstract. The article discusses the problem of control automation for wells equipped with sucker rod pumps. The main goals of such automation are presented, the achievement of which allows increasing well productivity, as well as improving working conditions of staff. As a result of the study, the analysis of the features of wells automation equipped with sucker rod pumps was carried out. The principles of automation of such an object were considered and a control system diagram was presented. The presented functional diagram of the SCADA system involves the use of a number of sensors to measure the current parameters of the well. Using the expert assessment method, a reasonable choice of specific measuring devices was made. Reviewed measuring devices are modern equipment of Russian and foreign production, which has a good service life and the necessary measurement accuracy.

1. Introduction

Many factors of the current economic situation, for example, the depletion of oil reservoir resources, the limited amount of funds for repairing wells, the high cost of electricity, as well as the high complexity of the work, necessitate the automation of oil production processes [1, 2]. Automation is one of the factors that can increase productivity and improve working conditions [3 - 5].

The automation of wells equipped with sucker rod pumps (SRP) consists of the control of such technological parameters as a dynamogram, wattmetergram, dynamic fluid level, oscillation frequency, current consumption, pressure at the wellhead [6, 7]. The control functions must provide remote switching on and off of the drive motor, periodic operation, emergency shutdown of the installation, smooth regulation of the motor rotation speed using a frequency converter [8, 9].

Many foreign and Russian enterprises are engaged in the development of SRP automation equipment: Lufkin Automation (USA), NPP Grant (Ufa), NPF Intek (Ufa), LLC Mikon (N. Chelny), TNPVO Siam (Tomsk) and others. Nevertheless, not a single company can boast of absolute success in this direction, and this is due to the rapid development of measuring, converting and microprocessor technologies, which provides developers the ability to solve more and more complex problems.

In this paper, the main task is to analyze the metrological support of an automated control system for a rocking machine (RM).
2. Principles of automation of a well equipped with a rocking machine

Rocking machine refers to the equipment that is involved in the operation of oil wells using sucker rod pumps. Moreover, such equipment is one of the surface drives of sucker rod pumps. Oil specialists give it such a definition as “individual balanced mechanical drives of a sucker rod pump” or simply “rocking chair”. By the principle of action, the rocking machine is often compared with a hand-held bicycle pump, which converts the reciprocating motion into air flow. From a rocking machine, an oil pump converts such movements into a stream of liquid hydrocarbons that enter the surface through tubing.

Let us consider the principle and operation sequence of the rocking machine. The electric motor rotates the mechanisms of the rocking machine, the balancer moves on the principle of a swing as a result of the suspension of the wellhead rod receives reciprocating motion. The received energy is transmitted to steel rods twisted together with the special couplings. Through these steel rods, energy is transferred to the sucker rod pump, which begins to pump oil and feed it up.

Figure 1 shows a diagram of the SCADA-system of the well’s functioning, equipped with SRP (ensuring the well’s work in the regime of periodic supply of products to the surface).

![Figure 1](image_url)

**Figure 1.** Control system of the well operating mode, where: 1 - well; 2 - oil-filled furnace (installed with a high content of paraffin in oil); 3 - coil; 4 - electric heater; 5 - measuring modular converter (MMC); 6 – MMC electronic device; 7 - analyzer of the well products supply nature; 8 - electric starting equipment; 9 - control station; 10, 11 - self-cleaning devices; 12 – telemechanic block (TM).

Functional diagram of the SCADA-system for the SRP-equipped well is shown in Figure 2.

3. Selection of metrological support for the automation system

To ensure measurements in the automated control system of the technological process of the SRP-equipped well’s exploitation, it is necessary to make a reasonable choice of metrological support of the following types: force sensor, strain sensor, position sensor, viscosity sensor, flow meter, pressure sensor, temperature sensor, gas analyzer. The dynamometer sensor is the main element used for SRP automation, because this sensor allows us getting data to analyze the object operation and its condition.
Figure 2. Functional diagram of the well’s SCADA system, where: 1 - force sensor (JISA) is located on the rod above the upper traverse; 2 - balance deformation sensor (NISA); 3 - position sensor (GIR); 4 - viscosity sensor (VIR); 5 - electric motor; 6 – watt-metering sensor (EIRC); 7, 10, 13 - pressure sensor (PIRC); 8, 9, 12 - position sensors of electric valves (GA); 11 - temperature sensor (TIR); 14 - pressure sensor (PIR).

Force sensors on SRP are installed in the following positions: directly on the stock itself (overhead sensors); between traverses; between the upper traverse and the locks; on the SRP balancer.

Sensors that are located above the upper crosshead, perceive the load on the rod directly, and, therefore, provide maximum sensitivity to determine the force. As a result of expert analysis, a Loadtrol sensor from Lufkin (USA) was selected as a force sensor.

The strain gauges that are installed on the balancer are designed to measure the deformation of the balancer. However, the measurement accuracy of such sensors is not enough.

In order to increase the accuracy of strain measurements, it is possible to use the EPSI AX strain gauge (Figure 3), which is designed to measure the longitudinal strain of various structures under static or dynamic load.

Figure 3. Deformation sensor EPSI AX.

As a position sensor mounted on the reducer of the pumping unit, due to the expert analysis, Honeywell sensor 103SR12-A1 (HONEY) was selected (Figure 4).

This sensor operates on the Hall Effect. The position sensor is mounted with a bracket to the reducer of the SRP installation and is triggered when two magnets pass by it. The position sensor is mounted so that the magnets pass the Hall sensor at the moments when the rod of the SRP installation is in the extreme lower and / or upper positions.
Aveni Sense DEVIL sensor (Figure 5) was chosen as a viscosity sensor, which is designed for oils and pure oil and has strength and wide range of viscosity measurements.

Such a sensor was chosen due to the following advantages:

- Built-in performance.
- Possibility of continuous measurement of density, dynamic and kinematic viscosity.
- High performance with small sizes.
- MesoScale and Selfbalancit technologies. The MesoScale design is used to reduce the internal volume of the sensor to less than 1 cc/cm, providing a clear and easy to clean path for fluid flow. “Selfbalancit” technology allows us taking measurements in accordance with ASTM requirements.
- Reliable solution for explosive atmospheres. Robust construction and ease of use are the key elements to ensure stable metrological performance. DEVIL is made from corrosion resistant materials and is certified intrinsically safe.

During the operation of the rocking machine, it is necessary to monitor the flow of pumped oil. To measure the flow rate, a Metran-350 flowmeter based on the Annubar was selected (Figure 6).

This flowmeter was selected due to the following advantages:
- Integral design eliminates the need for impulse lines and additional devices, thereby reducing the number of potential leakage sites.
- Low irretrievable pressure loss in the pipeline reduces energy costs.
- 3051SMV multi-parameter transmitters as part of flowmeters provide the necessary calculation of the instantaneous mass flow rate of steam, liquid, gas or gas volumetric flow rate reduced to standard conditions.
- Installing a flowmeter is economical and less time consuming compared to installing a measuring complex based on a standard diaphragm.

As a result of the expert analysis for measuring pressure, the Elemer AIR-20/M2-N pressure sensor was selected (Figure 7), designed to continuously convert absolute, differential and overpressure, as well as overpressure, hydrostatic pressure, into a unified output current signal 4 ... 20 mA.

![Figure 7](image)

**Figure 7.** Pressure sensor Elemer AIR-20/M2-N.

In order to measure the temperature, a TPK 135 high-temperature thermocouple is used (Figure 8), designed to continuously measure the temperature of liquid, vapor and gaseous media.

![Figure 8](image)

**Figure 8.** Thermocouple TPK 135.

Optimus IR is used as a gas analyzer (Figure 9) - an infrared optical sensor for detecting the presence of explosive gases and is intended for continuous monitoring of explosive concentrations of methane, propane, butane, isobutane, pentane, cyclopentane, hexane, propylene, methanol, ethanol, as well as oil vapor and petroleum products in the area of the working zone in the range from 0 to 100%.

![Figure 9](image)

**Figure 9.** Gas analyzer Optimus IR.

The Optimus IR gas analyzer was selected due to a number of its advantages, such as:
- Ability to work in the temperature range from -60 °C to +75 °C and relative humidity up to 98%.
- Robust design that allows the sensor operating in extreme climatic conditions, in aggressive atmosphere, in explosive areas of rooms and outdoor installations.
- Presence of a standard output current signal 4-20 mA, digital signal HART and RS-485 Modbus RTU, relay “dry contacts”, LED light indication and display.

All sensors selected above have a unified 4-20 mA current signal.

In order to transmit signals from pressure sensors, flow meters, ammeters and a monitoring system to the shield of instrumentation and equipment, three wires must be used, and two wires for signaling devices. To connect the equipment, a control cable was selected with copper conductors with vinyl insulation in a polyethylene sheath, designed for fixed connection to electrical devices and switchgears with a rated alternating voltage of up to 660 V, frequency of up to 100 Hz or constant voltage of up to 1000 V at ambient temperature from -50 °C to +50 °C.

4. Conclusion
As a result of the study, an analysis of the automation features of the wells equipped with sucker rod pumps was carried out. The principles of automation of such an object were considered and a control system diagram was presented.

The presented functional diagram of the SCADA system involves the use of a number of sensors to measure the current parameters of the well. Using the expert assessment method, a reasonable choice was made of specific measuring devices, which are modern equipment of Russian and foreign production. The selected measuring devices have a good service life and the necessary measurement accuracy.

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