Drilling automation based on rigs equipped with the top drive system

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Abstract: The article overviews the issues of increasing labour productivity due to the introduction of drilling automation systems into the technological process.

1. Introduction
At present, billions of dollars are being invested in the oil and gas industry, and the intellectual forces of many countries are working on the improvement of technology [1]. In this connection, the problem arises of increasing the efficiency of capital investments. One of the ways to improve efficiency is automation of technological processes.

The least studied area of the oil and gas industry is drilling automation. Drilling automation helps to increase labour productivity by improving technological processes, optimizing the rate of penetration. In addition, drilling automation should improve the efficiency of environmental protection, labour protection and compliance with safety regulations. Formalization and algorithmization of the drilling process can be considered as a way to consolidate best practices and accumulated knowledge and, subsequently, as a basis for unification and standardization.

When choosing a drilling drive, among other factors, the level of automation of the drilling rig is also considered, which can be the key to the efficient and rapid solution of complex tasks arising during drilling.

2. Research
As is known [2], a path to the creation of automated drilling systems can be represented as the passage of the three stages (levels) of automation:

1. A system offering recommendations:
   - proposes a full range of alternative solutions and actions;
   - proposes a number of alternative solutions (minimizes their number);
   - proposes one action plan.

2. A system that makes a decision but requires approval:
   - selects a recommendation and executes it if approved;
   - provides limited time to disable the action before proceeding to its automatic execution;
   - executes the action upon obtaining approval.

3. An autonomous system:
   - executes the action automatically, provides information only on request;
   - executes the action automatically, informs about the execution of the action;
makes all decisions and acts autonomously. The possibility and efficiency of drilling automation depends on the type of drive used in drilling rigs.

3. Results and discussion

One of the ways to improve the quality and increase profits of oil and gas enterprises in the field of drilling is the use of drilling rigs equipped with a top drive system (TDS), which have proven themselves in operation in difficult climatic conditions. An example of such drives, widely used both in the North of Western Siberia and in other regions of the post-Soviet space (Azerbaijan, Belarus) are TDS by Bentek.

TDS by Bentek can be used on wells with a large vertical bottom-hole deviation, as well as for wells with a deviation in the direction of drilling. They meet the requirements of the existing market (in terms of reliability and power) for a large torque load, allow reducing repair costs, provide a high level of safety. In addition, they are accompanied by an affordable and high-quality service.

Using TDS by Bentek, the following functions can be implemented:

- rotation of the drill string with frequency control while drilling, reaming and expanding the wellbore, while raising/lowering the drill string;
- braking of the drill string and its retention in the set position;
- tripping operations (build-up/dismantling of the drill string with stems and single pipes, screwing/unscrewing of drill pipes, fastening/unfastening of threaded connections of sub-assemblies and ball valves, feeding drill pipes to the wellbore/taking the swivel away from the wellbore);
- carrying out operations to run casing strings into the well.
- flushing the well and simultaneously turning the drill string;
- setting and maintaining torque and speed, their measurement and display of readings on the display of the control cabinet, remote display, control panel and the station of geological and technical studies;
- remote control.
- sealing the inside of the pipe with ball valves.

TDS by Bentek are equipped with variable frequency drive (VFD) modules. Figure 1 shows a diagram illustrating the work of the VFD.

![Diagram of functioning of VFD](image)

**Figure 1.** Diagram of functioning of VFD.

As can be seen from the diagram, regulation is performed using insulated-gate bipolar transistors (IGBT). These modules regulate the rotational speed of the electric motor rotating the drill string.
In the event of an error during the power-up procedure, or if it has already occurred and has not been acknowledged, the automation does not allow the unit to be switched on. In the event of a malfunction during the operation of the drive, the inverter will be disabled by the following algorithm:

- shutdown of the frequency drive by locking the power field IGBT and shutdown of the power circuit-breaker; if the failure conditions allow, then before the shutdown, the drive is controllably stopped;
- alarm signalling by means of a contact relay;
- displaying and saving the cause of the controller’s memory fault.

In addition to local optional indicators (displays, LEDs), fault signals are also displayed on the front panel of the converter control unit and can be interrogated in the ecoWin parameterization program.

TDS by Bentek are equipped with the InfoDrill drilling control system. Let us consider in more detail the features of this system.

Pages of the InfoDrill system screen are always divided into the following sections: a section for failure messages at the top of the screen, a section for displaying parameters in the centre and a navigation section at the bottom of the screen (Figure 2).

In the section for failure messages, a table displays the actual faults (latest from the top). There you can find information about the failure number, the date/time of occurrence and a text message for easy troubleshooting.

Failure messages are coloured in the appropriate colours depending on the status which are as follows:

- incoming failure;
- confirmed failure;
- current failure.

Selecting the appropriate symbol (mouse click) initiates the following actions:

- confirmation;
- turning off the alarm signal;
- displaying the failure overview page.

The navigation section allows you to select the desired page with drilling parameters.

Two monitoring pages serve to indicate the parameters during drilling and during tripping operations (Figure 3). The management and layout of both pages are almost identical. The corresponding page is called up in the navigation section.
All the necessary drilling process data (drilling/tripping operations) are displayed on these respective screen pages. In the middle of the screen there are circular indicators of load on the hook and on the bit, which also have digital displays in the centre showing numerical values of these parameters. An indicator in this area also shows the status of the path of the hook block movement - free/busy.

There are also additional functions for managing and tuning the above-named instruments.

To display and analyse time trends, there are three pages of InfoDrill system screens, such as time trends for drilling, tripping and user-defined ones (Figure 4). The management of all these pages is similar, except for the user-defined time trends which they can customize at their own discretion. After activating the screen, time trends in the navigation section must be selected from the drop-down menu of the trend page of interest.

Figure 3. Drilling parameters.

Figure 4. Time trends for drilling
If the time trends screen in the navigation section is activated, then you need to select the trend page of interest in the drop-down menu. The indicator shows the status of data transfer for time trends.

The time trends screens contain 5 columns of 2 recorders each, which display the actual data of the current drilling and tripping parameters.

To view the status of the tank system, two screens are available. The management and layout of both pages is almost identical.

The corresponding page is called up in the navigation section.

This monitoring page (Figure 5) displays active drilling mud tanks, as well as the time trend for changing its active volume.

![Figure 5. Active tanks.](image)

In addition to displaying the drilling fluid level for each tank, it is also possible to set the upper and lower alarm limits. To set the level of the alarm signal, as well as the resolution of the scale using the pop-up window, you must click on the symbol of the tank of interest. The output of the drilling fluid level in the tanks beyond the limits of the set values causes an alarm. Using the buttons, this alarm can be activated or deactivated for each tank separately.

Tanks that are part of the active volume of the drilling fluid can be activated separately.

The first linear indicator on the left shows the total active volume of the tanks. The next two linear indicators show the input/output of the total flow volume and specific tanks. Just like in tanks, here you can set the upper and lower alarm limits for each line indicator.

The InfoDrill system provides a page for displaying the status of the operation of mud pumps. The corresponding page is called up in the navigation section (Figure 6).
This page displays the status of mud pumps and their auxiliary equipment in a separate window for each pump. The following information is displayed for each pump separately:

- status of auxiliary drives, depending on the colour of the symbol (OFF (grey), ON (green), FAULT (red));
- status of mud pumps.

Under the graphic symbol of the mud pump is an indicator showing the mode of operation as a plain text on a coloured background. In addition, the background colour changes depending on the mode of operation:

- OFF (grey);
- ON (green);
- FAULT (red);
- Warning (yellow).

In the InfoDrill system, it is possible to set up and control the anti-collision system (ACS). The start screen is called up in the navigation section. There are two modes of operation: hand and automatic.

When working in hand mode, it is necessary to pay attention to the fact that the restriction and tracking of movements of the hook block are not activated. Calling up the automatic mode of ACS immediately initiates the system setup procedure.

When you click on the corresponding symbol, the following ACS functions are available on the screen:

- setting upper/lower work points;
- ENTER and ESCAPE to confirm or reset the entered value;
- calling up the procedure for determining the length of the brake distance;
- confirming the procedure for determining the length of the brake distance;
- cancelling the procedure for determining the length of the brake distance;
- setting tool compensation;
- crown block in emergency mode.

In the automatic mode (Figure 7), the current position of the hook block, as well as the upper and lower work points, are displayed on the linear indicator. In addition, there is a numeric display which shows all values in percent.
Switching on the soft torque rotary system (STRS) is carried out by a switch on the driller's console, and its adjustment is made on the page of the InfoDrill system screen. The start screen is called up in the navigation section (Figure 8).

The screen is divided into sections as follows:

1. **Status Information:**
   - actual Kf / Cf parameters of STRS (set or calculated);
   - STRS response s (OFF/READY/ON).

2. **Time trend (parameters):**
   - TDS speed and torque time trend;
   - enable/disable the additional display, time trend parameters;
   - 1/5/15/30/60min time scale.

**Figure 7.** ACS Automatic mode.

**Figure 8.** The STRS system with parameter calculations based on the drillstring data.
3. Printing out the screen by an external printer.
4. Entering drillstring data and Cf, Kf for calculating.

If the parameter input section for calculation is on, the values of the parameters Cf and Kf are calculated based on the length of the drill pipe, its outer and inner diameters, and the same parameters for the bottom-hole assembly (BHA). The input of the BHA parameters should be performed sequentially, beginning with the bit and up, i.e. first - BHA 1, then - BHA 2, and so on. If there are several components, the length of which is very small, then they can be neglected or if the components are the same, then they can be combined into one. When entering the parameters of the drill pipe (DP), there are three sections for entering different lengths, outer and inner diameters. When entering parameters, pay attention to the correct sequence, DP1 is first drill pipe from the bit. Once you specify the outer and inner diameters, you only need to adjust the length based on the number of stands added during the drilling process.

In the InfoDrill system, it is possible to display the status of the gas warning system. The corresponding page is called up in the navigation section (Figure 9).

![Figure 9. Gas warning system.](image)

The status of the gas level is displayed on this page. Gas levels measured by sensors are displayed as a percentage on linear indicators, as well as a function of time on the time trend. Exceeding the limit values immediately causes an emergency message.

When switching to the third panel in the navigation section, additional Data Export (Figure 10) and Equipment Diagnostics (Figure 11) buttons appear. While on the data export page it is possible to export user-defined measurement parameters, the Equipment Diagnostics page displays the status of the components of the InfoDrill system.
4. Conclusion
The mechanized equipment of the drilling rig, proposed to date, allows replacing the same type of operations previously performed manually with the operation of technical means, minimizing the number of personnel present in the potentially hazardous area of the drilling site. However, this can hardly be called "drilling automation". Direct automation of drilling should allow the driller to penetrate productive layers more efficiently in comparison with the results of manual control, with less effort and resources, and strict observance of safety rules.

Drilling automation has to deal with a problem similar to the one that had to be overcome in the automation of other industries: many drilling specialists treat it with suspicion and see it as a threat to their professional experience.

Some side-effects of drilling automation are the reduction in the number of personnel and the ability to perform tasks with remote control.

To automate the drilling process, a system is needed that can function effectively under conditions of variability and uncertainty. Downhole and surface data introduced directly into such systems make
them respond to changes, for example, of lithological characteristics, in order to maximize the efficiency of the well, increasing its production time and production performance.

References
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