Romanian Journal of Petroleum & Gas Technology
VOL. IV (LXXV) • No. 2/2023

AUTOMATIC SYSTEM FOR ADVANCED SPEED CONTROL OF THE DRILLING HOE

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DOI: 10.51865/JPGT.2023.02.15

ABSTRACT

Drilling consists of the operation of creating a well, which involves a complex set of activities. In a narrower sense, it includes the dislocation of rocks and the extraction of rock fragments to the surface. A drilling tool called a bit is used to dislodge rocks, being connected to the surface drilling rig via a drill string. Automating the processes associated to drilling is extremely important to ensure its development in optimal conditions. This work is focused on the control of the drilling hoe rotation speed, in order to damage it as little as possible.

Keywords: drilling, automation, control system, drilling hoe, PLC controller

INTRODUCTION

A drilling rig is composed of several specialized components and equipment that work together to perform drilling operations, including the following main elements: *drilling rig* - a set of interconnected metal tubes that are successively inserted into the borehole to reach the desired depth; *drill motor* - a specialized motor that provides the energy needed to drive the drill bit and other auxiliary equipment such as the drilling fluid circulation pump; *drilling fluid supply system* – a complex system of pumps, pipes and reservoirs that supplies and circulates the drilling fluid within the drill string; *control and monitoring equipment* - sensors and measuring instruments, which monitor drilling parameters such as drilling fluid pressure, temperature and bit rotation speed; *auxiliary equipment* - drill pipe handling equipment, drilling inclination and direction measuring devices, material loading and unloading equipment, and safety and protection equipment.

ROTARY DRILLING

In this paper, rotary drilling will be used for the simulation of the automatic system for controling the advance speed of the drilling hoe.

In the rotary drilling method, the rotary motion of the hoe is transmitted from the surface through the drill rod assembly. The drive machine is the rotary table. This method of drilling is based on the continuous rotation of the hoe, which consists of a cylindrical trunk equipped with cutting teeth. The force required to dislodge rocks in the drilling process is generated by unloading the weight of a portion of the drill rods at the bottom of the drill string onto the drill bit. The drill hook takes up the weight difference, holding the entire drill string in place. In order to clear the bottom of the well of detritus, drilling pumps (or mud pumps) are used to introduce a flow of drilling fluid Q through the hydraulic head inside the rods. This fluid is then directed at high speed through the nozzles of the hoe to aid in the process of dislodging the rocks. During its upward movement through the annular space between the rods and the borehole wall, this fluid entrains the detritus particles, carrying them to the surface where they are then cleaned. Over time, the hoe wears out and must be replaced. Removing the hoe from the well is done by extracting step by step the entire set of rods.

Rotary drilling is a common drilling method, which involves extracting a step composed of three rods with the help of a maneuvering system from the drilling rig. After extracting the step, fitting back into the well is done in reverse order, while a complete cycle of extracting and inserting the drill string is called a march. The rotary drilling rig includes three main working systems: the maneuvering system, the rotating system and the circulation system. These are the three main systems that are responsible for different aspects of the drilling process: downforce on the bit, angular velocity of the rotating mass, and drilling fluid flow rate. In addition to these systems, there are other auxiliary systems that are part of the drilling rig, such as the drive system, the automatic hoe advance system, the reversing system, the winch system, the control system, the mechanization and automation devices, the system for drilling mud preparation and cleaning, the blowout prevention system, and the lighting system [4][5].

THE AUTOMATIC CONTROL SYSTEM OF THE HOE ROTATION SPEED

The automatic control system of the rotational speed of the bit is used in hydraulic turbine drilling, for which the rotational speed decreases approximately in proportion to the increase of the resisting torque moment of the bit in rotary table drilling. Automation of the advance process can be achieved by means of the hoe rotation speed control procedure or by means of the hoe rotation power control. In the case of turbine drilling, where the influence of the bit resisting moment on the bit rotation speed is significant, the bit rotation speed control can be used. In the case of submersible motor drilling, where the value of the power absorbed by the motor and measured at the surface is a measure of rotation of the hoe, the control of the rotation power of the hoe can be used.

In the case of drilling with a rotating casing, the rotational speed of the bit is practically constant, because the bit-rock subsystem has only one input quantity, namely the load on the bit, and only one output quantity, namely the advance speed of the hoe.

In this paper, mud will be used as a drilling fluid to simulate the effect of flow on the rotation speed of the hoe. A good mud contains clayey material made up of minerals belonging to the smectite group, especially montmorillonite. Ordinary mud is stable, has a pH between 8 and 10 and a specific gravity of 1.12 -1.30 daN/dm3. The viscosity measured with the Marsh funnel is 36 - 45 seconds. The amount of sand should not exceed 3% in normal drilling. An essential characteristic of the drilling mud is that it forms, on the wall of the borehole, the clogging cake, of a maximum thickness of 2 mm [3].

This work want to implement a monitoring and control system, which helps to maintain some parameters within normal limits, with the aim of preventing dangers and damaging the drill bit as slowly as possible. The project intend to build an assembly that controls and monitors the following systems: the monitoring and control system for the rotation speed of the hoe and the monitoring and control system for the fluid flow.

The systemic approach allows an unitary treatment, regardless of which segment of reality the characterized phenomenon or phenomena belong to. The systemic approach represents the most important basis, from which the design, control and monitoring of any automation system must be started.

The block diagram of the automatic system for the control of the forward speed of the drilling hoe is presented in Fig 1.

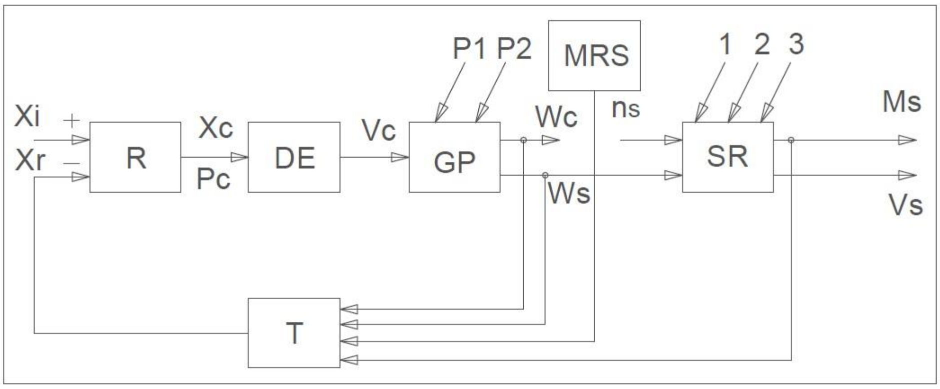

Figure 1. *Functional diagram of the control system [6]: R - controller, DE - execution device, GP - rod set, SR - hoe - rock subsystem, MRS - rotation motor of the drilling hoe, T - transducer.*

Drilling fluid plays an important role in the drilling process, helping to clean the bottom of the well, to dislodge the rock, sending the detritus to the surface, at the same time having a role in stabilizing the wall of the well. The most important aspect for the simulation application in this paper is the fact that it helps us calculate the velocity of the fluid jet, which may have a role in increasing the rotational speed of the hoe.

The calculation formula for determining the flow rate is:

$$Q = Qsp\ At, \tag{1}$$

where Q is the flow rate, Qsp is the specific flow rate (0.045...0.060 dm^3/s) and At is the sole area.

It will be take fictitious values for the specific flow rate Qsp = 0.050 dm^3/s and for the sole area At = 0,2.

$$Q = 0.05 \times 200 \Rightarrow Q = 10\ dm^3/s$$

Drilling fluid velocity: if the jet velocity exceeds 70 m/s (typically between 80 and 100 m/s), then a significant increase in the advance speed of the hoe will occur. The diameter of the nozzles can be calculated, after choosing the flow rate and speed [7].

The engine, which has a role in the actuation of the rotary table, transmits the movement to the rotary table and, further, to the drilling rig. It represents the drive part and must be adjusted by means of a frequency converter, so that the forward rotation of the hoe is optimal. This adjustment was made by calculating the engine power, which is variable. When the frequency converter senses an increase in the intensity of the motor, which leads to the forcing of the motor, (caused by the encounter of a material, an obstacle, a harder layer through which the spade passes), it respectively senses the increase in amperage, a quantity that can be adjusted so that the trench is not damaged and the process is as optimal as possible.

Also, for the simulation, the case of a 55.36 kW three-phase asynchronous motor with a maximum rotation of 1511 RPM was considered, and a gear ratio for the rotating mass reducer of 16:1 was also considered. Interlocks were created in the application so that the motor does not exceed certain threshold values, such as for example, not to increase above the value of 100A (in case of overload). Automatic adjustment is done when a value of motor intensity increase is simulated, it is detected in the program and the speed is adjusted until the 50A threshold is reached, so as not to damage the hoe. Stopping the process is done by the stop button, respectively the start button for starting.

The active power of a three-phase motor is given by the formula

$$P = \sqrt{3} U_l I_l \cos\varphi \qquad (2)$$

where *P* is the power, *U* is the voltage in a three-phase system (400V), *I* is the intensity that varies with the load, and $cos\ \varphi$ is the power factor (in our case it will be 0.8)

*55360 w/h = 1.73 * 400 V * I * 0.8 => I = 100 A*

To display these values, a display called motor trend was created, in which one can graphically see the variation of the motor parameters values, on an axis-type system.

Processing and control unit represents the most important component on the PLC chassis - at its level the arithmetic-logical operations are carried out, with the role of controlling the process in a fast and concise way [1, 2, 3]. The 1756-L61 ControlLogix 5561 processing module (Fig.2) from Rockwell is a controller capable of handling a large number of inputs and outputs (I/O). It can be mounted in any slot of the chassis and it is allowed to mount several processing modules/controllers on the same chassis. Rockwell's 1756-L61 ControlLogix 5561 controller can monitor and control chassis-mounted I/O as well as network-connected I/O.

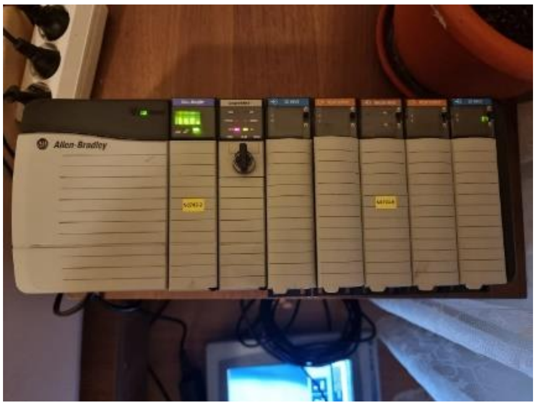

Figure 2. *Allen Bradley 1756 PLC with L61 processor*

This type of controller uses the RSLogix5000 software application from Rockwell as a programming environment, through which the programmer can implement the logic of the desired process, through the three programming languages available in the application. The display used is the Allen Bradley 1500 Plus; it is a 15-inch display and can also fulfill the function of a controller, having a built-in processor and memory. The HMI can be controlled through the touch screen, but in this work it only calls certain tags from the PLC so that the user can use a much more accessible graphic interface. It is programmable via Rockwell's Factory TalkView app.

The application made for the logic programming of the PLC, RSLogix 5000, is illustrated in Fig.3.

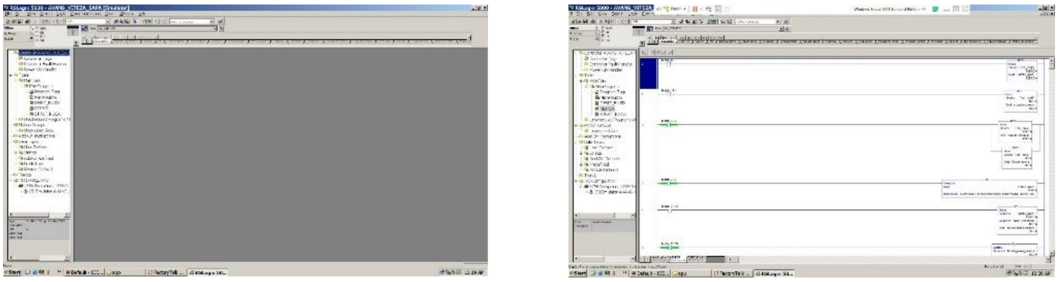

Figure 3. *PLC logic programming*

The images associated with the application developed for Panel View in Factory Talk View are presented in Fig. 4.

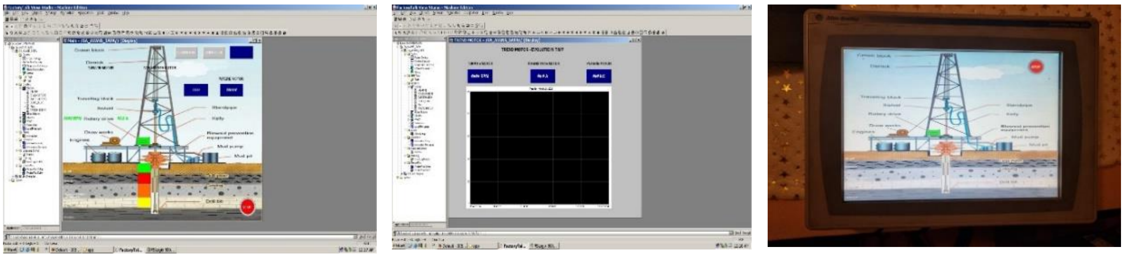

Figure 4*. Creating the TREND MOTOR display in the Factory Talk View application.*

Communication between devices is created through the RSLinx application (Fig. 5).

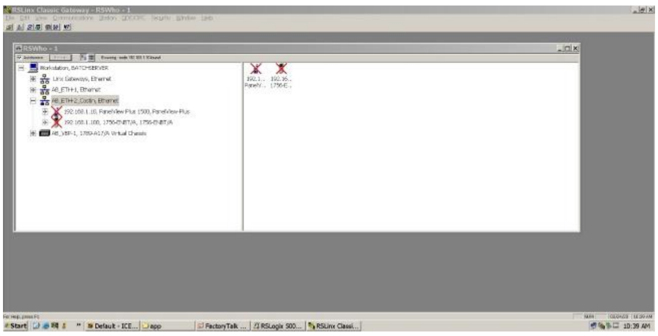

Figure 5*. Creating the connection between the devices.*

CONCLUSIONS

Following the research carried out and the tests carried out, we can draw the following conclusions: a system with automatic control of the advance speed of the drill bit can significantly improve the efficiency and performance of drilling, reducing the time and costs required to complete the work. Automatic control systems can be built using advanced technologies, such as artificial intelligence, machine learning or adaptive control, which makes it possible to adapt the system to specific drilling conditions. Implementing such a system requires a significant initial investment but can bring significant long-term savings due to increased efficiency and reduced operating costs. Another benefit of an automatic speed control system is increased safety and comfort for the operator, who may be tired or have difficulty maintaining a certain constant speed.

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Received: November 2023; Accepted: November 2023; Published: November 2023