

## MPD and Process Automation Optimizes Drilling Performance

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### Abstract

This paper presents technology advances within both drilling and managed pressure drilling (MPD) control systems, by combining a drilling automation operating system for holistic optimization of drilling performance with a fit-for-purpose MPD system. The combined system includes precise automatic, coordinated control of the main drilling machines, including the rig's mud pumps, drawworks, top drive, and MPD equipment. The MPD system includes electric chokes combined with an MPD control system integrated with the main drilling control system on the rig.

High-resolution performance data obtained from wired drill pipe shows the drilling performance and unparalleled control of wellbore pressures that can be achieved through holistic optimization.

The results demonstrate the value of integrating a fit-for-purpose MPD control system with an automation operating System. The integrated system ensures consistent high performance, and eliminates dedicated MPD operator stations and HMIs, redundant instrumentation, temporary cabling, and sub-optimal communication interfaces through direct use of high-speed data from all drilling machines on the network.

### Introduction

Managed pressure drilling is a proven tool for dealing with narrow downhole pressure limits in challenging wells. Moreover, MPD has been demonstrated to increase rate of penetration (ROP), since it allows drilling with reduced mud weights, and reacting to changes in formation pressure by intelligently applying surface pressure. Other commonly mentioned advantages of using MPD include less nonproductive time due to pressure related incidents, such as stuck pipe, lost circulation, and gas in the wellbore.

A common concern with MPD, however, is that it can introduce invisible nonproductive time into drilling operations due to the array of complicated systems needing to effectively interact with one another. For example, a typical MPD operation involves distributed control systems, additional human-machine interfaces, and standalone components that have limited integration with the rig. Consequently, most MPD systems will only be *reactive* to what the driller is doing with other drilling machines.

To combat these challenges a drilling system that combined holistic optimization of drilling performance with

an MPD system needed to be created for both onshore and offshore drilling rigs.

The architecture enables automation of key drilling activities, benefiting drilling contractors by allowing drillers to focus on consistent process execution and safety, and benefiting operators by optimizing drilling programs. Critical sub-activities such as connections can be customized to consistently perform at the highest level. Connection times can be minimized while maximizing accuracy of the MPD system, based on best practices for a given field or operation.

### MPD System

The MPD system consists of a single electric choke, a PLC-based control system, and integration and operation from the driller's chair.

The choke is the third generation of a field proven design, with a long track record in pressure control operations. An external nut and gantry device allow quick and easy service to the choke such as inspections or trim changes, as illustrated in Figure 1.

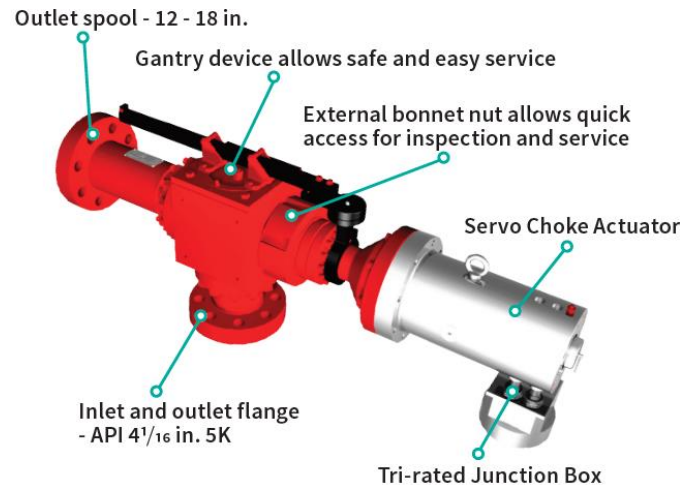


Figure 1: MPD choke with electric actuator and gantry device.

The choke features an outlet spool with unique “wear-sub” design, which provides 18 in. of downstream wear protection with a standard of 12 in. The reversible gate and seat are designed to direct high-velocity wear away from the positive

sealing surface. The external bonnet nut threads allow for bonnet removal without disconnecting servo motor.

The servo motor is a maintenance free design with roller screw technology which provides predictable and reliable service life without the need for mechanical adjustments or periodical lubrication. The maximum choke velocity is 9.8 mm/sec, which will fully seat the choke in as little as 5.7 seconds. The mechanical components can handle 100% duty cycle without diminishing the expected service life. The motor is globally certified for ATEX/IECEX Zone 1 and Class I Div. 1 Groups C&D, with tri-rated Junction box with terminal blocks and 3/4-in. NPT gland ports for flexible wiring and termination, and temperature rating for -40 to +60°C. Industrial automation grade components enable a very compact and rugged design, which enables continuous duty rating and capable of millions of maintenance free pressure adjustments.

The self-locking fail in place design with rugged NACE MR0175 compliant steel exterior is fully sealed to IP67 specifications. The motor comes with a simple 5/8" Hex key design which does not require special tooling and allows manual override for power loss operation.

The MPD Control System<sup>1</sup> handles all the control and inputs needed to manage a single electric choke and an optional Coriolis flow meter. It accepts inputs from the rig sensor network and adjusts the choke as needed to control the wellbore pressure to achieve a target pressure. The control system is built for performance and reliability using electric actuated choke and triple redundant wellbore pressure sensors.

The control system features three main modes of operation for controlling the surface back pressure:

- **Manual Position mode:** In this operating mode, the operator can remotely set the choke position from 0 – 100%.
- **Choke Pressure Control mode:** The Choke Pressure Control mode enables automatic control of the choke pressure. The control system will automatically adjust the position of the choke to maintain the choke pressure set point.
- **Choke Pressure Table mode:** The Pressure Table consisting of choke pressure set-point vs. different flow rates. When activated, the choke pressure setpoint will automatically be adjusted according to the current flow rate from the rig pumps.

## Drilling Automation Operating System

The Automation Operating System (AOS) is a process-control-software layer installed on an alternating-current electrical drilling rig<sup>3,4</sup>. With requisite hardware and baseline drilling control system in place, it enables automated drilling process automation. The intent of this software is to automatically deliver routine processes consistently, such as ramping up pumps, tagging bottom, and optimizing parameters while drilling. This will enable the driller to focus on safety and monitoring of operationally critical processes, including crew-resource management. These tasks require an in-depth knowledge of the operational context, informed

largely by data that are not captured digitally, which an experienced and informed driller is more adept at managing than a computerized system.

The AOS consists of several single-board computers installed in the rig's controller cabinet, an additional or supplemented screen, and an interface switch, with the latter two installed in the driller's cabin. The system has an initial installed configuration that defines how the AOS will perform certain tasks such as pump ramp speeds and block acceleration while transiting back to bottom.

Configuration options are extensive and allow for high levels of customization. Configuration, however, is not isolated to installation, and the AOS interface allows for on-the-fly changes to the system setup, allowing for active optimization management as conditions change. This allows the users to configure the system to perform the automatic tasks optimally and in compliance with company best practices or field- and or well specific considerations.

Integral to the AOS system is the well program. This allows the drilling engineers to provide the AOS with sets of operating-parameter envelopes [e.g., weight on bit (WOB), rotational speed, torque, flow, pressure, rate of penetration (ROP)] that define how the well should be delivered by the system. These can be specified for a desired interval and are digitally uploaded into the system. Crucially, the driller does not have access to edit these parameters while operating within the AOS, so any change required must go through a defined escalation and review protocol.

One of the key features of the AOS, is that it allows for the installation of "Apps". Apps are built using a Software Development Kit (SDK), that guides software developers through the process of creating an application that lives on the AOS platform and includes visualization tools and widgets for design of a human machine interface. These value-adding apps can be hosted on the AOS, and thereby gain access to sensor values and information in the AOS system. The Apps are operated by the driller from the AOS screen in the driller's cabin.

## MPD Integration

A new MPD "App" was developed to achieve integration with the AOS. The MPD App interface is illustrated in Figure 2.



Figure 2: Main screen of the MPD App in the AOS.

With the new system placing MPD operations on the driller's control screen, it enables him/her to focus on more consistent process execution and safety while the integrated, highly automated control system controls the electric MPD chokes.

The system also allows for critical sub-activities such as connections to be customized and automated to consistently perform at the highest level, minimizing connection times while maximizing the accuracy of the MPD system. When every pump ramp is performed automatically with consistent pump ramp speeds, it becomes an easy task to configure an MPD control system to optimize pressure control accuracy for every connection.

The driller-operated MPD control system, when used in the field, improves performance and consistency while significantly reducing cost by decreasing minimum personnel requirements. Rather than having dedicated MPD field personnel on location, the MPD service is provided by the drilling contractor, while the OEM provides maintenance and remote support, leveraging equipment expertise with existing technology infrastructure.

### Testing and Field Implementation

As with any system with the complexity being proposed in this system, R&D testing was done to validate the concepts and usability of the system in the use cases it was expected to be deployed. Only after these use cases were evaluated and performance data reviewed from similar systems was the system moved to the next steps.

#### Testing

The MPD control system was subject to extensive testing in a hardware-in-the-loop simulator, that included a virtual wellbore that gives realistic feedback in a simulated environment. This enables testing of functionality and robustness of the system throughout the development process.

All new applications that are to be installed on the AOS go through extensive testing in a Quality Assurance lab. This lab is set up to detect instabilities in the application, and importantly ensure that the application does not introduce instabilities into the AOS. Once an App has passed the Quality Assurance test, it is ready to be deployed on a live system.

The complete system framework was tested on an advanced R&D Technology Center<sup>2</sup>, designed for testing and validation of new technology. The test facility comprises a full-scale land rig with state-of-the-art drilling equipment and "wired drill pipe" for real-time interpretation of downhole pressure, as illustrated in Figure 3.



Figure 3: R&D Technology Center.

During the testing, the AOS was configured to perform a number of automatic sequences, while the MPD control system automatically maintained a constant bottom hole pressure. In Figure 4, the automatic operating system is running a sequence of drilling connections, while the MPD system is controlling pressure. One key aspect of the AOS is the consistency and repeatability in the operation of the drilling machines, which leads to more stable and accurate pressure control, which is evident in the figure below.

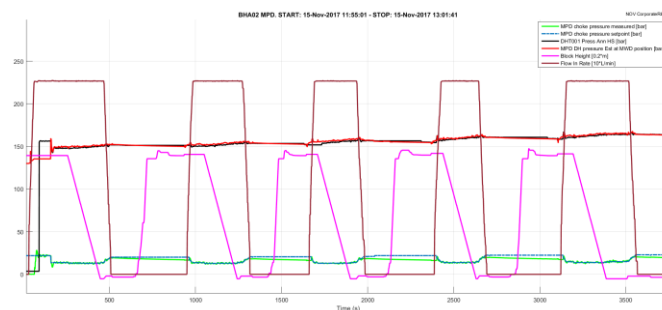


Figure 4: Results from R&D Technology Center. Maroon: Flow rate, Cyan: Block position, Green/Blue: MPD choke pressure, Black/Red: Downhole pressure from "wired pipe".

#### Field Trial

The combined system was installed on an advanced land drilling rig. The MPD choke was mounted to facilitate easy rig moves, by not requiring any significant rigging between wells and pads. Trained Field Service Technicians were available on site to assist with the installation, and to train the drillers on how to operate the system, as illustrated in Figure 5.

Part of the install included installing the MPD app on the AOS environment which allowed it to share the high-performance data network used by all apps on the AOS network. Simple tasks such as adjusting the pump efficiency, monitoring the bit depth, and adjusting the mud density was shared equally between apps on the AOS. During the field trials, the driller was able to set the target pressures based on

flow, monitor the chokes performance for faults, and make adjustments on the system using the same familiarity and training they had on other apps on the AOS.



Figure 5: Demonstration of MPD App on AOS screen.

## Conclusions

It is important that the industry continues to push for integration of MPD systems with existing drilling control networks. Achieving this goal will provide essential MPD data on the primary driller's screen, allowing him/her to monitor and control MPD parameters as part of standard operating procedures versus trying to control the disparate pieces of a complicated system.

True integration of MPD control systems will provide better overall performance, and relevant data for post-run optimization, at a more sustainable price, driving greater adoption and increased acceptance of this performance-enhancing drilling tool.

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