Design of an Automated Drilling-Prediction System

Data-mining processes are fundamental in obtaining the predictive benefits of real-time systems and have been progressing from descriptive to predictive optimization methods. These methods are enhanced by real-time and historic data. Advanced sensor technologies, improved data-quality control, wellsite information-transfer standard-markup-language (WITSML) data advantages, and virtual real-time drilling-optimization concepts have been assimilated into the design and implementation of prediction systems.

Introduction

As technologies evolve and the WITSML standard allows data exploitation by many specialized applications, more-accurate and reliable drilling data are available at real-time operation centers (RTOCs) to analyze and mitigate drilling issues. This enhances and speeds up the drilling-optimization process, and allows a small group of highly skilled drilling engineers to support several wellbore constructions simultaneously.

However, the traditional tasks of monitoring drilling parameters are still constrained by the constant need for human intervention. First, the particular field-operations knowledge gained by RTOC monitoring engineers is very valuable but fragile, because it requires the continued participation of team members. To ensure that nothing is overlooked, that knowledge should be gathered and used by an intelligent system. Second, the status of a particular event or well is constantly changing as key drilling factors change, and monitoring engineers must review all data in detail before manually defining the new status of a system. Third, a complete update of a general well-operations status report is time consuming. The operations status for a set of wells being drilled and monitored can change dramatically from one minute to the next and therefore requires the constant participation of an engineer. Such a report should be automated to derive maximum benefit from the best real-time and historic data.

Drilling-Data Mining

The drilling industry is aware of the importance of pattern analysis and past performance of correlation wells. It has looked to similar drilling-well experiences to predict the probability of a particular event or drilling outcome. This has been achieved effectively with human intervention, despite the fact that multiple data families that needed to be taken into account were difficult to access for different reasons.

As well complexity has increased, computer data-processing technologies, telemetry instrumentation, and real-time data-acquisition systems have advanced, providing the ability to use computer power to choose and examine an increasing volume of more-complex data. This has enabled discovery of previously undetected drilling patterns from correlation wells and known potential events from ongoing drilling programs, making real-time data exponentially more meaningful and more efficient for monitoring purposes. Because real-time data are properly related to drilling-program and well-correlation data, it is possible to develop models for predicting future outcomes through new software systems that automatically relate, set apart, and announce a potential drilling challenge.

Application of the Traffic-Light Methodology

To reduce the time engineers invest deciding where to focus their attention on conventional real-time consoles, the event or well status is defined by intuitive colors used on the system interface. They are predefined as green for stable, or on the program; yellow for alert, or near the limits of the program; and red for critical, or outside of the program. This applies to a particular drilling aspect and to a general drilling-operations dashboard able to reflect the status of several wells being drilled concurrently.

The criterion and color definition are automatically applied by the system as new real-time values, and trends are constantly renewed and compared with relevant historic information. The status can be modified manually by the monitoring engineers if necessary.

More-Accurate Alerts

Traditionally, alerts have been prepared by monitoring engineers at RTOCs. However, most of them were triggered by engineers' data visualization or alarms displayed by the real-time systems. This is inefficient, because it demands significant time from monitoring engineers to validate the accuracy of the alarm before an alert is posted.

Therefore, alarms in the computer-driven system were automated under the premise that all should be as accurate and important as the data make possible. Hence, algorithms were developed

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specifically to assess a limited set of the most recent data points for temporal trends, and to compare them with those expected on the basis of the drilling program and correlation wells from the WITSML database. This reduces the number of false alarm emissions coming from data-point outliers that sometimes are part of a log curve or from a data-transmission failure (such as noise). Algorithms have been intentionally designed to avoid system alarms being triggered if the transmission system is missing family data at a certain time or depth interval, if one value is outside of the program range, or if a block of received data is outside of the range at a depth or time where it is expected to be that way.

Alarms are triggered taking into account two data sources (real-time stream and historic database). Thus, alerts represent warnings derived not only from surface potential issues or imminent downhole threats being identified in real time, but also from potential wellbore issues identified through correlation wells or as predefined in the drilling program.

Because this process requires data to be compared by a unique computer application, the drilling-data standard WITSML was put in place, as well as a system of measurements for downhole and surface parameters—the set of units that operators use. Similarly, new features related to the fluids data displayed were developed for the pre-existing application. All drilling-program data must be available in a standardized format to be uploaded to the system.

More-accurate automated alarms maximize the decision value of the alerts that are finally prepared by the monitoring engineers.

Anticipating Events and Trouble Zones

The design of an automated drilling-prediction system was started by covering drill-bit performance, fluid changes, and varying rock formations. These three points have data in the form of a program as well as in real time.

Drilling performance has a direct relation to drill-bit efficiency. Therefore, drill-bit information is used to monitor the well, taking into account start/end depth; casing-stage diameter; initial/final weight on bit; minimum/maximum revolutions per minute; minimum/maximum rate of penetration (ROP); and minimum/maximum pump pressure, flow rate, torque, type, diameter, and total flow area. These parameters are filtered, related into a database, and displayed on a console. If a real-time value is outside of the range defined by the program, the system will send audible and visible alarms. This is complemented and supported by a depth-based plot on which real-time data of ROP, resistivity, and gamma ray are visibly compared.

This information is complemented with downhole-drilling-equipment features if available, either from a conventional-motor or a rotary-steerable system. The data taken into account are maximum tool temperature, hours of motor life, and motor brand and model. An indicator of formation temperature vs. motor temperature completes the information immediately available to the monitoring engineer before an alert is posted.

Drilling-fluids aspects taken into account include program values for density, plastic viscosity, yield point, salinity, water/oil fraction, filtration, emulsion stability, equivalent circulating density, loss, and gasification. All program values are uploaded to the system, where specific algorithms are applied to compare them with real-time and near-real-time fluid data. This results in a display that quickly shows which parameter requires attention; each has a traffic-light indication.

Rock-formation and lithology-column information can be compared using the real-time data stream and static data stored in the system. Data available from correlation wells and from the drilling program are matched with logging-while-drilling data and near-real-time lithology data, if available. The era, formation, and lithology description are related to measured depth below the rotary table, to true vertical depth below mean sea level, and to measured depth and measured bed thicknesses. Once these static data are related with the real-time data, a traffic light is displayed on the console, indicating at least whether, for a specific measured depth, the rock era, formation, and lithology match those in the program.

This console is complemented with a depth-based well-correlation panel that provides gamma-ray, resistivity, and lithology-column information that enhances the decision-making process to trigger an alert.

Adding a degree of importance to each one of the described-in-detail information tracks, it is possible to define a general-parameter status by use of complex algorithms, resulting in a traffic-light expression. Each data family is used as a macro or rule that specifies how a certain input sequence should be mapped to a replacement input sequence, and how much impact it should have on the general well status. It is important to mention that other family data such as trajectory or cementing data can be taken into account for the anticipation of drilling issues and fast, accurate alert generation.

Thereafter, two other well-status screens enter the process: one that takes into account the set of events such as kicks, total loss, and friction and torque issues that occurred on the correlation wells; and one that takes into account the current well-operation status. These provide easy-to-read key information to the monitoring engineer, who is now able to focus more on data-trend analysis than on data validation and data-trend identification. It is important to mention that the automated status can be edited manually by the monitoring engineers if the status shown is not what the operator or the rigsite staff confirms.

General RTOC Dashboard

Ironically, RTOC status reports are not commonly available in real time. Instead, this task is performed from time to time, depending on the operator company's interests, because it demands full attention of monitoring engineers for significant periods of time. All real-time plots must be reviewed by the monitoring engineers around a specific time, looking for deviation from the plan as trends change for the wells being monitored at the RTOC. Combining the three main statuses of all wells monitored at the RTOC into a unique automated dashboard makes the status-report update an efficient task requiring almost no human intervention. **JPT**