Abstract - With rapidly growing global demand for energy resources, oil and gas exploration & production companies face mounting pressure to maximize supply and increase the rate of discovery for new energy sources. Increasingly operating in more remote locations and investing heavily in equipment and facilities, companies face greater financial and operational risks than ever before. Optimization of drilling parameters during drilling operations aims to optimize weight on bit, bit rotation speed for obtaining maximum drilling rate as well as minimizing the drilling cost. Communication and computer technologies are among the most important disciplines which can contribute to drilling optimization. Large amount of data could be piped through different locations on the planet in reliable and time efficient manners.

Index Terms—Drilling Optimization, Drilling Parameters, Weight on Bit, Real Time Service.

I. INTRODUCTION

Drilling optimization can be defined as the provision of real-time data to expedite decision-making based on information transmitted from downhole. Trends in data need to be looked at to derive accurate conclusions about bit status, weight transfer, drilling dynamics situation, hole quality, etc - all aimed at achieving enhanced well site efficiency [1]. Reliable information is at the heart of optimized performance. Companies that lack accurate, timely and integrated information cannot adequately control and optimize well production, leverage a centralized repository of data for real-time and historical analysis, or monitor and enhance field production strategies-leading to sub-optimal performance. Today’s industry challenges are impacting drilling success and overall system cost. Operators are faced with:

- Higher efficiency wellbores resulting in fewer required wells for reservoir drainage. Fewer wells spaced much farther apart means less offset data for pre-drill risk identification;
- Recognition that traditional pre-drill models are obsolete upon spudding a well due to geology and geomechanics changes from offset to new well;
- Increasingly complex reservoir drilling targets requiring more in depth knowledge;
- Unknown, but expected governmental regulatory requirements dictating some level of real-time data usage; and
- Continued pressure on existing in-house resources, which will only become more so with activity increases and increasing regulatory requirements [5].

As less and less offset well data are available, the quality of associated pre-drill models is being compromised at a time when it is needed most. The best option for offsetting these shortcomings is to use all drilling data generated during the well construction process to update models, allowing for the ability to forecast and mitigate potential problems on the fly [4]. The largest amount of money spent on any one class of cutting tools is spent on drills. Therefore, from the viewpoint of cost and productivity, modeling and optimization of drilling processes are extremely important for the manufacturing industry [6].

In recent years the increasing emphasis that is being paid by the oil and gas field operator companies towards working much efficiently at the rig sites are based on some important reasons. The most important of all are: cost and trouble free operations [1]. Directional techniques allowed drilling multiple wells from one location, thus eliminating construction of expensive structures for each well [1, 10]. Due to the drilling requirements similarity of the wells located at close distances, collecting past data, and utilizing in a useful manner is considered to have an important impact on drilling cost reduction provided that optimum parameters are always in effect.

II. HISTORY

The concept of rotary drilling originated in the beginning of the year 1900. The development of rotary drilling can be divided into four distinct periods: Conception Period - 1900 to 1920; Development Period - 1920 to 1948; Scientific Period - 1948 to 1968; and Automation Period which began in 1968. [11]. The conception period the rotary drilling principle marked the usage of cementing methods, rotary bits, drilling fluids and casing installations. The scientific period
began by emphasizing on drilling research in order to provide a better understanding of the hydraulics, the drill bit technology, improved drilling fluid technology which culminated to obtain optimality in the drilling techniques. By 1975, automation flourished with computer systems having the ability to control the various drilling variables. Automation offered a high degree of precision which humans could not deliver. One of the first attempts for the drilling optimization purpose was presented in the study of Graham and Muench in 1959 [12]. They analytically evaluated the weight on bit and rotary speed combinations to derive empirical mathematical expressions for bit life expectancy and for drilling rate as a function of depth, rotary speed, and bit weight [1]. In 1963 Galle and Woods [13] produced graphs and procedures for field applications to determine the best combination of drilling parameters. One of the most important drilling optimization studies performed was in 1974 by Bourgoyne and Young [14]. They proposed the use of a linear drilling penetration rate model and performed multiple regression analysis to select the optimized drilling parameters. They used minimum cost formula, showing that maximum rate of penetration may coincide with minimum cost approach if the technical limitations were ignored. In the mid 1980s operator companies developed techniques of drilling optimization in which their field personnel could perform optimization at the site referring to the graph templates and equations. In 1990s different drilling planning approaches were brought to surface [15]. New techniques identified the best possible well construction performances. Later on “Drilling the Limit” optimization techniques were also introduced [16]. Towards the end of the millennium real-time monitoring techniques started to take place, e.g. drilling parameters started to be monitored from off locations. A few years later real-time operations/support centres started to be constructed. Some operators proposed advanced techniques in monitoring of drilling parameters at the rig site.

III. DRILLING PARAMETERS

The drilling parameters may be broadly classified under two types: Rig and Bit Related Parameters and the other being Formation Parameters. The rig and bit related parameters can be controlled but the formation parameters have to be dealt with. The parameters recorded for drilling optimization are critically important to be representative of data they are meant to reflect. The parameters that come under the rig and bit type are: Weight on Bit, Torque, Rotational Speed and Hydraulic Parameters such as flow rates, density of drilling fluid etc. The parameters under the Formation type are: Local Stresses, Mineralogy, Formation Fluids, Rock Compaction and Abrasivity of Formation [2]. Beyond the above stated parameters, determining the Rate of Penetration is among the most sought after parameters in drilling industry. This is due to the fact that it allows for optimization of drilling parameters to decrease drilling costs and enhance drilling process safety. Some of the parameters are given below:

A. Weight on Bit (WOB)

It represents amount of weight applied onto the bit, that is then transferred to the formation which in turn is the energy created together with string speed that advances drillstring [1].

In a field study [10] it was shown through testing that doubling the bit RPM in 6,000-psi rock while keeping WOB constant resulted in 70% increase in ROP, however, doubling WOB, with RPM constant, resulted in 300% increase in ROP [9]. Bit condition is very important as there is blunting while drilling progresses, which depends on the formation being drilled [9].

B. RPM

This parameter stands for “revolution per minute”. It represents the rotational speed of the drillstring. With the invention of TDS; the reading is directly linked to the electronics of the unit itself. It is considered that the measurements for this parameter are accurate as long as the acquisition system set-up has been thoroughly made up [1].

C. Pump Parameters

The pump parameters are composed of the liner size in use, pump strokes, and the pump pressure. In case there are two pumps working simultaneously all of the data for two of the pumps should be acquired. With the electric pumps the stroke is transmitted in the same way as RPM. The pressure at the pump in case of having been acquired could be compared with the reliability of the standpipe pressure. Pump pressure should always be greater than the standpipe pressure. Use of flow meters could also be adapted for accurate flow rate measurements [1].

D. Depth

The value of depth, in other means the bit position is input in the MLU. The operator is the responsible for that; usually it is linked to the position of the block, by means of the sensors located at the crown block [1].

E. Inclination – Azimuth

These two parameters are in the responsibility of the directional driller. An efficient communication between the MLU and the Measurements While Drilling (MWD) unit is to the benefit of these two parameters.
which may be very important for Wellbore Stability considerations [1].

F. ROP

This parameter is the most important parameter, since all of the calculations in this study are based on estimations of Rate of Penetration (ROP). It is measured through the relative change of the position of the block in time. Accurate calibrations are very important in order to have a representative ROP parameter [1].

G. String – Casing Properties

The string and casing properties are very important when the frictional pressure losses are to be calculated [1].

H. Fluid Properties

Rheological properties and the density of the drilling fluids are also among the very important parameters to be recorded for optimization purposes. Usually the drilling fluid density is measured through calibrated MW sensors. Rheological properties on the other hand are still measured manually. Recent developments in regards to real-time pipe viscometers dictate alternative solutions. There are experimental studies performed in the laboratory using pipe-viscometers [24]. Continuous real-time viscometer probes placed on the flow line (which are reportedly under development) could facilitate data acquisition over the rheological properties of drilling fluids in real-time [1].

I. Torque

This parameter is the torque of the drillstring while it is rotating. It is measured by means of TDS systems. Previously the readings for this parameter were relative. This parameter is going to be significantly important for inclined and highly deviated wellsbores, which is also related with the wellbore cleaning issues [1].

J. LWD

LWD stands for Logging While Drilling. Formation related parameters could be captured during drilling and be used in the optimization process. However in the scope of this study no LWD consideration has been taken into account [1].

IV. FACTORS AFFECTING RATE OF PENETRATION [1]

The factors known to have an effect on rate of penetration are listed under two general classifications such as controllable and environmental. Controllable factors are the factors which can be instantly changed such as weight on bit, bit rotary speed, hydraulics. Environmental factors on the other hand are not controllable such as formation properties, drilling fluids requirements. The reason that drilling fluid is considered to be an environmental factor is due to the fact that a certain amount of density is required in order to obtain certain objectives such as having enough overpressure to avoid flow of formation fluids. Another important factor is the effect of the overall hydraulics to the whole drilling operation which is under the effect of many factors such as lithology, type of the bit, downhole pressure and temperature conditions, drilling parameters and mainly the rheological properties of the drilling fluid. Rate of penetration performance depends and is a function of the controllable and environmental factors. It has been observed that the drilling rate of penetration generally increases with decreased Equivalent Circulating Density (ECD).

V. DRILLING OPTIMIZATION [8]

The optimization of the drilling performance, even more in a field development context, will require:

1. Data Acquisition:

   Relevant measurement (High sampling rate – time-based data) of drilling data (surface and/or downhole): WOB, RPM, TQ, ROP mainly and Flow rate and SPP

2. Data Processing

   Based upon relevant drilling data, the processing leads to:
   
   - Drill Bit Response follow Up: (MSE, HMSE logs, E/S Diagram)
   - Events identification (steady drilling, vibrations, cleaning issue, wear development)
   - Drilling Response optimization (drilling parameters adaptation)

   The surface Data allows tracking of the drilling behavior. This is especially possible when the full bit design is known as it is the case when using DDS products. In other cases, detailed information on the design needs to be provided (cutter distribution, orientation and position). Using the bit signature together with the GeoScan lithology, we can then assess on a real time basis the drilling performance. The wear phenomena can be tracked and a wear logs is created. The vibrations are also monitored using surface data, bit signature and predicted ROP from the GeoScan.

Two main services are provided:

a. Real time service (RTS), using the above, the RTS provides the decision maker with the information needed to modify and optimize the drilling parameters in order to increase ROP, Bit life,
decrease vibrations. Pull out decision can also be supported by this RTS.

b. Next Well Service (NWS). Using the parameters logs recorded during drilling operation and electric logs, the lithology can also be reviewed and the field mapped, well after well. Lessons learned are gathered. This leads to the construction of a Reference Knowledge Database (RKD). BHA components and bit design can then be adapted to improve performance for the next well. Guidelines are given to the drillers.

VI. CONCLUSION

More than ever, E&P companies are under intense pressure to maximize productivity, reliability, and efficiency while addressing increasing cost and profitability pressures. Significantly high financial and operational stakes in oil and gas recovery production, coupled with sophisticated processes in extremely harsh environments, calls for renewed focus on the criticality of wellhead operations. There have been oil companies that have dedicated to the exploration and exploitation of hydrocarbons applies approximately 60 % of its budget to the investment of its wells drilling program [7]. The latest technology solutions that integrate safety and control onto a single platform enable companies to achieve more reliable, efficient wellhead operations. Such solutions deliver continuous monitoring and precise control in a wide range of situations—onshore and offshore—delivering increased production uptime and asset performance, and lower total cost of ownership. As oil and gas wells are being drilled to greater depths and distributed over further and wider areas with higher associated risks and greater upfront investments, high performance is imperative for companies to succeed. Companies that focus on optimizing wellhead operations while ensuring safety and reliability can begin their path toward capturing greater profitability in upstream production for long-term growth [3].

VII. REFERENCES

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