Master Thesis

“Analysis of Human – Machine Interface for Drilling Rig Personnel to enable Remote Drilling Operations Support”

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Eidesstattliche Erklärung

Ich erkläre an Eides statt, dass ich diese Arbeit selbständig verfasst, andere als die angegeben Quellen und Hilfsmittel nicht benutzt und mich auch sonst keiner unerlaubten Hilfsmittel bedient habe.

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Abstract

A new visualization of real time drilling data to simplify detection of early drilling problems can result in a future developed driller rig interface.

Through the development of new drilling technologies, equipment and monitoring systems, the requirements on drilling personnel increased rapidly. The ability to detect early drilling problems from the driller's cabin, by observing trends of real time drilling data, is limited considering that the driller doesn't have the time to follow single parameters over a longer period of time during rig operations.

Various companies already provide early drilling problem detection software, but without taking a human-machine interface located in the driller's cabin into account. A display located in the driller's cabin, showing trend changes of main drilling parameters over a longer period of time is missing, but exactly this trend analysis of key drilling parameters are cause to detect drilling problems at the start of occurrence to enable earlier counter measures.

A visualization is introduced called the Driller's Display to present actual versus simulated key drilling parameters in addition to fingerprinting charts to observe three main rig operations. The simulation models and fingerprinting charts are newly developed. Various testing and evaluation phases have shown promising results. Through the reduction of displaying only the core parameters with trend analysis, the driller is able to detect drilling problems in an early stage with the advantage of counteracting as early as possible by adjusting drilling equipment directly controlled by the driller.

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Kurzfassung

Um eine stetig Weiterentwicklung der Bohranlagenautomatisierung zu unterstützen sollten Echtzeitdaten dazu verwendet werden, dass zukünftigen Schnittstellen zwischen Mensch und Maschine eine frühzeitige Bohrproblem Analyse unterstützen.

Durch die Entwicklung immer fortschrittlicher Technologien, Geräte sowie Überwachungssysteme wird den Bohrarbeitern immer mehr abverlangt. Die frühzeitige Erkennung von Bohrproblemen mittels Trendanalyse von Echtzeitdaten ist derzeit an der Bohranlage für den Kranfahrer sehr schwer möglich.

Es wurden bereits schon von verschiedenen Firmen mehrere Softwares für die Erkennung von Bohrproblemen entwickelt, jedoch wurde die Schnittstelle zwischen der Bohranlage und dem Kranfahrer vernachlässigt. Eine Anzeige in der Kranfahrerkabine welcher Trendveränderungen wichtiger Bohrparameter über einer gewissen Zeitspanne anzeigt um frühzeitige Bohrprobleme zu erkennen fehlt.

Um die Schnittstelle zwischen dem Kranfahrer und der Bohranlage zu unterstützen und eine frühzeitige Bohrproblemerkennung zu ermöglichen, werden Trend Analysen von wichtigen Bohrparametern verwendet, um ein Auftreten von Bohrproblemen frühzeitig zu erkennen und entgegen wirken zu können.

Die vorgestellte Kranfahrers Anzeige wird dafür verwendet, um einerseits aktuelle gegen simulierte Bohrparameter vergleichen zu können; sowie auch spezifische „Fingerprinting“ Diagramme darzustellen zu können. Eine Unterteilung in die drei Hauptarbeitsprozesse erfolgt durch die unterschiedlichen Anforderungen. Die dafür benötigen Modelle für die Simulationen sowie auch die „Fingerprinting“ Diagramme sind neu Entwicklungen. Eine erste Testphase hat zuversichtliche Resultate geliefert. Durch die Reduktion der Bohrparameter in wenig wichtige mit der Kombination von Trendanalysen, ist es dem Kranführer möglich frühzeitig Bohrprobleme zu erkennen und diesen sogleich auch entgegen zu wirklich.

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Introduction

During the past 20 years, major changes occurred in drilling operations due to technological advancement. Nowadays, it is standard to drill with AC-driven rigs, which provide a high level of surface sensoring as part of the drilling service package, thus enabling for a greater amount of live drilling data conveyed, for every main operation on the rig site. This data is primarily used by the driller on site in addition to external sources (e.g. head office) for remote monitoring. The driller readily has gauges and displays of sensor data available, but lacks a direct display of processed data, which would enable him to detect drilling problems in an early stage. The challenge is in the presentation of this data, combined with the ergonomics of the driller's seat in the driller's cabin. It is typical, that the different displays and gauges are distributed in an 200 degree viewing angle in front of the driller, which poses a strategic placement challenge; it's difficult to focus on the correct instrument for any given operation if so many are "available". Due to this high amount of drilling data, there is a probability of not visually detectable trend changes of main drilling data in the driller's cabin.

The main aim of this thesis is to improve the safety and efficiency of a drilling rig in conjunction with the deliverance of adequate information to the driller in order to operate the rig on a suitably efficient level by investigating the human-machine interface. The focus is to create a work environment, which enables the driller to react against drilling problems in an early stage using trend analysis. An additional benefit may include extinguishing potentially lost time, thereby reducing overall operation cost. The first objective is to attain an understanding of the drillers work station and the human-machine interface. The primary step is to investigate the control panel conjointly with the various interfaces for sensor data. Due to the various operations during a drilling process, there are also different main operations parameters for each working stage. To identify these, the principles of operation were analyzed and questionnaires with drilling personnel conducted; the objective being to outline a set of information, which is relevant for each different operational stage the driller has to perform.

The intent of this is to provide an analysis and consequent improvement plan for a driller's typical work environment (doghouse). Major focus will be given to the strategic placement of all displays and gauges as various are still placed out of a driller's immediate reach (behind).

In conclusion, a straightforward information tool for the driller used to detect drilling problems is introduced. The system can be used for trend analysis of main drilling parameters to detect early drilling problems.

Human-Machine Interface

The human machine interface is a part of a system, which administers human-machine interactions.

This complex system requires a high engineering quality to optimize the ergonomics of this interface. This is provided by "Human Factors Engineering" and general "System Engineering" (4).

To establish communication between human and machine, various different interactions are possible. In basic terms, communication is based on the input and output of data. A human has three main possibilities to receive and forward information. These are based on the human's sensory system and include:

- Ears, for the auditory system
- Eyes, for the visual system
- Hands, arms, feet and legs for the somatosensory system (4)

The machine input is mostly provided via keyboards, mice, joysticks, microphones, button, switches and nowadays touchscreens. To supply humans with output information, displays, speakers, warning lights and mechanical gauges are typically utilized in the industry.

The conversion of most of the data is completed via humans' brain and versa via a machine's software.

For the design of a human-machine interface, various types of the day-to-day procedures have to be taken into account.

The working principle of a human-machine interface is based on a constant feedback loop.

Driller's Interview

To establish an inside view of the working place of a Driller, interviews with various drillers were done. These interviews took place on the RAG drilling rig E-200 located in the Lower Austria. RAG Energy Drilling is a contractor of OMV E&P Austria.

These interviews were used to gain a good knowledge of the drillers working processes on a drilling rig and the interface between driller and rig in the driller's cabin. An investigation of the whole rig system especially the sensor system of the rig contractor and mud logging company was also performed.

Next to that the interviews were also used to bring the idea of an early drilling problem detection system to the driller. One of the goals was to receive feedback from the driller to develop the first concepts of such a system.

Further detail of the interviews can be seen in the Appendix. Based on the information which were governed during these interviews further steps of this thesis were planned.

Driller-Rig Interface

The investigation of the interaction between driller and rig is one of the foundations of this thesis. The communication process between driller and rig is shown below in Figure 1. This Figure further details how the rig interface is a means of communication, which is highly reliant on its' individual components. A driller inputs information via the hands and processes this via previously gained knowledge. The driller forwards his outputs to the rig by using the provided hardware in the driller's cabin. Most of the control units are included in the drillers chair and in the driller's console.

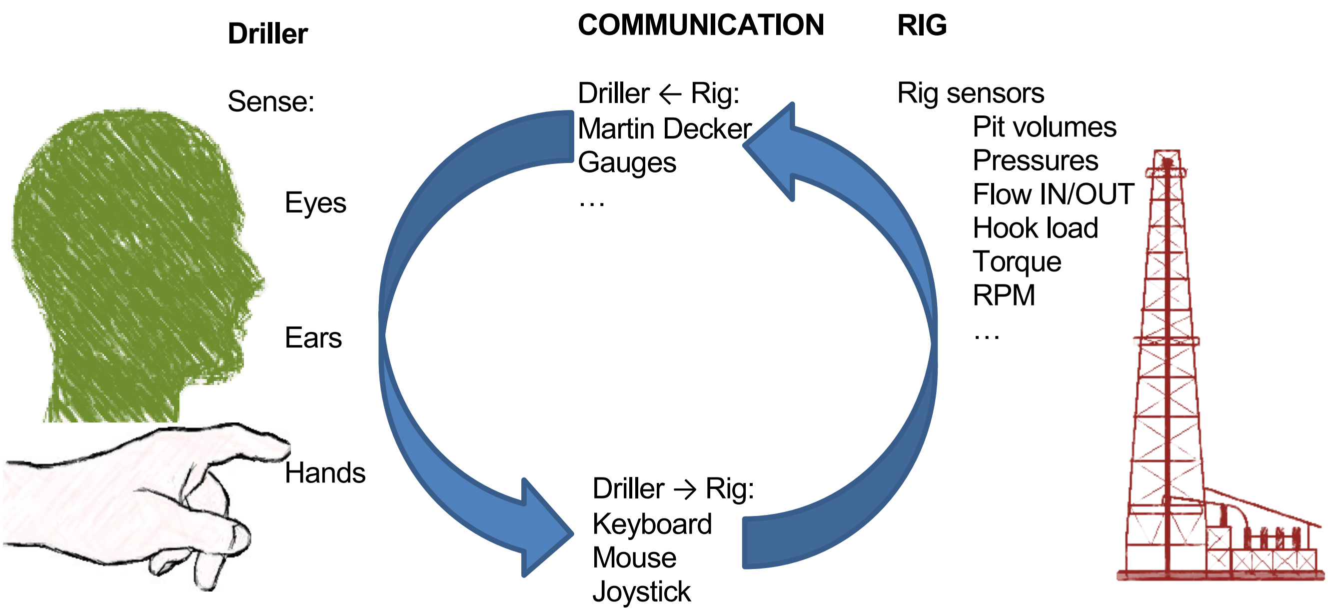

Figure 1: Transition of the human-machine interface to the driller-rig interface. This figure shows the communication in a closed loop. The improvement of the communication part is one of this thesis's main aims.

The rig provides data via several TFT displays and gauges as the main display devices.

Bad sensor data can result in misinterpretation with the possibility of wrong decision making. Due to the high dependence to each other, the communication path between a driller and a rig should be as direct as possible which can be supported by a well-organized driller's console located in a driller's cabin.

Development of the Driller's Cabin

Over the last decades a larger development of the driller's cabin took place. One of the changes is the increase of measurement and data processing possibilities on the rig site, increasing information displayed to the driller increases continuously. As a result the interface between driller and rig also changed dramatically.

Figure 2: Kelly drilling rig with a simple driller-rig interface. Including a Martin Decker, torque observation gauge and stand pipe pressure manometer.

Old systems shown in Figure 2 provided basic control units and simply displayed information. The main control possibilities included the driller's break, the pump control panel, and controlling of the rotary table. These three main control units are still in use today to operate the rig. The driller's break in combination with the draw works is used to control the movement of the drill string and as a result the hook load (HL). With the pump control panel the driller controls strokes per minute (SPM) and consequently the flow rate. Driller-rig interface is commonly located directly next to the hole. This placed the driller directly located next to the most dangerous area and simultaneously exposes him to the elements.

The automation process introduced various new technologies to minimize hazard, thus improving work safety and quality. The first one was the integration of the iron roughneck with automated slips. With the availability of an iron roughneck on the rig floor the required personnel was reduced. Only one worker is needed to make or break-up connections on a modern drilling rig. Nowadays, automated pipe handling systems aim to further reduce risk and improve the automatisation process.

To fully exploit the benefits of mechanization, the driller-rig interface needed to evolve.

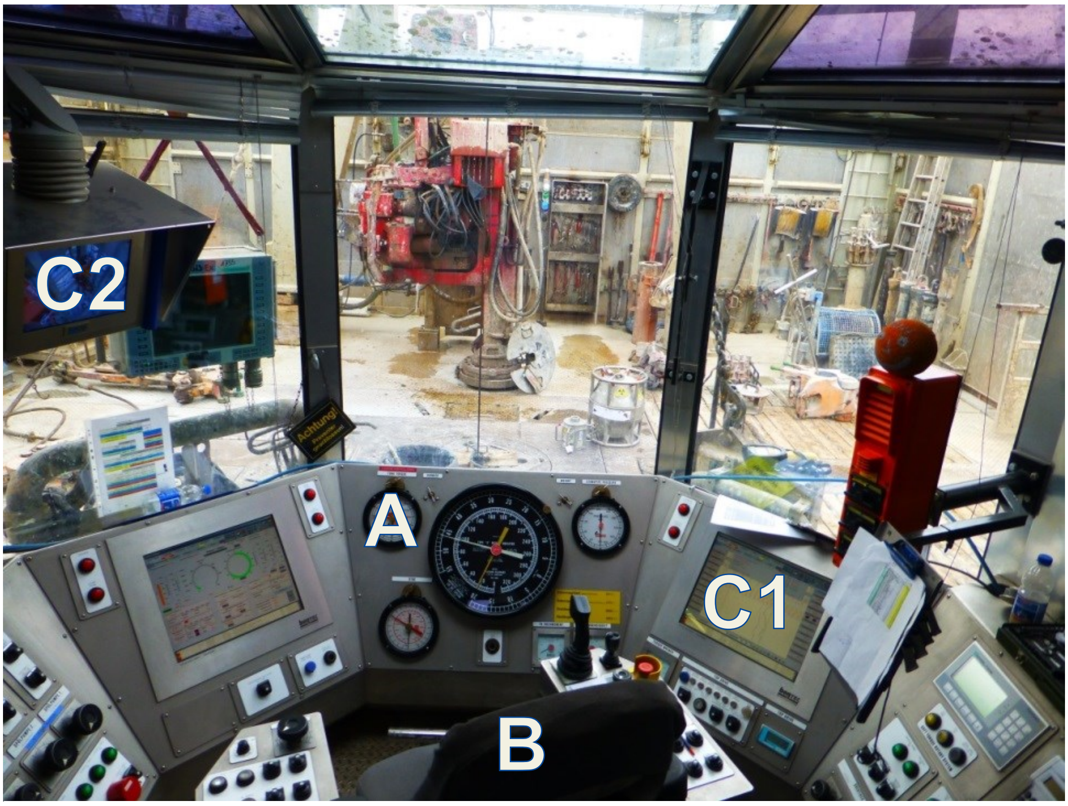

Figure 3: Drillers cabin on the RAG Energy Drilling rig E-200

A modern driller rig interface illustrated above in Figure 3 offers the possibility of displaying more detailed information to operate the rig compared to older systems shown in Figure 2. Another difference between the old and the new system is an enclosed shelter for the driller to safely operate on the rig floor.

The new design of the driller-rig interface provides basically consists of three main components:

- Driller's Console (A)
- Driller's Chair (B)
- Drilling monitoring system (C)

The drilling monitoring system is integrated into the driller's console including a mud logging monitoring system (C1). The video surveillance system of the rig site is located above the drilling monitoring system (C2).

Drillers Console

The drillers console surrounds the driller's chair. As a result, a driller cannot see all information in his field of view (maximum direct sight area being around 160 degrees in a distance of approximately 1 meter). The layouts of the various displays on the drillers console are sorted by importance. The arrangement starts with the high priority display in front of the driller.

Martin Decker

This high priority display is called "Martin Decker" (A) seen in Figure 4. It's an instrument, which is used to indicate the weight applied on the hook (hook load) and the weight on bit (WOB)

Figure 4: This figure shows the drillers console in front the driller, including the Martin Decker, SPP, TD TQ and TD RPM, tong TQ as well as the iron roughneck TQ

Next to the Martin Decker, other important parameters are located directly in front of a driller.

- Pressure: the stand pipe pressure (SSP) (B)
- Top Drive: torque (TQ) and revolutions per minute (RPM) (C)
- Iron roughneck: torque (TQ) (D)
- Tong torque (TQ) (E)

Rig Monitoring System

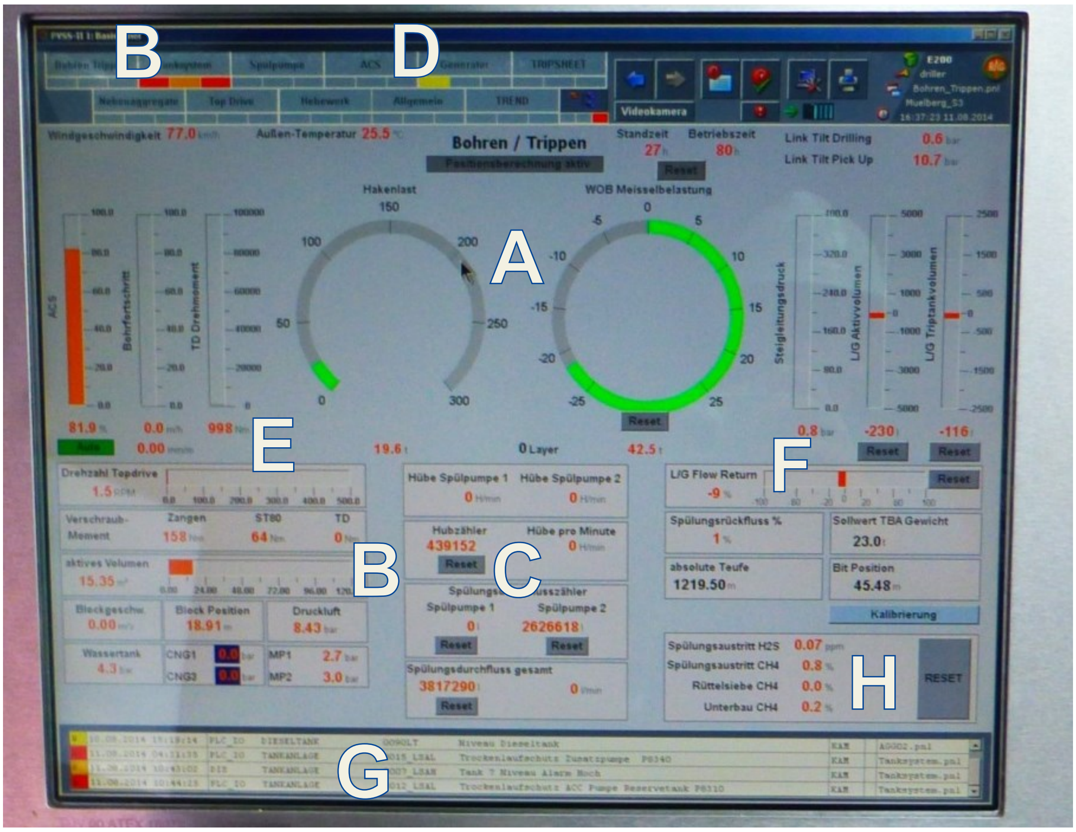

Figure 5: Main rig monitoring information system (RAG Rig E-200)

The rig monitoring system shown in Figure 5 is located on the left side of the driller's console. This display includes a whole monitoring system of the drilling rig, including a digital Martin Decker (A). The displayed information can be individually configured by the driller himself. Most common information include the tank system (B), mud pumps (C), generators (D), top drive (E), flow lines (F), gas detection (H) and much more.

On the bottom part of the display, a history of various alarms is shown (G). The alarm system differs between priorities of the alarms by difference in color; yellow for minor problems, orange for important alarms and red for very crucial incidents.

Mud logging monitoring System

The geoNEXT monitor system is provided by Geoservice® and an example of a mud logging monitoring system used on the investigated RAG rig E-200 shown in the Figure 6 below. This monitoring system provides a good overview of the main parameters for each operation. The data acquisition is based on the rig sensor system to calculate and display information like mud weight return (A), bit depth (B) and total depth (C), cutting lag time (D), pit level (E), ECD (F), various temperatures in the mud system (G) and so on. This information can be shown by values or graphs, which can be adjusted by the operator. Used strip charts can display values either over time or depth.

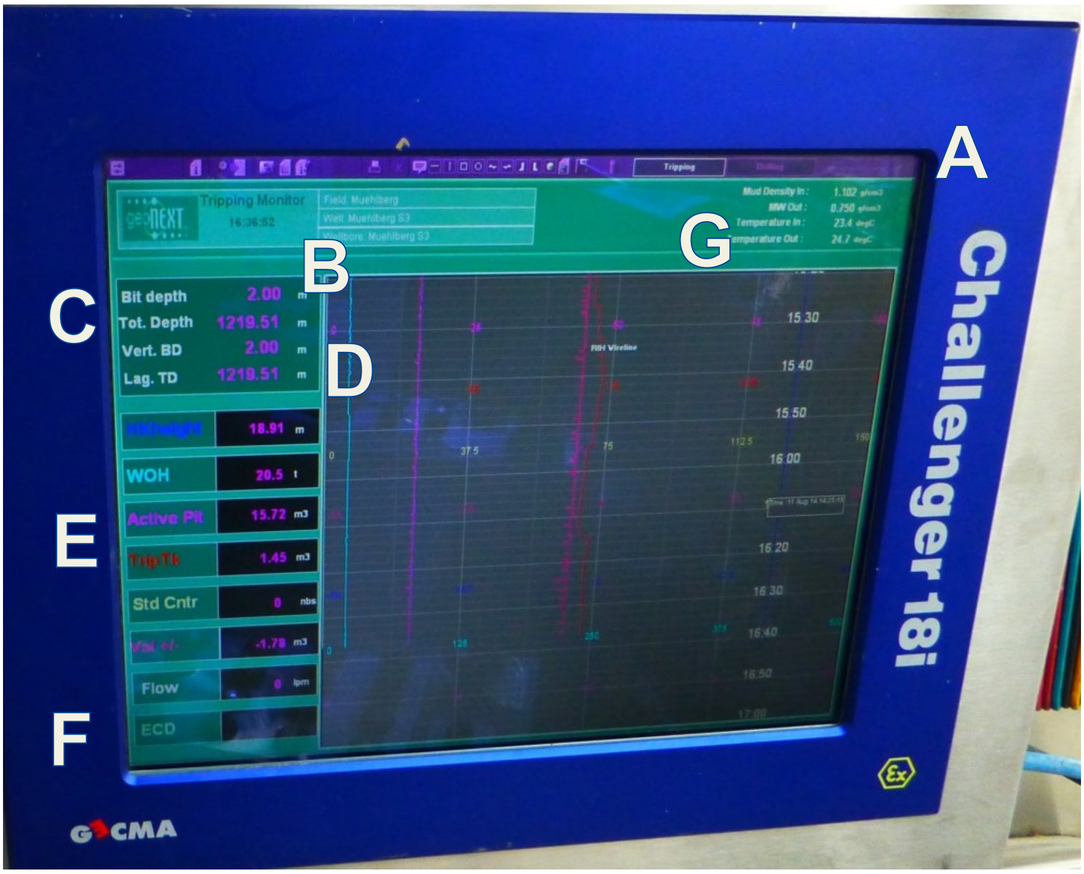

Figure 6: The geoNEXT System provided by Schlumberger is used to monitor the various drilling operations.

Control Panel

One of the control panels is located next to the rig monitoring system. This panel shown in Figure 7 includes control units of mud pumps (A), gas- and diesel generators (B), eddy current brake of the draw work (C) and pumps of the trip tank (D). Mud pumps are controlled by adjusting the speed of the pump (SPM). Flow rate is controlled via the strokes per minute and volume displacement per stroke. Flow rate information is given to the driller in the unit of [l/min].

On the right side of the "Martin Decker", a second display is located on the driller's console; it is used to monitor various trends versus time. To establish a trend, all different kinds of measured values can be used. This can include trip tank volume, active tank volume, hook load up to calculated values like rate of penetration (ROP).

The top drive monitor system is located below of this display. Errors are indicated via several lamps and acoustic alarms.

Figure 7: Main control panel located to the left of the drillers view on the drillers console

Driller's Chair

To simplify the control possibilities of a rig and improve the ergonomics for the driller some control function are actually included into a driller's chair. The chair provides a comfortable and a clearly arranged view on the control panel and on the rig monitoring system. The driller's chair includes controls to operate the draw works, the top drive and the surveillance system of the rig. The draw works can be controlled via a joystick and the top drive is steered by a wheel to adjust the revolution per minute (RPM). State of the art drilling rigs with a pipe handling system also include a subsequent control unit on the driller's chair.

Key drilling parameters

As discussed a driller controls the rig via the driller's chair and the control panel.

The driller is able to directly control three types of main drilling equipment. (Figure 8)

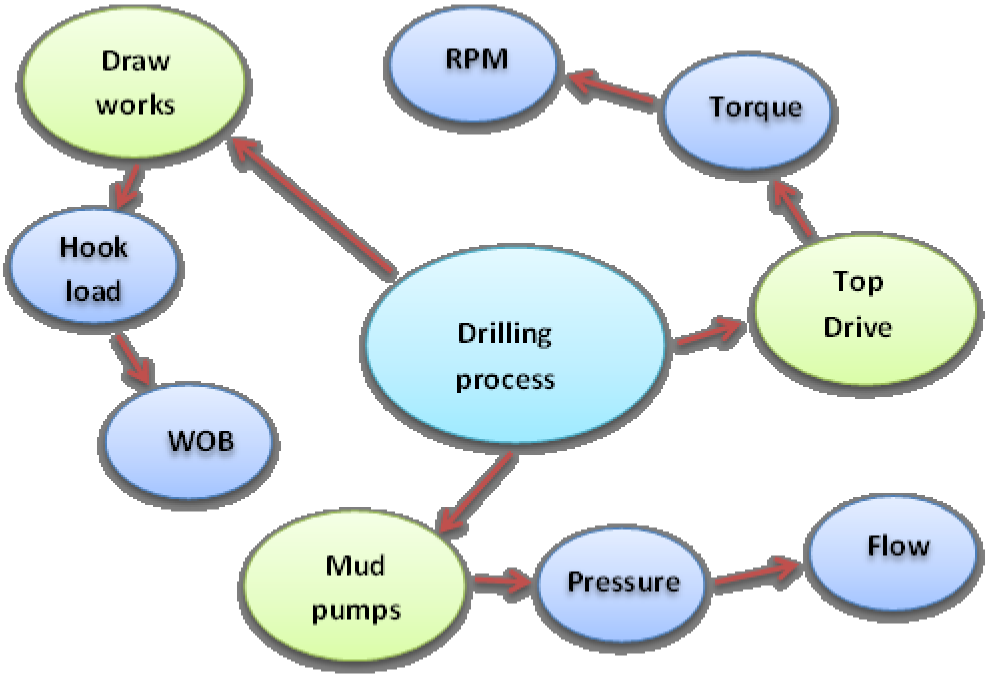

Figure 8: Mind Map of the three types of drilling equipment; each equipment controls two main parameters of a rig.

"Main equipment" denotes draw works, top drive and mud pumps. Any of these machines influence two parameters which are dependent on each other.

These key drilling parameters are used by drillers according to the performed interviews to observe and control rig operations and to enable a fast and efficient decision making process.

Decisions making during drilling problems

Current situation

Nowadays several software modules from different companies are available to detect drilling problems early. The two most advanced ones are Sekal and Verdande, which are described in greater detail later.

One of the biggest disadvantages of these programs is the "off-site" location of the user. These systems operated by engineers mostly located in an office anywhere in the world. Some application of these systems considers an engineer on the rig site but not directly in the driller's cabin. This implies communication issues in both directions. The first one being transport of the real time drilling data to the server for further processing. If this connection is lost, the software providing drilling problem detection stops working. The second issue is a lack of communication between the responsible personnel during the occurrence of drilling problems.

Currently, the decision-making process during drilling problems is embossed by an exchange of communication between the driller, tool pusher, company man and the responsible engineer in the office.

View into the future

To lower the risk of getting into issues such as differential sticking, stuck pipe or a kick, various countermeasures can be executed the earlier the better. To react as early as possible the driller must be provided with information regarding drilling problem as early as possible in an easy and understandable way, by a warning system located in the driller's cabin.

Another benchmark is to build up an on rig site system, which is:

- Independent of a connection between data acquisition on a rig site and a data processing computer anywhere in the world
- Independent of consulting engineers

To attain the absolute trust of an operator, a system like this needs to be as robust as possible. This was also mentions by various drillers during interviews on rig sites. They are not averse against new technology but demand a flawless system. What means that the system runs without any errors (e.g. wrong simulations) and is tolerant to bad sensor data. Out of this reason reliable real time drilling data is essential to enable right decision making.

Real time drilling data

Vital for early problem detection is the availability of real time drilling data. Over the past decade, there was an increase of the amount of sensors on drilling rigs. With the increased quantity of sensors also the quality of drilling data increased over the last decades.

Data acquisition

Data acquisition is used to process measured values and convert these into digital values. Measured values are for example load on the hook, pump pressure and so on. To provide data transition of analog signals of various sensors into digital signals, an A/D converter is needed. This device converts the measured information into a unified form and is able to filter and amplify or attenuate the signal. Most sensors works in a frequency range of 10 Hz. Due to the most common transmission rate on rig sites, frequency of data transition is lowered to 1 Hz. The data acquisition process can be seen in Figure 9 below.

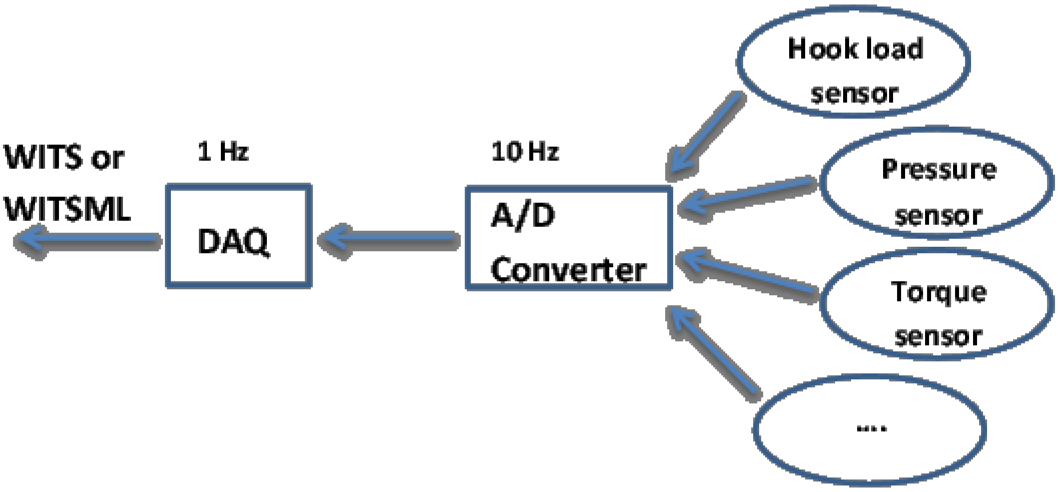

Figure 9: Data acquisition process from various sensors over an Data acquisition process into WITS or WTISML

Data communication

The data collection process is almost entirely conducted by a mud logging company. Sensors which are integrated in the rig like of hook load, rpm and torque of the top drive, pump pressure, flow in and so on are provided by the rig contractor. The collected and processed data is then conveyed in a coherent and secure way, for further applications and actions.

With the unification of data transfer it is possible to enable a reliable communication between different hardware devices and software application of various companies.

Data format

For the real time data system, there are various possibilities of data transfer around the rig site as well as transfer data to e.g. Kongsbergs Rig Manager® System. Over the past decade, several protocols were developed to continuously improve data transfer. The most known ones are:

- WITS (Wellsite Information Transfer Specification)
- WITSML (Wellsite Information Transfer Standard Markup Language)

WITS

The WITS is an older protocol to transfer drilling data. It's based on serial data exchange on a "Point to Point" basis (5).

The enhancement of this data format system is WITSML, which is described in the next section.

The WITS standard of data is used very often by international companies and is supported by most of the hardware devices and employed software programs. The "WITS is a multi-level format in 5 layers;

- Layer 0 describes an ASCII-based transfer specification
- Layer 1 describes a binary-based format based on 25 predefined fixed-size records and the Log Information Standard (LIS) data-transmission specification
- Layer 2 describes bidirectional communication using LIS Comment records
- Layer 2b describes buffering of data
- Layer 4 extends the previous layers to use a different data exchange format, RP66 (http://home.sprynet.com/~carob/ Date: 07.08.2014)

The main problem of WITS is that each service company defines their own record definition. These definitions can alter often during an ongoing drilling operation of a well which also occurs with WITSML (5).

Another problem is that the various channels of the WITS data format have to be assigned manually. This can result in wrong input data.

Despite these issues, WITS is still used in the oil industry, but slowly getting replaced by WITSML standard.

WITSML

The WITSML standard is an advancement of the WITS. It is the key to handle an increasing number of real time data and support them constantly. The WITSML is not only used to transmit well site sensor data, it is also possible to communicate drilling and service reports. WITSML is built on the XML technology (13).

The open standard of WITSML allows all companies to use this standard without restrictions. This encourages companies in the oil business to use this standard for their entire product line of tools and systems.

Currently the latest version is WITSML Version 1.4.1.

Advantages / Disadvantages between WITS and WITSML

One of the big benefits of WITSML is the improved communication between well site and office. Next to that quality of communication in comparison to WITS is improved due to the reduced manual data input. The WITS standard was developed three decades ago and using a binary file format to transfers well site drilling data. Due to this format no standard programming interface is used which can result in wrong data transfer (12).

A big advantage of WITSML to WITS is the situation of a data streaming interruption. In comparison to WITS, WITSML is able to stream missing data from an earlier point in time, due to the usage of timestamps for each data set per time step. WITS is only a live connection, any data which is not transmitted in time is lost (13).

Types of drilling data

There are two main types of drilling data available on site determined by the location of the sensors either above ground or below.

The sensors, which are located above ground, can be split up into fixed rig sensors, provided by the drilling contractor and temporarily placed sensors, installed by the mud logging company and the drilling contractor.

Sensors, which are used in the wellbore, are split up into two different parts:

- Logging while drilling (LWD)
- Measurement while drilling (MWD)

These tools are located in the bottom hole assembly (BHA). These sensors can be used to collect data close at the drill bit like real WOB or bit torque. The big disadvantage lies within the limitation of the data transmission rate to surface, because of the mud pulse data transmission. Mud pulses are only capable of transmitting low amounts of data per unit of time, with a reasonable possibility of interrupted and disturbed signal.

Rig sensor system above ground

Ordinary drilling rigs have three main equipment functions - the subsequent command functions are overseen by the driller:

- Rotary system
- Circulation system
- Hoisting system

The rotary system is the top drive. It’s driven mechanically, hydraulically or electrically. To provide full control, data from several sensors is required. The two important ones are monitoring rotation per minute (RPM) and torque.

The circulation system provides a system to circulate the drilling mud under certain pressure. It consists of rig pumps, surface hoses, stand pipe, drill pipe, heavy weight drill pipe, drill collar, various BHA components and annular geometries between casing ID and drill string OD. To further enhance command function, multiple sensors are also located here. The most important ones are: pressure sensors, flow in sensors, outflow sensors and pit monitor sensors.

The hoisting system consists of equipment, used to raise and lower whatever tools may are on the hook. It consists of draw works, drilling line, a dead line anchor, a crown block and a travelling block. To control lifting operation, a driller is able to run the draw works. To control the movement, the system maintains mainly sensors to measure hook load, position of the block and direction of movement.

Detailed information according the various sensors are available in the Appendix.

Quality of sensor data

The availability of reliable sensor data is important to monitor drilling operations in a proper way. There are two possibilities of quality issues. The first issue regards to wrong sensor calibration. The other one is data outage. Two possibilities data quality issues are given below.

Hook load

The most commonly used measurement of hook load is done via measuring tension on the dead line anchor. This principle of measurement does not take the different tensions between the fast and the dead line into account. For this reason hook load measurement differs due to the different movement directions. Overestimating during POOH and underestimating during RIH (15).

Another quality issue regarding hook load is the calibration of WOB which is done by the driller. As a result wrong WOB estimation can occur. Calibration of WOB has to follow a specific procedure. It has to be adjusted with the bit of bottom, required rpm and pump rate during drilling. Due to wells with high deviation WOB cannot be used further more to control the drilling process. To replace WOB pump pressure can be used. If the bit is on bottom during drilling the mud motor requires a certain amount of pressure for operation.

Pit volume

It is very common that all the sensors, which are listed and described above, are provided by the rig contractor. In addition to these sensors, a mud logging company often provides extra pit tank sensors. The difference to the contractor ones is the location and the mounting position. The sensors of the contractor are mounted in the inner part of a pipe. This pipe leads close to the bottom of the pit tank. As a result, measurements are devoid of alteration due to foam generation. This feature cannot be provided by most logging companies due to sensor positioning restrictions.

Figure 10: Most common pit level sensor positioning, without any protection against incorrect measurement due to foam.

Figure 11: Optimum solution to provide accurate pit volume measurement despite foam

Types of drilling problems

One of the aims of this thesis is to investigate a system to simplify early detection of drilling problems and improve its display to the driller. Due to this reason knowledge about various drilling problems and their characteristics is important.

This chapter deals with the specific attributes of the numerous drilling problems. Drilling problems can be split up into two main groups:

- Stuck pipe
- Volume control

Detailed information about of types of drilling problems with key indicators, which can be used to identify these problems, are attached in the Appendix.

Available systems for early drilling problem detection

For the efficient detection of drilling problems, there are two types working principles commonly used:

- Case Based Reasoning
- Simulation with process models

The main issue with these methods is the dependence on input data. The risk of system failure is determined by wrong or missing input data. This is a result of either bad sensor data or wrong input data, inserted by the maintenance staff of the system.

Case Based Reasoning

The main idea is to reduce the non-productive time (NPT). The idea is utilizing a method, which is able to conserve human experience in a computer data base.

The goal is to generate a library of problem cases. Each of these cases of drilling problems has a specific data trend. The system is continuously checking current real time data with case data from the library. If there is an occurrence, which looks similar to one of those cases, there has to be an alarm for the driller alongside an outline of issue's specifics. The approach used in this method, is the combination of recognizing patterns in the sensor data by using trend changes, without using complex physical models. This whole process implies that all these cases are previously reviewed by an actual drilling engineer. With the knowledge and experience of an engineer, the current situation can be resolved and recorded as a new case (2).

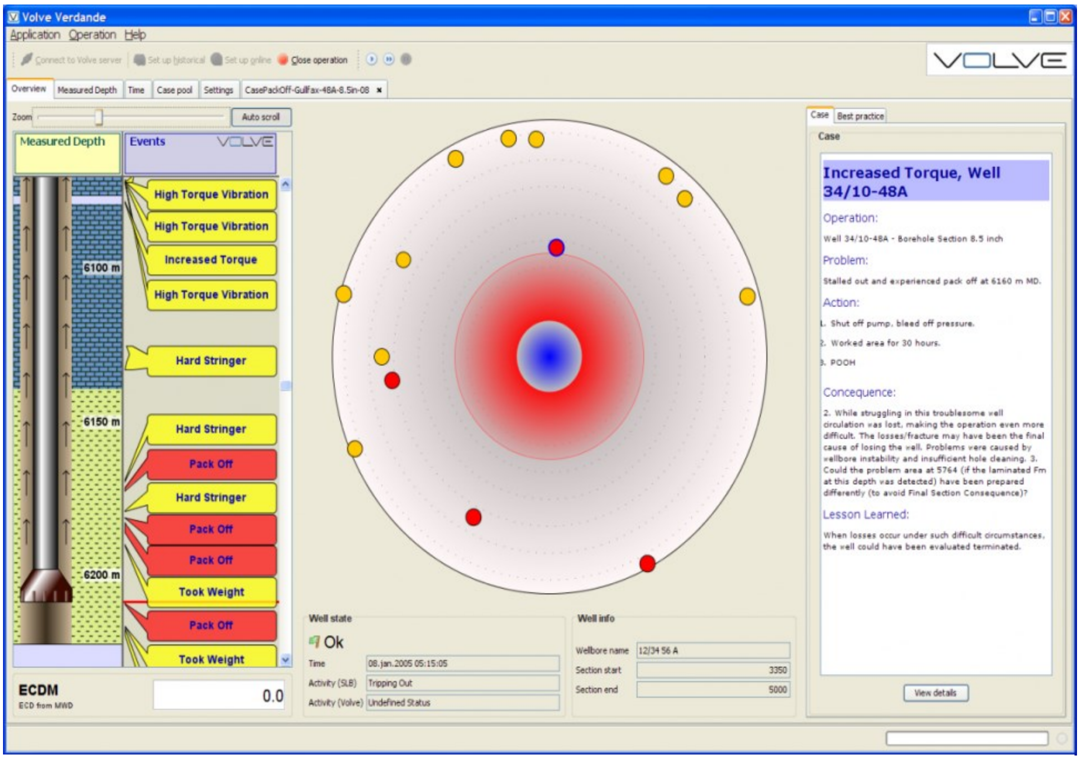

Figure 12: Verdande Technology "DrillEdge®". This screen shot shows the working principal of the case based upon reasoning.

The DrillEdge® Software is an information software, which is set-up like a "case radar" shown above in Figure 12. The current operation is shown as a point in the middle of the radar. If the current operation is getting closer to a problem situation, a smaller point is getting closer to the middle. The circles, which surrender the middle point, indicate the probability of occurrence. By clicking on the point, more information in form of a text is shown to the user (7).

Tests of the System

A test of the system is presented by Verdande in the SPE paper 141598 which produced strong results with problems like stuck pipe. The prediction of this problem happening occurred 6-8 hours in advance.

For the loss of circulation, the results were acceptable (7). The modest performance of the model was a result of the differences in signatures between wells, used in the cross validation test from those used in the live test.

One of the problems with this system or method was the requirement for a lot of manual engineering input. Another problem was that drilling problems like wash-out or stuck pipe occurred quiet early on the "radar" display and disappeared as quickly as they had appeared. With this early information of specific drilling problems, the driller becomes desensitized; taking major drilling problems not quite so serious (7).

Another main issue is the very high quality data input necessary. Due to an average drilling rig lifetime of 30 years, the availability of state-of-the-art rig sensors is very unlikely.

Conclusion of Case Based Reasoning

Due to the working principle of Case Based Reasoning (CBR) the system of Verdande is depended on the knowledge of a case library. CBR works better and more precise the higher the amount of various cases with specific trend changes of operations parameter is available. Drilling problems are presented to the user via a radar display with a certain percentage of occurrences. This also represents the major issues of this working principle. The user can get unsettle due to the amount of various drilling problems with different probabilities displayed to the driller.

Simulation with process models

The main goal of this simulation is to present a system which is capable to improve the efficiency and safety by monitoring and controlling rig operations.

The system consists out of several calculations modules which are connected to each over via a database to provide data exchange. These models use real time data from the surface as well time-based downhole data. A pre-processing of data is performed to ensure only reliable real time data is used in further process (3).

Basic models

These simulations use two main types of models. The first one is a flow model which performs dynamic calculations of temperature and pressure in the wellbore. This model is based on the injection flow rate, any movement of the drill string as well as thermal boundary conditions of the well bore. The second one is a string mechanics model which is calculating torque and drag. Input of the model is provided via surface torque, surface hook load and the flow model (3).

Modules

Tripping/Reaming

One aim of this model is to evaluate the optimal velocity for tripping. A too fast acceleration or deceleration can result in a surge and swab effect. With this information, the pore and fracture pressure can be triggered. Aside of this consideration, machine limits can be additionally considered (3).

Automated friction test

The model is using the soft string torque and drag model as a base to provide four types of automated friction test. A friction test provides a standard pick-up and slack off test with or without rotation. The system offers four types of tests:

- Pick Up, slack off
- Pick up, rotation off bottom and slack off
- Back reaming, rotation off bottom, reaming
- Pick up, slack off, back reaming, rotation off bottom, reaming

These four types of tests introduced a limit for tripping, rotational velocity and time of rotation of bottom (18).

Pump Start-up

The goal of this model is to prevent pressure peaks during the starting process of a pump. This is done by using two different kinds of modes:

- Stepwise: converges to an unknown flow rate
- Resume: operates with a pre-defined flow rate

With these approaches, it is possible to not exceed fracture pressure. Another big advantage is the time optimization of the pump starting process. With an automatic modus, it is possible to reduce the startup procedure to a minimum (3).

Bit load optimization

This module records WOB and RPM in relation to ROP at low frequencies. These records are used to calculate factors which are indicating the effect of different WOB and RPM on ROP (2).

Conclusion of simulations with process models

These systems are sophisticated programs. The various results of the simulations are very promising (3). The main issue is the highly dependence on data amount and quality. Due to the broad range of drilling rig types and generations, data quality and quantity can be an issue for these models.

Newly Developed Models

The previously described models of CBR and simulation with process models are already sophisticated models but are not capable displaying processed data directly to a driller in the driller's cabin. In addition to that processing data directly on the rig site minimize data transfer issues. As a result of this configuration, the alarm takes a certain amount of time to forward the information of the problem to the driller on the rig floor.

Think and Vision an affiliated company of TDE (Thonhauser Data Engineering) provides a "hybrid approach" by using both the basic idea of both already introduced models.

Three models are considered for the future planned driller's display.

- Artificial neuronal network - ANN
- Intelligent Data Quality Control of Real-time Rig Data
- Automated Drilling Performance Measurement – ADPM

With the usage of the ANN and data quality model, it is possible to simulate the main three key drilling parameters:

- Torque
- Hook load
- Stand pipe pressure/ pump pressure

The combination of the simulated parameters with the measured ones in addition to the • Automated Drilling Performance Measurement model enables to construct a tool to determine unexpected changes in drilling operations. The application to use this information in order to simplify the driller-rig interface is one of the main focuses of attention to eliminate drilling problems.

Artificial neuronal network

Neuronal networks are one solution to simulate torque, hook load and stand pipe pressure. With the usage of an artificial neuronal network (ANN) issues of conventional simulation can be overcome. Conventional simulations are controlled by a very complex calculation process, which considers all different kinds of variables. As a result of that, the simulation is very sensitive to wrong input data as well as correct simulation formulas (8).

The big advantage of ANNs is the non-use of conventional physical formulas.

On the basis of the disadvantages of previous models the ANNs model simulated hook load, torque and stand pipe pressure. The general work flow of an ANN is described in the sections below.

A definition of an ANN with the working principle, the learning process and the ANN's quality characteristics are given in Appendix.

Simulation of the ANN

To use an ANN for simulation, various input data and working methods have to be introduced.

Training basics

The training process is based on the idea of comparing the simulated "learned" values and the known actual ones. If there is a too high deviation from the initial classification, the first record is fed back at the start of the network. This process of iterations is done as long as the deviation is too large. During this process, quality control is highly recommended. The issues of quality characteristics have been described above.

The training process is using ten input parameters. These input parameters are based on the available sensor data above ground, which is commonly available on a rig site.

- Bit measured depth (Bit MD)
- Hole measured depth (hole MD)
- Hook load (HL)
- Block position
- Pump pressure
- Fluid flow in
- Torque
- ROP
- WOB
- RPM

Training process

As described above, ten drilling parameter are used for the ANN training process. The training intervals of the used ANN differentiate between the start of an operation and the retraining due to simulation issues or major drilling parameter changes.

The principle of the training and simulation process is based on a simple work flow shown in Figure 13 below.

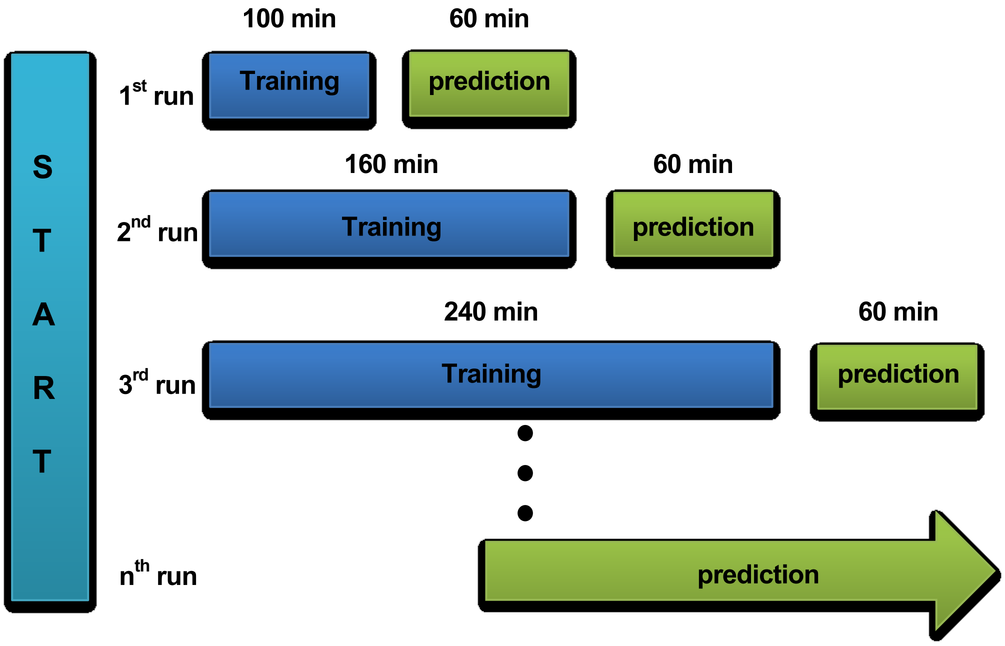

Figure 13: Trainings process from start until “n” steps, where no further training is needed.

1st run:

The first part provides the first prediction run of 60 minutes; it uses a training run of 100 minutes. The first training run compartmentalizes all ten drilling parameters to start the simulation. After the first training, the prediction interval of one of the key drilling parameters of 60 minutes follows immediately.

2nd run:

The second training run already uses the first 160 minutes of drilling data. This run utilizes eight measured parameters and simulates the two remaining ones. The prediction run continues like the first run for 60 minutes.

nth run:

Each of these runs is operated by the same working principle. The only difference is the amount of simulated parameters. Each of these is using 60 minutes more time to train the system. Next to that, each of these steps uses one less actual measured drilling parameter and replaces this one with a simulated one.

The amount of training runs is defined in such a way, that the quality characteristics are provided as accurate as possible.

The adjustment of the training process is provided by individual adjustable time steps. Each duration of the trainings and predictions runs can be selected to improve the simulation process. The time data, which is displayed above, is used in the first version of the driller's display. Possible adjustments of durations will be mentioned in the individual sections of the versions.

Repetition of the Simulation

The simulation process of the ANN program is designed in a very robust way. Simple changes - for example in hole depth or fluid flow - can be considered and simulated. This is a result of the training process. Parameters like pump pressure, torque, hook load, RPM and so on various all the time but due to the fact that they are considered in the training process, these parameters do not influence the simulation process. With this ability of the ANN the simulation works further on without any interruption.

Major changes lead to a new simulation. These are for example a new bottom hole assembly (BHA) or a change in mud weight. These parameters are included in the simulation process, but none are part of the training parameters. That means these parameters are included as values in the learning process of the ANN.

A new simulation means that the training process, which is described in the section above, has to start all over again. As a result, the simulation during this time period is not working adequately. This situation of error-proneness has to be investigating due to the restricted service of the simulation.

Intelligent Data Quality Control of Real-time Rig Data

The ANN simulation model needs a high amount of rig data and places a high demand on data quality. Due to these requirements, data quality control has to be implemented. Issues with the quality of data result in incorrect analysis and system breakdowns. These problems are decreasing the possibility of drilling problems detection and losing the confidence in the system.

The quality control system is considering various quality criteria's:

- Completeness of the data set
- Continuity and timeliness to receive continuous set of data

- Validity of sensor data
- Accuracy, consistency and integrity of drilling data

To identify and control the quality of data, various key performance indicators are used. This process can be operated in real time. As a result, the possibility of monitoring actual data quality is provided (14).

Human error issue

One of the main issues of data quality is the transmission of it. Often, the old WITS data format is still in use to transmit drilling data. This data format is working with data channels, which have to be assigned manually. Consequently, there is the possibility of human error. An approach of the WITS data format transmission has to be clarified. Most quality issues are a result of wrong channel description, wrong units and calibrations (14).

Data issues due to sensor quality and transportation issues

Sensor data problems are a result of the various issues in relation to time, depth and channel problems, caused by the principle of WITS data format.

Data channel problems

One part of the channel problems is already discussed in the section above. Independent of the human quality issues, the transmission of driller data via data channel also has various sources of error. These are mainly missing values - so called "gaps", "drifting values" and "outliers".

Time problems

The data transmission of real time drilling data over time involves several time issues. Each transmitted values of a sensor need a dedicated time step or time and date of origin. Lacking information regarding time or data, results in a useless value.

Depth measurement problems

Data quality issues, related to depth, have two main reasons. The first one is a result of bad sensor data related to bit and well depth. The second issue arises by reason of the heave compensation on floating drilling rigs. This issue won't appear during the field test related to this work.

Advanced Drilling Performance Measurement

This system is used to automatically detect the various operations on a rig. The system can distinguish between various operations. The main operations are drilling, making and breaking up connections, circulation, running in hole and pulling out of hole during tripping and various reaming operations.

Due to the mud logging systems on modern drilling rigs, numerous sensor data is provided. This results in a high amount of real time data like hook load (HL), block position, flow rates, pump pressure, borehole and bit depth, rotation per minute (RPM), torque, hook load, rate of penetration (ROP) as well as weight on bit (WOB). Data background of the system can be seen below in Figure 14.

With all this measured data, the “Automated Drilling Performance Measurement” (ADPM) system is employed to detect different operations automatically. This model runs successfully over a decade.

This automation of detecting drilling operations like POOH, RIH with or without rotation as well as drilling, reaming, cementing and casing runs can be used to simplify the interface overview of the program.

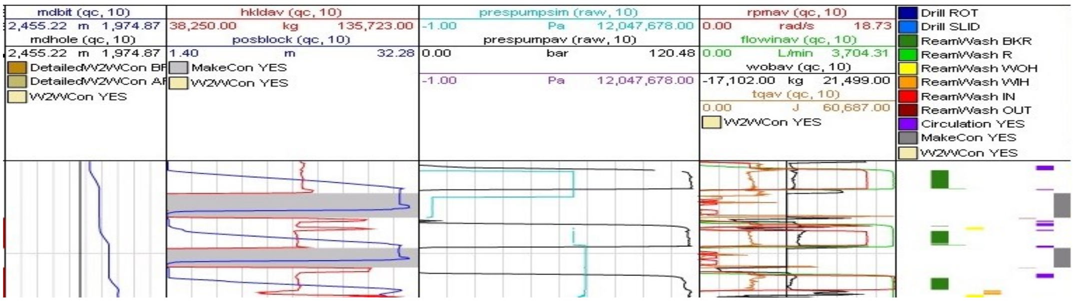

Figure 14: The ADPM is located in this figure on the right hand side. Especially this data indicates a reaming operation which is also determined by the system.

Fingerprinting

The Fingerprinting Chart is a simple approach to determine changes by recognizing alterations in trend after a number of working cycles during operations. To start the fingerprinting chart, a threshold has to be defined. With the definition of a triggering threshold the fingerprinting chart starts every time at the same time of operation. As a result the recorded data can be compared to each over by overlapping the charts. The newest one is indicated by a different color to the older ones. This working principle simplifies monitoring rig operations in a very straight forward looking way.

Two types of fingerprinting charts are introduced and explained below.

Hook load chart

The Hook Load Chart runs on the same principle like the flow back chart. The main area of application is the tripping process. During this, a high amount of drill string stands are pulled out or run into the bore hole. During the movement of a stand the hook load does not remain constant. Due to the fact that the static friction is higher than the dynamic one the hook load increases to a peak at the beginning of the movement. When the drill string is constantly in motion the hook load is reduced to an average value. This typical characteristic of data can identify drilling problems more easily. An increase of peak hook load can indicate differential sticking. A change of average hook load can either be a result due to the higher weight of the drill string or for an example of bore hole instability.

The identification of operations by using the ADPM can act as a triggering threshold. Each finished connection starts a lifting operation during a tripping process.

Flow Back Chart

The Flow Back Chart is a simple approach to monitor the development of a trend. This chart is used to observe the active tank volume after a pump shut down during connection. An example of a Flow Back Chart is given below in Figure 15. With this information, the volume control is enabled, which is adept to detect any changes in active tank volume as a result of changes in flow in or flow out. These changes of active volume can indicate drilling problems like ballooning, fluid losses or kicks. The finger printing of active tank volume starts via a defined triggering threshold. The flow back chart uses pump pressure as the triggering threshold. The value can be defined via the configuration file on the driller's display. For the first versions of the system, 20 bars are exploited as a threshold. Pump pressure is exerted due to the fact, that the pumps are shut down during the making or breaking up connection process.

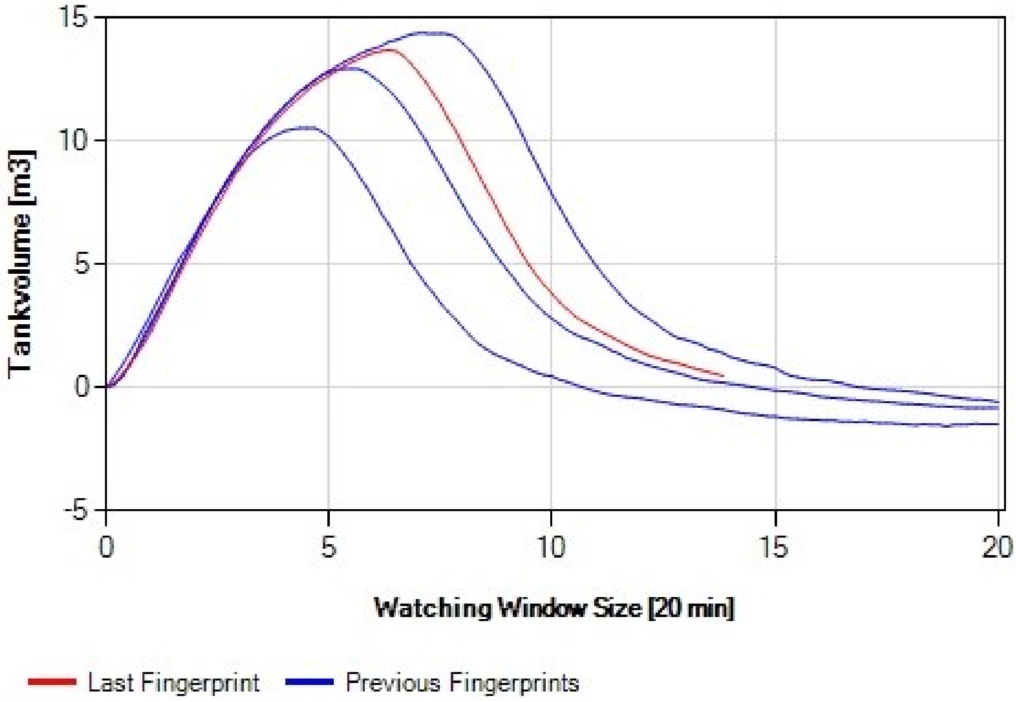

Figure 15: This Flow Back Chart shows three previous data sets shown as blue. The red line represents the actual recoded tank volume.

Driller's Display

The main aim of this thesis is to simplify early drilling problem detection by using an information tool displaying trends of key drilling parameters to a driller. To enable this possibility the previous introduced models and the Finger Printing Charts are used for this information tool called Driller's Display. The working principle of the software is introduced in the following chapter.

First concept draft version

The first phase of development is to plan a draft version of the driller's display. This first step included several stays on rig sites. This meant multiple observations of the operations on site, especially the outline in the dog house. Another focus of attention were various interviews onsite with drillers and tool pushers. The first concept was developed in cooperation with the drillers of RAG rig E-200.

This first step introduced a deep and extensive insight into the working process of a driller in the driller's cabin. The idea for the first version of the driller's display is based on the key drilling parameters, which are already mentioned in the first chapter. Drillers use these parameters since decades to control operations on the rig.

Due to the different operations on site, the driller's display should also vary between various operations. Based upon the interviews, the display is supposed to consider three different possible operations (drilling, reaming and tripping). These operations differ from each other by the importance of certain parameters.

As obvious from Figure 16, the DsD will include two types of systems. An ANN, which is used to simulate torque, hook load and pump pressure. Next to the ANN simulation, a fingerprinting chart is planned to create a flow back chart in addition to a hook load trend chart.

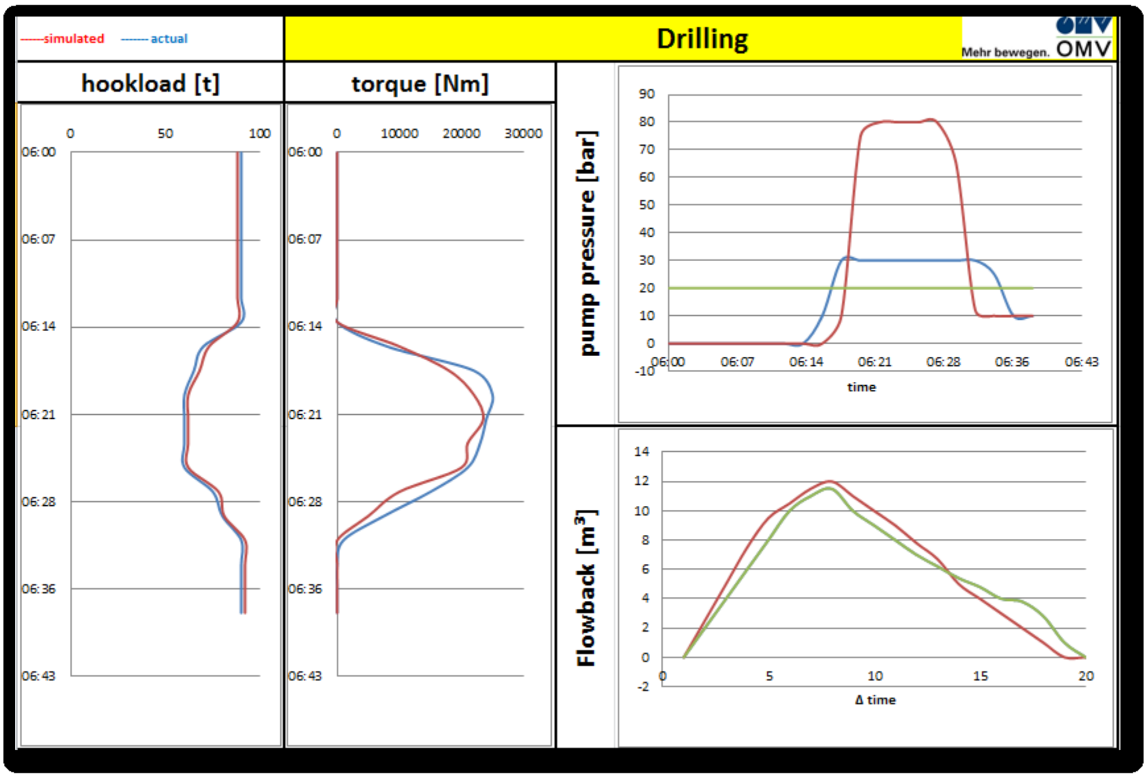

Figure 16: First draft design of the drillers display for drilling operations.

The hook load trend chart is used to analyze a trend development. A trend change seen by an increase of hook load can be used to detect early drilling problems like differential sticking. Differential sticking is indicated by an increase of a hook load peak in the beginning.

To improve the lucidity of the driller's display, the system should display the current operation (tripping, reaming or drilling) in writing as a headline.

Drilling / Reaming (IN/OUT)

For the first phases of the driller's display, the drilling and reaming processes are combined due to the same required information. In comparison to the tripping process, the drilling and reaming process uses the rotation of the drill string. Due to this fact and also the circulation of mud, all three key drilling parameters are considered as important. Consequently, the concept of the driller's display includes actual and simulated hook load, torque and pump pressure.

Furthermore, a fingerprinting method is used to observe the active tank volume during making or breaking up connection. This is based on the fact of unexpected changes in active tank volume during the shut-in and start-up procedure of mud pumps.

Tripping

The most interesting drilling parameter while tripping is the hook load. A graph of actual and simulated hook load is used to detect trend deviations. Three different hook load values occur during operations. The out of the slips weight is the highest weight of a drill string and occurs at the beginning of a drill string movement. This is a result of overcoming static friction. The second weight is the average weight of the drill string during the homogeneous travel with or without rotation. The third weight is the slack off weight. This one is the lowest and occurs during the process of putting the drill string back into the slips. For the first version of actual versus simulated hook load, the average hook load value should be used for the driller's display to simplify the development process.

One important subject during a tripping process is a completely filled borehole to provide integrity of the wellbore. This can be observed after each stand.

The Fingerprinting Chart for the tripping operation is used to analyze hook load development during the movement of the drill string per stand.

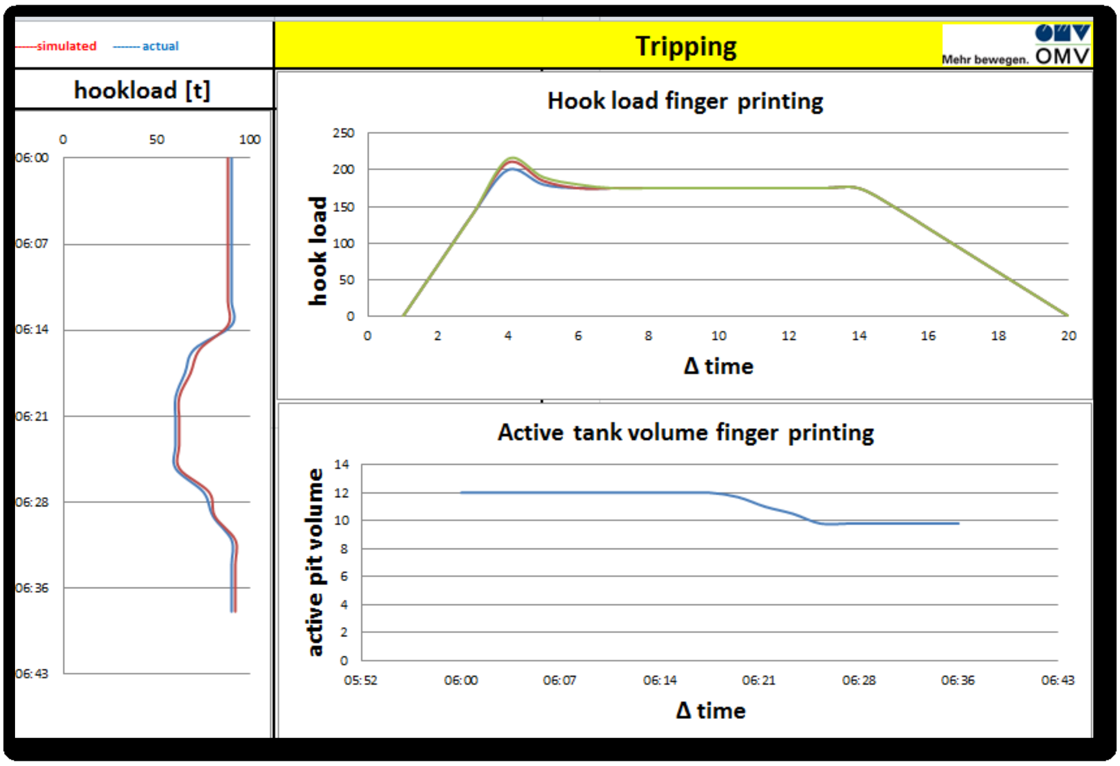

Figure 17: First draft version of the driller's display for tripping operation including the parameters of hook load and active tank volume.

Development process

The development process of the driller's display software is divided into several phases. Every phase is introducing a new version of the driller's display. Each of these phases consists of three development steps.

1st step

The first step involves a think tank to realize any ideas of the driller's display, based on the improvement recommendations, which were discussed in the last phase. The approved amendments are forwarded into step two.

2nd step

The second phase is mainly done by "Think and Vision" to develop the next version of the driller's display software. During this period, no interactions between the developers and other integrated personnel are allowed. This principle supports a clear process of development without interruptions.

3rd step

The third step is the evaluation process, including a testing phase. Achieved knowledge and suggestions for improvements are integrated into the next phase to develop the following version of the driller's display software.

Feature of the first phase

The work flow of the first phase differs to the following in the future phases due to the first step. This is a result due to the fact that the first version of the driller's display is a realization of a draft version.

Configuration of the system

For the third step of each phase, a testing phase of the software is planned. This is provided by a server of "Think and Vision". The access is available via a remote desktop connection. To provide access to various well data and to set up the software of the driller's display, a configuration file is available.

The configuration file has to be generated for each new well.

This configuration file includes:

- Well identification

  The well identification is defined by the unique well indicator (UWI). This standard consists of 16 characters to define the bottom of the wellbore location of each significant drilling or completion event in the borehole.

  In the used configuration file for the driller's display software, the UWI is replaced with an easier individual configuration system. This is done by allotting a three-digit ID for each well. This ID describes the scenario and the project.

- Start and end time

  These two time inputs are used to run the driller's display for a period of testing time. The time input is done via "Unix Time Stamp". The unix time stamp is a way to track time at a running total of seconds. The count started on 1st of January 1970 and every second increases the number by one.

  Next to that the system uses UTC.

- Time window

  This defines the time period of the fingerprinting graphs and the time window of the key drilling parameters.

- Channel definition

  With the definition of the various channels, all different kinds of information are imported, which are used for the driller's display. These include the simulated and actual hook load, the simulated and actual torque, the simulated and actual stand pipe pressure and finally the active tank volume for the finger printing function.

- Design of the Drillers display

  The design of the driller’s display is defined by channels. Each of these channels describes one of the used graphs for the display.

The last two information parameters of the configuration file are specially used for the fingerprinting method.

- Triggering Threshold

  The triggering threshold is employed to define a pump pressure to start the process of the fingerprinting chart. The principle of the fingerprinting chart is described in the chapter before

- Max number of fingerprints

  Defines the amount of latest fingerprints displayed in the chart.

With these defined parameters of the system, the ANN and the fingerprinting system can be displayed onto the driller’s display for early drilling problem detection.

Due that the fact of further software developments the configuration file can be extended to provide the connection between simulation and fingerprinting chart to the display.

Version 1.0 of the Driller's Display

The version 1.0 is the first development step of the driller's display software and the first try to realize the draft version which can be seen in Figure 18 below. The main focus of this version is to test the model's operational reliability.

In the first phase, well data of two wells is used to evaluate the software. This data is supported by two wells, located in the oil field Maari (New Zealand) MR6AP2 and MR8AP3.

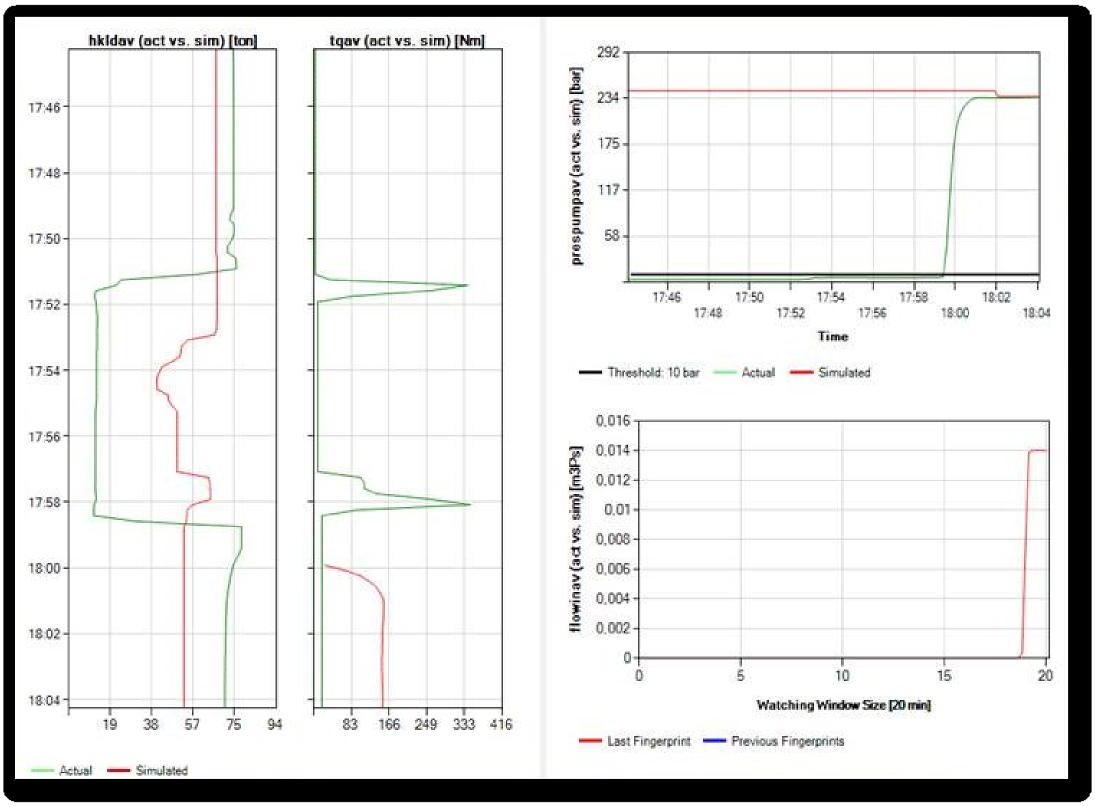

Figure 18: First version of the driller's display, which is provided by "Think and Vision". Red line represents simulation data and the green line actual measured data. The red line of the fingerprinting chart represents the latest measured process.

The main aim of the first version was to evaluate the simulations of hook load, torque and pump pressure and the finger printing chart of active tank volume.

Simulation issue of hook load and torque

As demonstrated in the Figure 19 of the first version (1.0), the simulation of hook load and torque wasn't very successful. The simulation is done via the same ANN as it's used in the pump pressure simulation. Several tests were performed to ensure that this simulation error is not a result of bad well data. Due to this outcome, the ANN is not used for simulating torque and hook load in next versions of the driller's display.

In the next versions of the driller's display, a conventional torque and hook load model is developed as a replacement of the ANN simulation of torque and hook load due to insufficient results. This can be seen in the Figure below by comparing actual values indicated in green and simulated values in red. Further development steps of this model are described in the driller's display version 2.0.

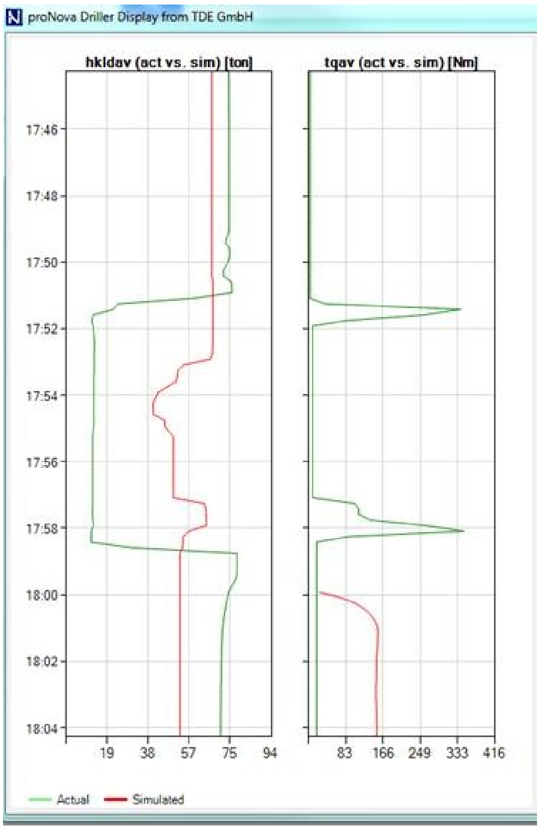

Figure 19: This Figure shows the first version of the Driller's Display with the ANN simulation of hook load, torque and pump pressure. As it can be seen on the left side the simulation of hook load and torque was not successful at all. For this reason a torque and drag model is used to replace the simulation of torque and hook load.

Version 1.1

For the first testing phase, the simulation of torque and hook load is eliminated due to bad results displayed in the Figure 19 above. The displayed hook load and torque (green line) represents the measured values.

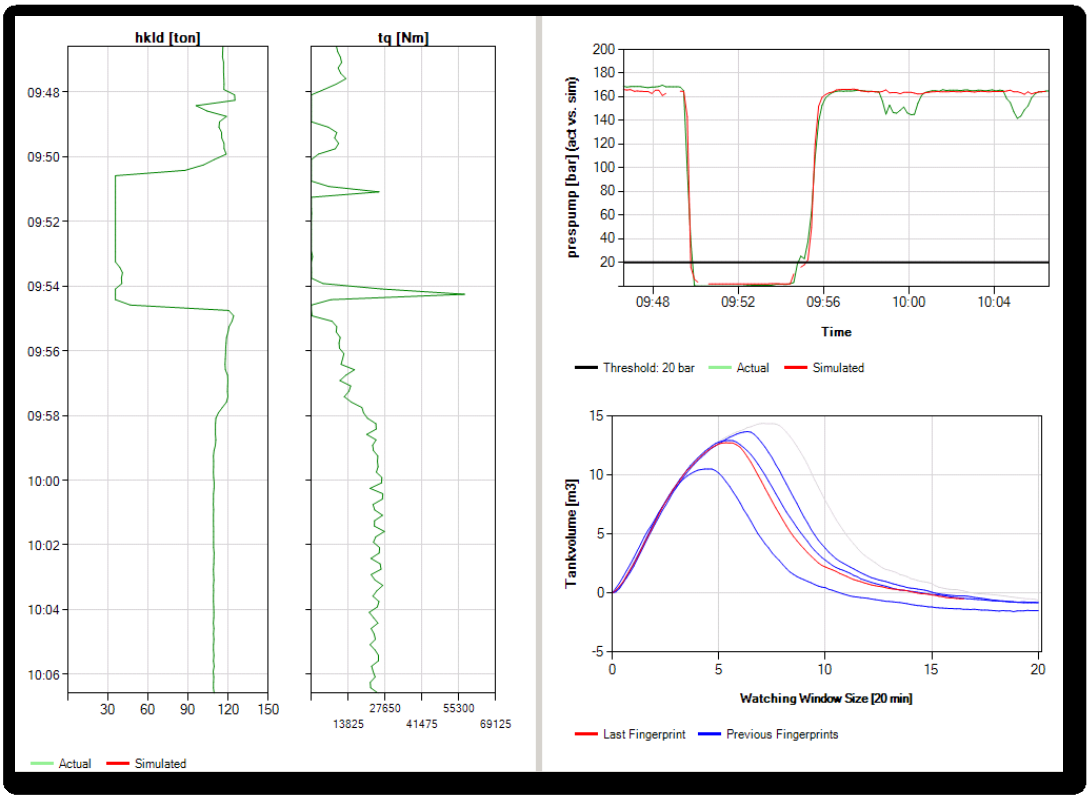

Figure 20: Version 1.1 of the driller's display software is used to evaluate the operation reliability of the pump pressure simulation and the fingerprinting chart. Maari well data of MR6AP2 is used for this figure.

Actual vs. simulated pump pressure

The simulation of pump pressure is done by an ANN simulation. This model is not a complete new product development. This version, which is in use, was already tested for several OMV wells in New Zealand.

The graph of actual vs. simulated pressure is operated in a 20 minutes time window. This time window can be extended in any order by using the configuration file. The green line indicates the actual measured data and the red line the simulated one. The black horizontal line signifies the pump pressure triggering threshold for the fingerprinting chart of active tank volume.

The pump pressure chart is used for the reaming and drilling process. Due to the fact that a tripping operation works without mud pumps, the pump pressure chart is neglected for this operation.

Fingerprinting

The fingerprinting chart of active tank volume is used for all three main rig operations.

The testing phase of fingerprinting is done via version 1.1, by using well data of MR6AP2. This well data supports a channel of active tank volume. Well MR8AP3 doesn't support an active tank volume channel.

The main aim of using the Fingerprinting Chart for active tank volume, is to provide a survey of any changes flow back between breaking or making up connections. A triggering threshold of 20 bar of stand pipe pressure is used to start one cycle. In an event of making or breaking connections, mud pumps are shut off and the pump pressure declines to zero. The duration of recording is defined by the configuration file and specified for 20 minutes. Aside this configuration, the amount of displayed fingerprints can be determined. To test the version 1.1, five fingerprints are used.

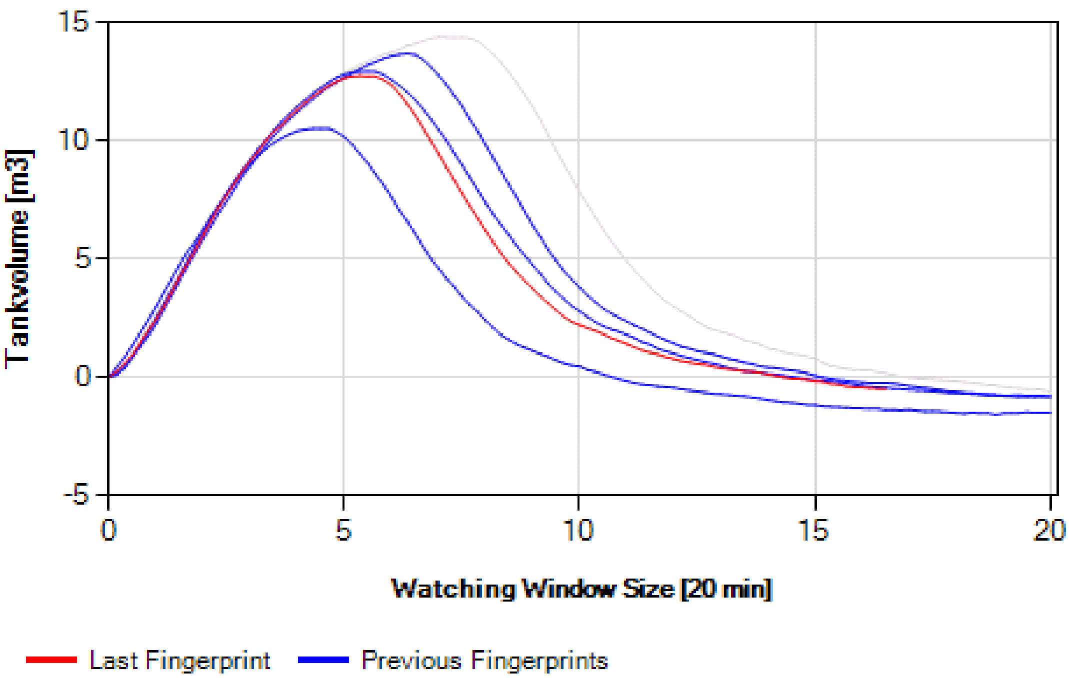

Figure 21: The fingerprinting chart is tested by using well data MR6AP2.

Obvious from analysis of Figure 21, the Fingerprinting Chart simplifies the observation of back flow of the well. The figure shows a variation of maximum tank volume. This can be a result out of several reasons:

1. Mud gain or loss due to drilling problems
2. Increase or decrease of active mud volume due to surface mud conditioner

3. An increase or decrease of mud volume due to the amount of drill string in the bore hole.
4. Decrease of active tank volume due to progress of drilling.

The alteration of the tank volume is done by the driller. The driller is using his knowledge about rig operations to identify the reason of mud gains and losses in active tank volume.

Test phase of Version 1.1

The first test of the pump pressure simulation is done by using well data of MR8AP3 for a day's duration on October 10th 2014. One of the main aims is to evaluate the quality of pump pressure simulation during drilling alongside the crossing between drilling and reaming before making connection, including circulation.

The evaluation of version 1.1 is done by using the output of the driller's display software and comparing them with data, which is used for the software simulation.

First test period of version 1.1

The first test period between 04:45 and 06:15 UTC on October 10th 2014 involves a drilling-reaming-drilling combination.

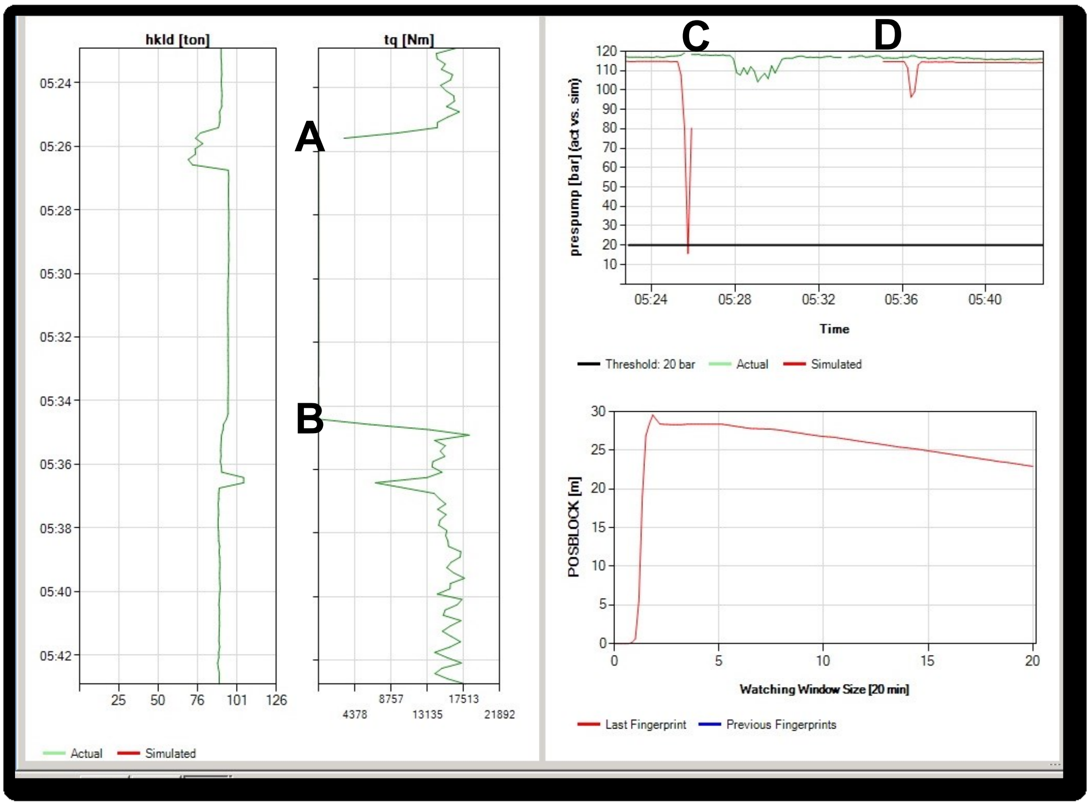

Figure 22: Simulation failure of pump pressure for 10 minutes

Figure 22 shows a simulation failure of pump pressure for 10 minutes.

The main reason of the simulation failure is a result of a lack of data. This can be seen by observing the actual torque values between point A and point B in the figure above. At the time of 05:26 no torque data was available for 9 minutes. Due to this reason also the pump pressure simulation (red line) fails between point C and D during this period of time. To evaluate this issue, a detailed overview is given below including Figure 23 were the work flow of 90 minutes is split up into five parts.

1st part: Drilling

The first one indicates a drilling process. The simulation works perfectly due to the fact that the ANN is primarily made to observe the pump pressure during drilling operation.

2nd part: Reaming

The second part indicates a reaming process. A reaming operation is normally done after each drilled stand. The amount of reaming runs is dependent on borehole conditions. The worse the condition, the more reaming runs are needed to provide a clean borehole. Reaming differs to drilling via lower torque and no WOB. The flow rate stays constant. As a result of a constant flow rate, the pump pressure should also vary in just a small manner.

The first simulation failure can be result of RPM reduction during the 2nd reaming run. The adaption to the new RPM happens in less than two minutes. Even though this is a small simulation issue, this behavior indicates a higher dependency of the ANN on actual real time data especial on RPM.

3th part: Circulation

The third part indicates a circulation operation. This operation in done to improve hole cleaning and remove cuttings from the bottom of the wellbore. It is driven by pumping mud through the hole, while the drill string is slightly off bottom to deliver space for circulation. Another characteristic is that no rotation can be observed and as a consequence no torque is available.

As in the previous operation (reaming process), there is an issue with pump pressure simulation. The ANN is highly dependent on torque, which is a result of RPM; the simulation was primarily made for drilling itself.

Next to that issue point A indicates a downlink. A downlink is used to communicate with the bottom hole assembly (BHA), especially with the directional drilling tools to execute the drilling process.

4th part: Reaming

The 4th part is another reaming run, which is done just one time. The small decrease in simulated pump pressure at the beginning indicates again the dependence of the ANN on RPM and torque.

5th part: Drilling

The 5th part displays the start of drilling operations for the next stand. This is indicated via an increase in rpm and weight on bit. As a result, the torque also increases.

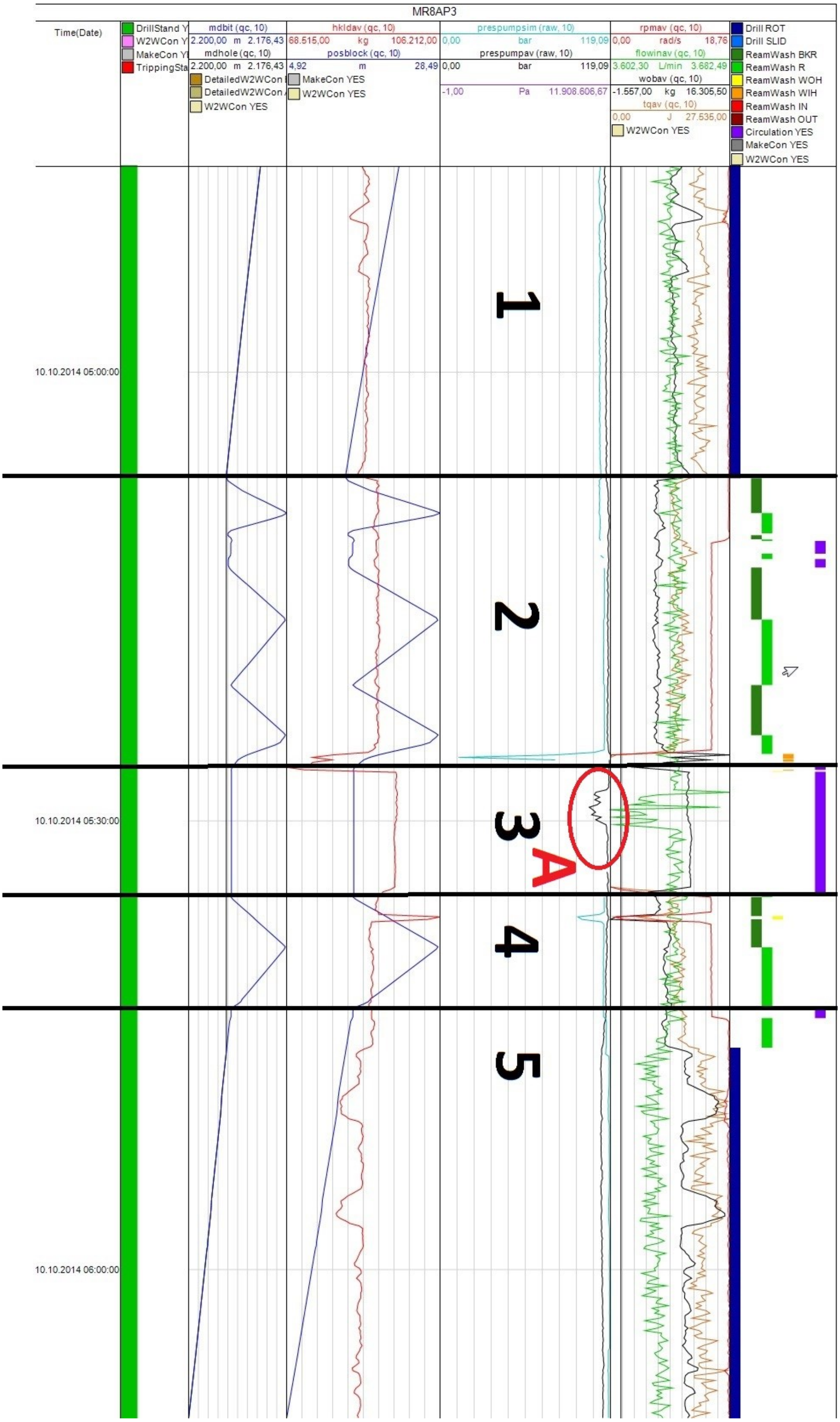

Figure 23: Detailed overview of the work flow, including the 10 minutes simulation issue

Second test period of version 1.1

The second test period displays a reaming process in Figure 24, including making up a connection. Deriving from the pump pressure graph, the pump pressure simulation fails during making connection. It differs from the failure in the previous test period, as the simulated pump pressure does not recover.

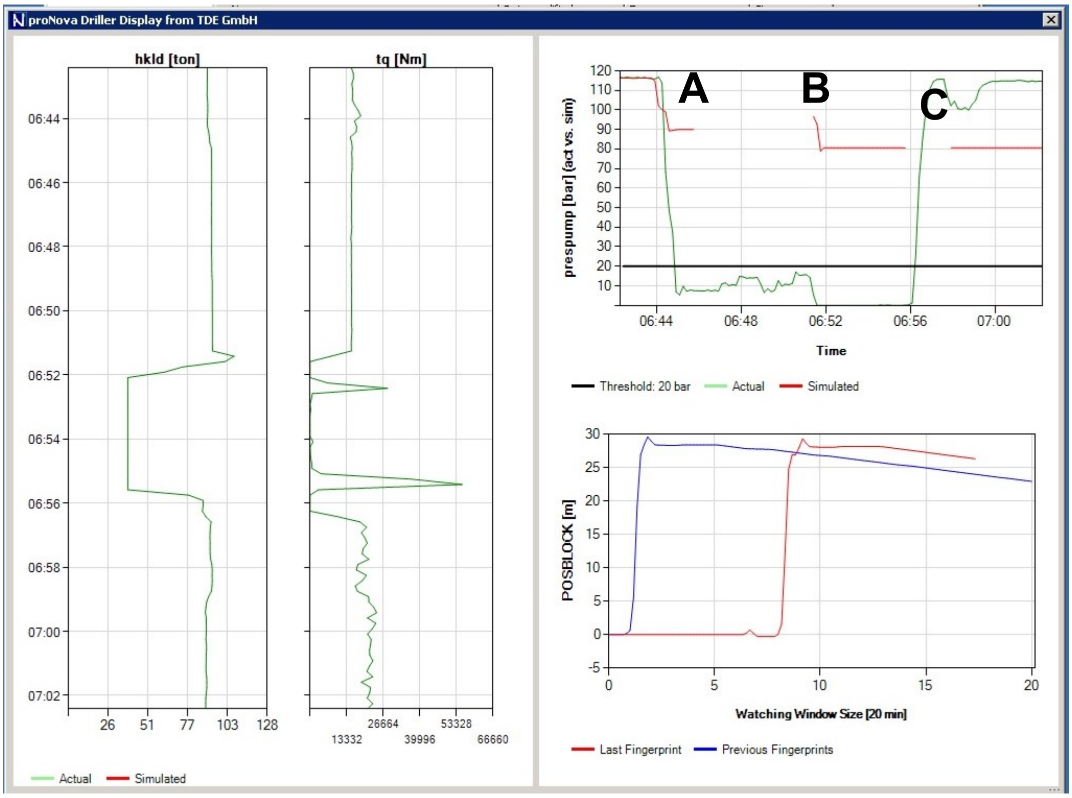

Figure 24: Lack of data during drilling operation, including making up connection and reaming.

The pump pressure simulation (red line) gab in between point A and B as well in point C is caused by a lack of data results in a retraining of the pump pressure simulation. Further information is given in via the next figure especially from part 5 on.

1st part: Drilling

The first part shows a drilling operation, which exerts a good response of simulated pump pressure.

2nd part: Reaming

After each stand of drilling, at least one stand is reamed. On this part, the simulation delivers very strong results and differs to the actual measured values just by one or two bars which can be neglected.

3rd part: Circulation

The response of the simulation during this operation is the same as in the first test period. Due to the fact that the simulation doesn't work without torque, the simulation fails. Compared to the previous test, the simulation of pump pressure also recovers after the end of the circulation process.

4th part: Reaming

The circulation process is followed by a small reaming operation. The reaming process is operated by just a half stand. But nevertheless, the simulation of pump pressure works without issue.

5th part: Circulation

This process is driven by reducing the flow rate and as a result, the pump pressure is also decreasing rapidly in the same manner.

The main problem with this operation is a data issue. Due to the fact that the RPM decreases to zero, the torque should subsequently follow this development. Instead, the torque stays constant for the whole operation at around 20 Nm. As a result of this lack of data, the pump pressure simulation fails. This lack is indicated in the following figure as point A.

6th part: Connection

The 5th part of circulation with a lack-of-data-issue is followed by making up a connection. Due to the combination of these two processes, including the lack of data, the simulation of pump pressure fails again. The simulation program identifies this combination as a major change in drilling operation. Due to this, the simulation of pump pressure restarts the training process of the ANN. The ANN configuration defines 60 minutes to retrain the simulation.

7th and 8th part: Drilling

As a fact of the 60 minutes training interval, the pump pressure simulation does not work for this period of time. The training process can be identified via a linear proceeding pump pressure which can be seen in the figure below starting in the 6th part and proceeding to the 8th part.

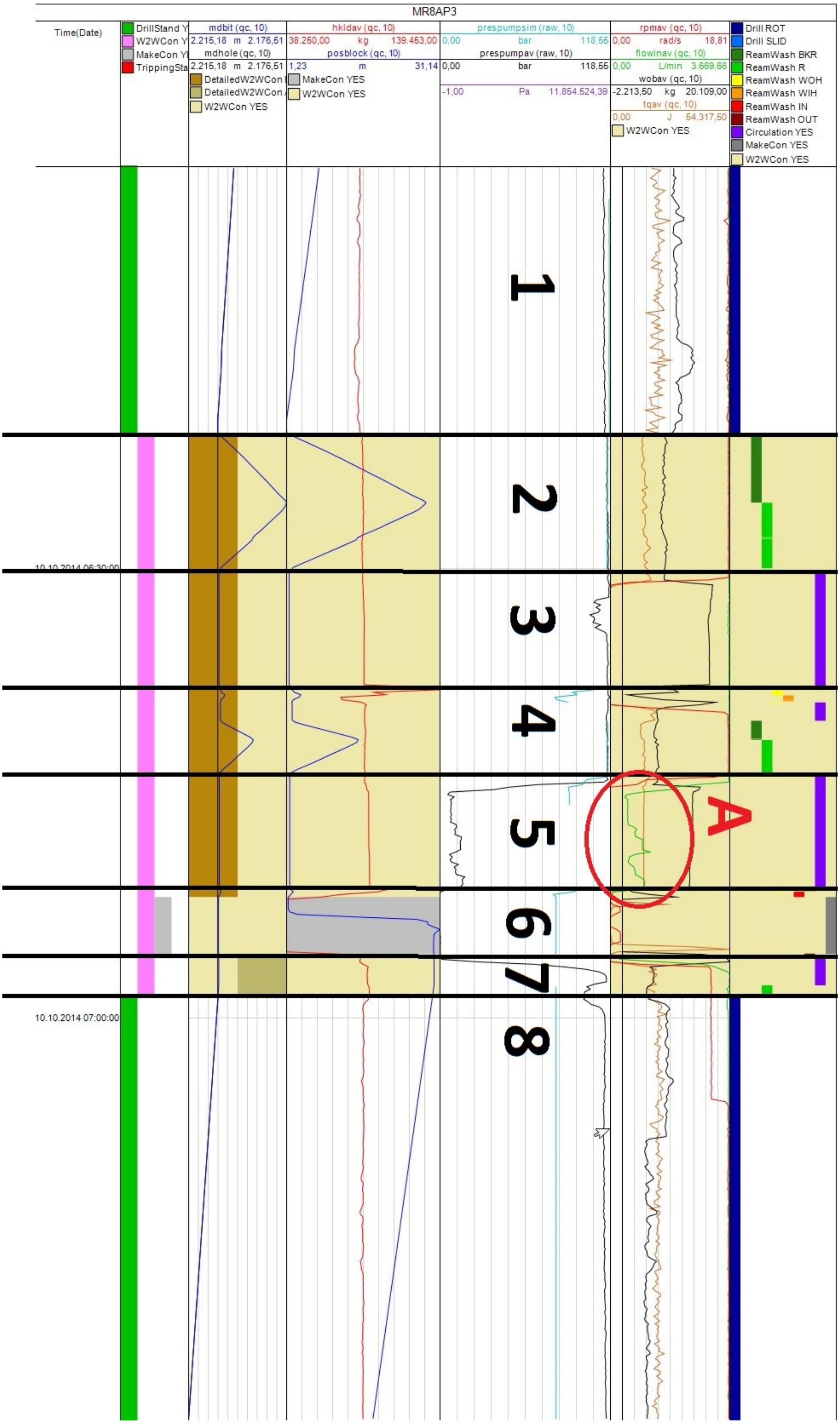

Figure 25: Detailed overview of the rig sensor data during the simulation issue resulting in a new training period.

Third test period of version 1.1

The third period indicates the end of drilling operation shown by the Driller's Display in Figure 26. This process involves various reaming operations at the bottom of the borehole. As a result of all these different operations, the simulation of pump pressure has some troubles with the transitions between reaming and circulation operation.

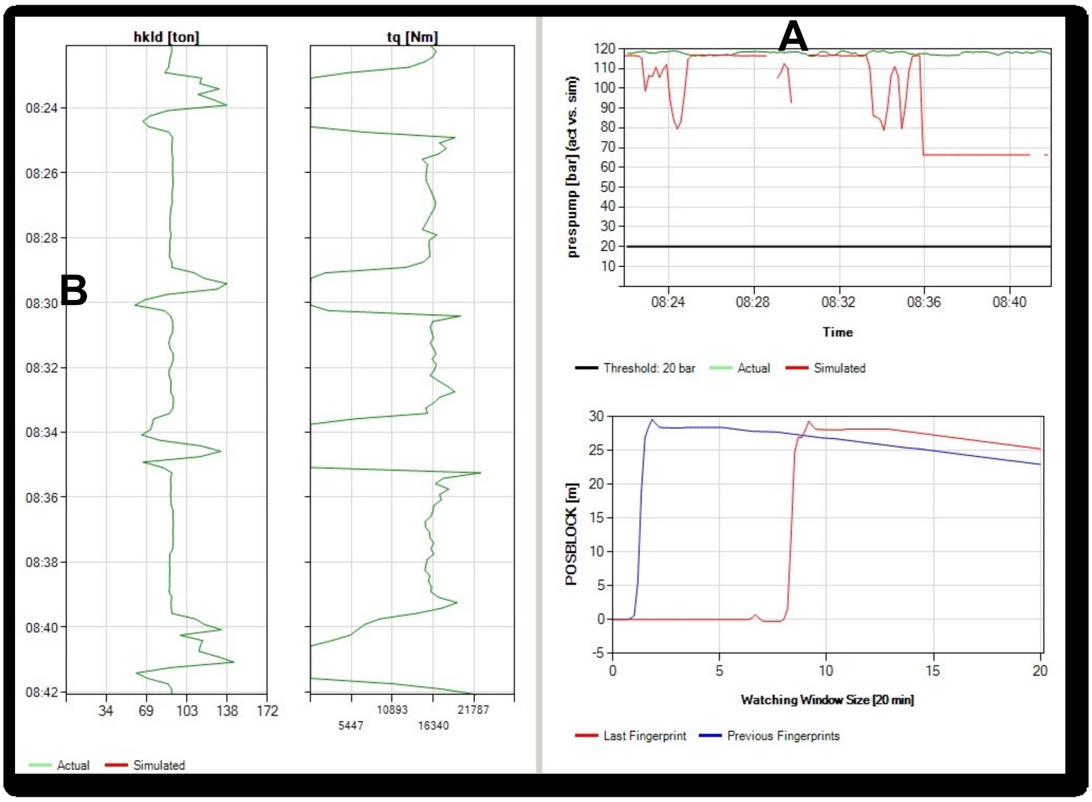

Figure 26: Simulation issue of pump pressure due to several transitions between reaming and circulation resulting in a retraining of the simulation by the ANN.

The main difference between the reaming operations of the 3rd period to the reaming operation of the previous test periods is the repetition of reaming and circulation. This is done to provide good borehole clean-up at the bottom of the well bore.

As it can be seen in the Figure above at point A the simulation of pump pressure (red line) fails for a short amount of time. One reason of this failure seen at point B can be a result of no rotation movement of the drill string.

1st part: Circulation

The 1st part indicates the end of drilling operation for this section. The simulation of pump pressure works during the drilling operation without any problem, due to the fact that the used ANN is primarily designed for drilling operation.

2nd part: Reaming

The reaming process is very similar in term of parameters to a drilling process. The differences in comparison to drilling are a lower applied torque and the upward and downward movement of the drill string to provide borehole cleaning. As a result of that, the simulation of pump pressure works very well also for this type of operations.

3rd part – 7th part: Circulation – Reaming

As already observed in the previous test periods, the pump pressure simulation does not work during circulation due to the simulation being highly dependent on RPM and torque, which is not provided during circulation. Even though there are several transitions between reaming runs and circulation, the simulation is very stable.

Every circulation process includes a peak of hook load. This is a result of picking up and slacking off the drill string during the circulation process. The peak occurs due to the non-rotating movement and indicates the pick-up (highest value) and slack off (lowest value) weight. These two weights can be used to identify drilling problems, which are a result of wellbore integrity.

8th part: Circulation – Reaming

This part differs to the previous one by the combination of reaming and circulation process. Due to these circumstances, the simulation of the pump pressure is overloaded (point A), which results in a new training period of 60 minutes.

9th part – 11th part: Tripping / Reaming

The 9th part shows the start of tripping operation. This part is operated like a reaming process and it's called "tripping rotary". The circulation of the mud system remains as during the drilling process and the rotation movement and torque development. The difference between rotational tripping and back reaming is an increase in torque during this operation.

The 10th part shows the first connection of the tripping process. As already mentioned, the simulation of the pump pressure during the tripping process doesn't work properly. Nevertheless, in comparison to ordinary tripping operation, the displayed one is operated by circulating mud and rotating the drill string. Due to this fact, the simulation of pump pressure should work better. The main reason of pump pressure simulation failure is the retraining process during this period. Other tests have shown that the simulation has the ability to work very reliable during the rotating tripping (back reaming). The only requirement is that the simulation is not in a retraining's process during start of the rotating tripping process with circulation.

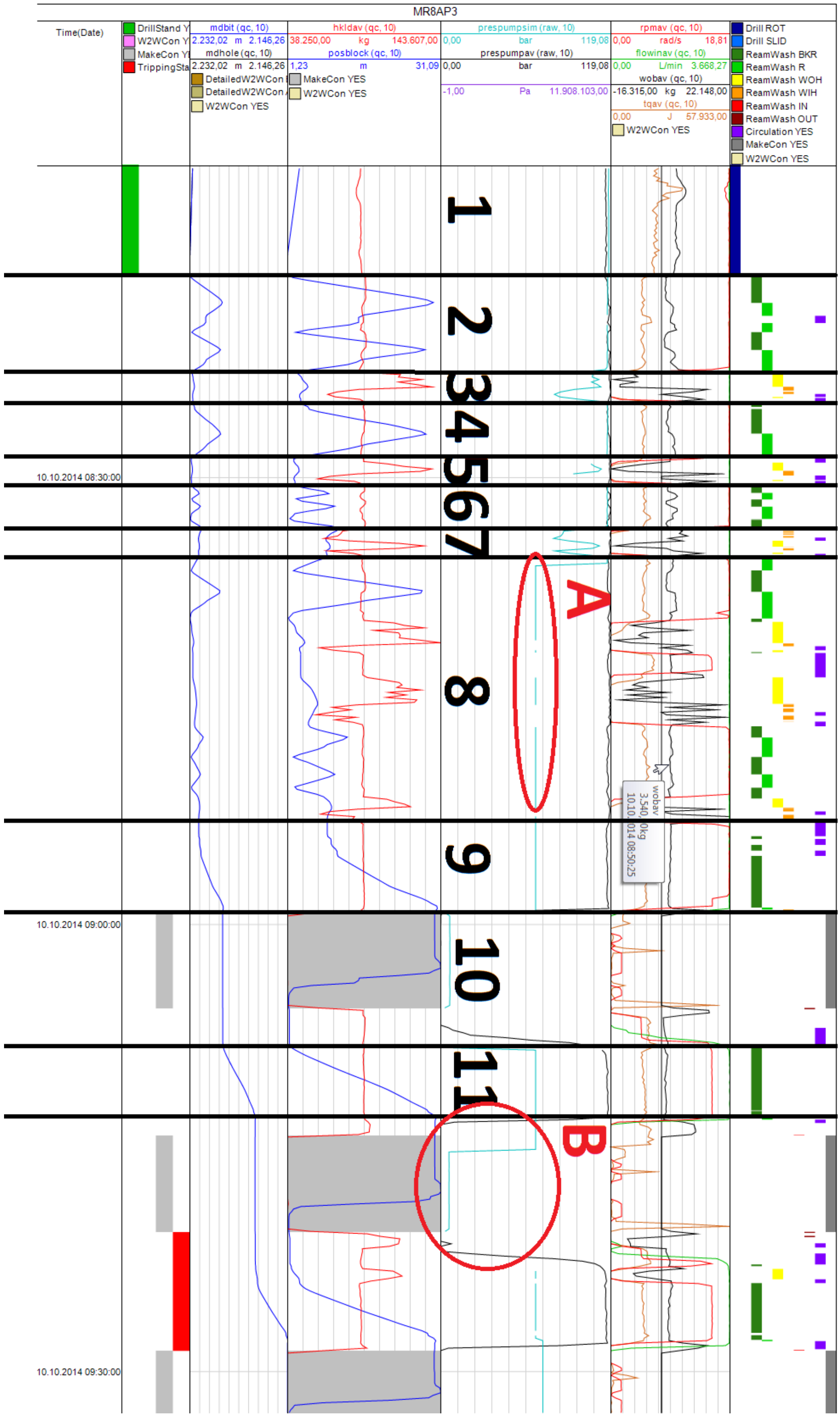

Figure 27: Detailed overview of the deepest part of the drilled section including the end of drilling operation, the transition across reaming operation due to hole cleaning and start of tripping operation.

Main test results version 1.1

The first version of the driller's display was used to test two functionalities of the system.

- Fingerprinting: flow back chart of tank volume
- ANN simulation: pump pressure

Fingerprinting using the flow back chart

The Fingerprinting Chart to observe tank volume by using a flow back chart achieved high results. The only issue of the first tests is a partially missing tank volume channel.

ANN simulation of pump pressure

The main issue of simulation is a high dependence of RPM and torque. The simulation was originally made to simulate pump pressure just for drilling operation. As a result, the current simulation cannot be used for tripping and circulation processes. A simulation of a reaming process should be possible. The only issue regarding this operation is a fast combination of several changes between reaming and circulation, which can result in a repetition of the systems training.

Another issue is the dependence an actual real time sensor data. A lack of torque or RPM data results in a simulation failure. The start of a trainings repetition process depends on the duration of a lack of data. The longer a lack of data occurs the higher the possibility of a required ANN trainings repetition is. This can be seen very clearly during previous testing phases.

The repetition of the trainings mechanism is the 3rd issue. The needed interval to repeat the training takes at least an hour. This result in an outage of simulation during this period of training. This training repetition process is similar to the training start of a new system simulation.

The main issue of this long interval is the missing pump pressure simulation during critical drilling operations. This problem can be neglected for a training process during the first hours of drilling a well. To improve the reliability of the system, a retraining during drilling operation should be performed at a shorter interval.

Driller's Display 2.0

Functions of the driller's display

The following functions are used to develop further versions of the driller's display software to improve the driller-rig interface. Already introduced versions of the Driller's Display 1.0 and 1.1 in addition to new ideas of models are used to develop a new Driller's Display. Furthermore, the display splits up into three different parts, according to the various operations at the rig site (Drilling, Reaming, Tripping).

Key drilling parameters

The key drilling parameters are further considered to improve the interface between driller and rig. Due to this fact, parameters of torque, hook load and pump pressure are used two different types used:

- Torque and hook load depth based and pump pressure time based
- Torque, hook load and pump pressure time based

The depth based torque and hook load diagram is using a conventional torque and hook load model with the three different types of hook load weights (pick-up, slack off, rotation of bottom)

Fingerprinting Chart

The fingerprinting charts are already introduced. In addition to active tank volume fingerprinting, hook load fingerprinting should be integrated. Block positioning can be used as a threshold to start the chart of fingerprinting and early drilling problems like differential pipe sticking could be indicated by trend analysis of the peak hook load.

Operation Indicator

Due to the fact that different operations of drilling, reaming and tripping require different information the operation indicator defines the current operation on site and displays the required information.

With this kind of information the idea of a communication tool between the responsible personnel can be established. It should allow an engineer at the office, to easily recognize, which operation is currently ongoing.

Communication tool

During interviews with several drillers' on various rig sites, one major aspect to improve the interface was discovered. The idea of using the DsD as a communication tool between the driller and the responsible personnel was born.

The main reason of the DsD idea is to improve the interface between the driller and the rig in addition to the communication between the driller and other responsible personnel on the rig site or offices. A more sophisticated communication tool is needed due to the fact that the drilling engineer of an operator in the office is responsible. The big advantage of the DsD is the possibility of displaying central information in a clear and efficient arrangement.

Good communication between a driller and - for example - a drilling engineer, results in more efficient drilling operation. The introduced combination allows a quick response in case of early drilling problems. If any of these occur, a driller and an engineer can jointly define subsequent countermeasures.

To provide a good and fast communication interaction between a driller and the responsible personnel, the communication can be started on either side. To support the information sharing process, the DsD is also available to the engineer. In addition, a video conference with other personnel could be added.

Drilling Window

The idea behind the drilling window is to operate drilling operation under perfect drilling parameters. As a result of using perfect drilling parameters the ROP (rate of penetration) increases to the maximum possible shown in the Figure below. The idea behind the Drilling Window came from Richard Kucs, adviser of this thesis. To allocate highest possible ROP, the introduced key drilling parameters are used to optimize drilling operation:

- WOB
- Torque
- Flow rate

This drilling window could be integrated into a future driller's display. An operation within ideal boundary conditions reduces the occurrence of drilling problems. In addition, the mean required duration for a well can be reduced.

The black dot indicates the actual drilling parameters. As long as the dot remains in the green area, an optimum ROP can be achieved.

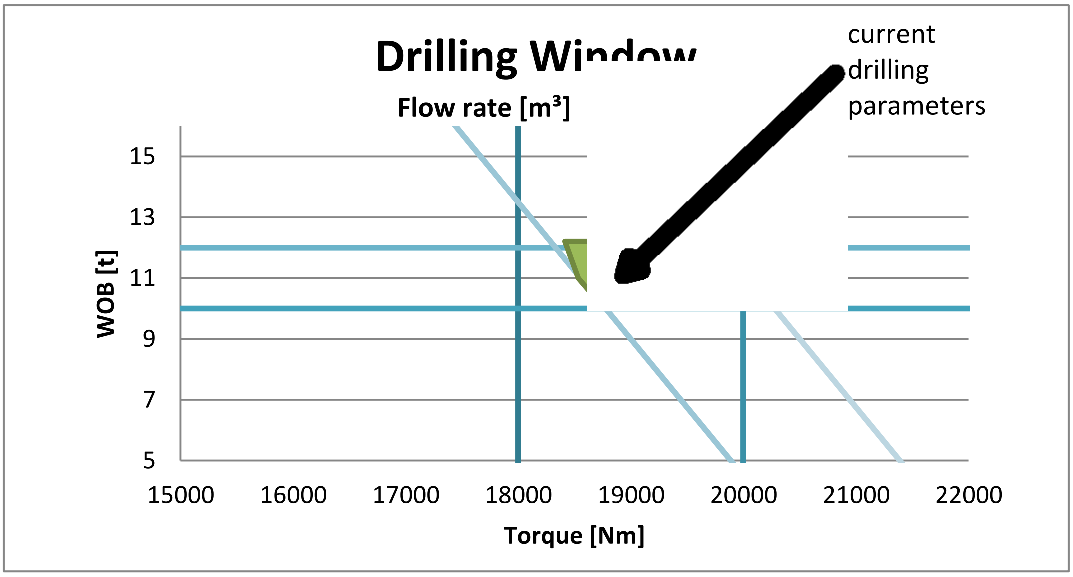

Figure 28: The driller's window is used to find the optimum of ROP during drilling operation. Due to the fact that the ROP is dependent of the key drilling parameter, this application is very useful to integrate into the DsD system.

The green area indicates the driller's window. As long all three key drilling parameters remain in the individual min/max range, the ROP remains at the highest level.

To incorporate this concept into a running system, much of effort is needed due to the complexity of this problem.

Concepts Driller's Display 2.0

The major difference between the already existing version of the Driller's Display and the future concept is the classification between the drilling, reaming and tripping operation. These are based on the facts of different information requirements of the various operations.

Drilling operation

Due to the required information during drilling operation, various models of the systems are included into a new version.

To optimize ROP (rate of penetration), the introduced drilling window is used in future development of the DsD. Furthermore, a conventional torque and hook load model is included. The mean values of POOH (Pulling out of hole) & pick up, RIH (Running in hole) & slack off and ROB (rotating of bottom) are used in the shown toque and hook load model. To observe stand pipe pressure, the extensively tested pump pressure simulation is located on the top right position. The monitoring process of the active pit volume during a new weight to weight connection is located on the bottom right position.

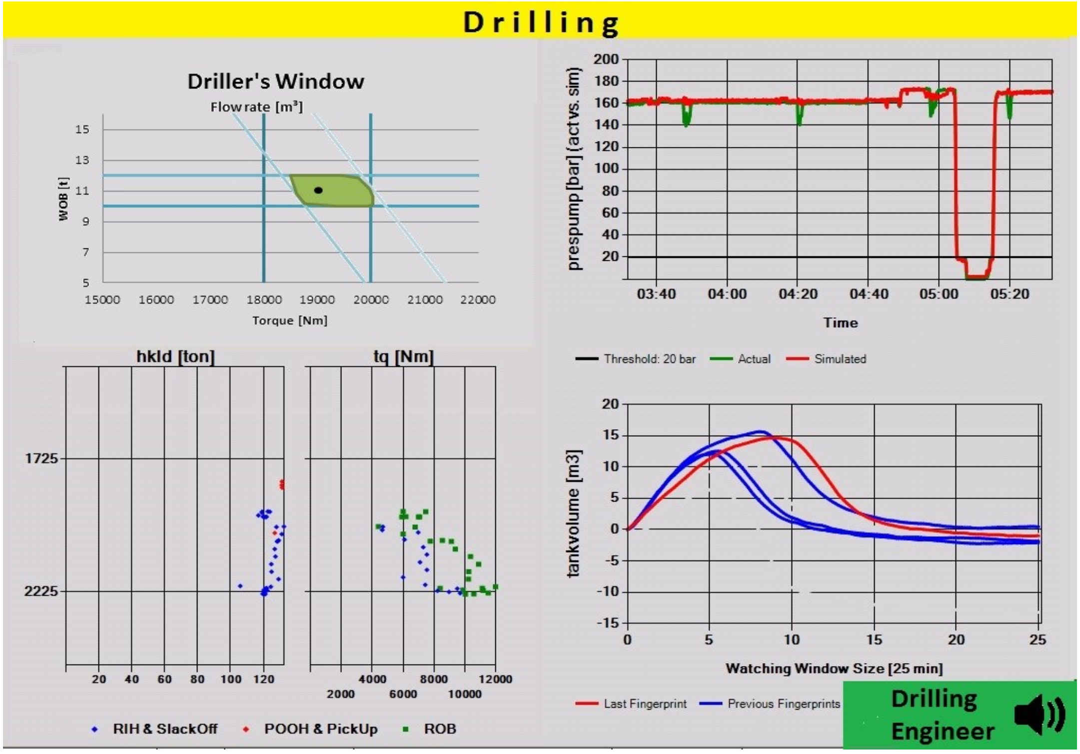

Figure 29: The further developed DsD of drilling operation includes the driller's window, a torque a hook load model, a pump pressure simulation and a fingerprinting chart of active tank volume. Furthermore, an operation indicator is used to display the current operation. Next to that on the bottom right side, the communication tool between the driller and the company man or drilling engineer is shown.

Aside of all the available information related to operations on rig site, a communication tool is included and shown in the bottom right corner. In Figure 29, communication between a driller and a responsible engineer is shown. The drilling engineer has the same display information of current operations like a driller. In combination with an operation indicator, the engineer has a well detailed overview on the current situation at the rig site. This permits the engineer to evaluate a critical situation in a very fast manner. As a result, decisions for consequent actions can be determined in a very fast and efficient way.

Reaming operation

Due to the fact that the reaming process is very similar to the drilling process, the reaming display uses the same interface shown below in Figure 30. The only difference to drilling operations is the non-usage of hydraulics. This device is only used for drilling operation.

Due to the fact that reaming is used to condition the borehole, the torque reading is specifically important.

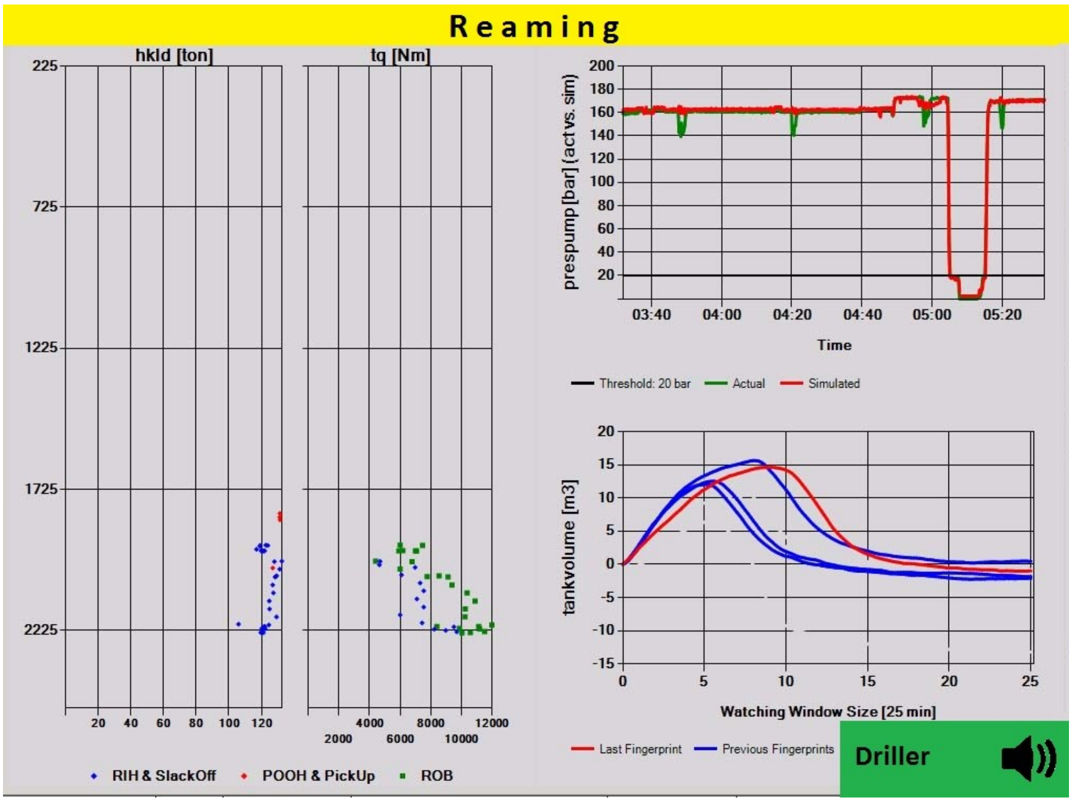

Figure 30: A reaming process is very similar to a drilling operation. The main difference is that the reaming process does not include an increase depth progression. As a fact, the driller's window is not included.

Tripping operation

The tripping process is one of the three main operations. The process differs to the reaming and drilling process in various models.

There are two main differences:

- Tripping may not always include rotation of a drill string
- No circulation done

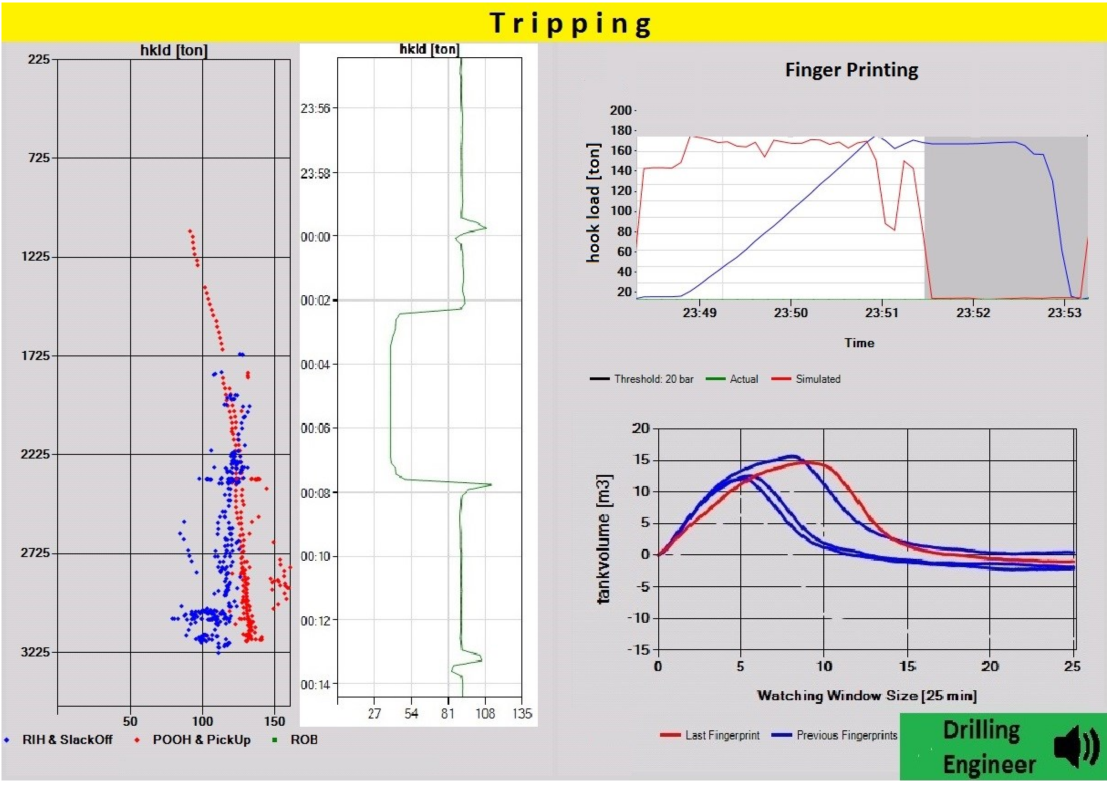

Figure 31: The tripping process is mainly dependent on hook load. Due to this reason, the display for tripping includes hook load versus depth and time and a fingerprinting chart including block position. The active trip tank is observed like the active tank volume during drilling and reaming.

One of the main aims is to provide a properly filled borehole. The mud in the borehole is one of the safety barriers, providing the integrity of the wellbore. An under pressure situation can result in a kick. Next to that the tripping speed is also limited due to the surge and swab.

An observation of hook load changes is very crucial. Any changes of hook load peaks at the beginning of every stand movement can indicate (for example) differential sticking. In addition to that, observation of slack off, pick up and rotating of bottom hook load versus depth is able to identify any changes of the borehole geometry. Furthermore, a simulation of hook load versus time can be added to the system.

Future driller-rig interface DsD 2k30

Under the term of a prospective DsD one means a look ahead into the driller's cabin future 2030. This part introduces future-oriented thinking to improve the interface between the driller and drilling rig.

The main idea behind this is the elimination of all common instrumentation the working place of a driller directly on the rig in the dog house. The common instruments are neglected and not used in the future concept and are replaced by using virtual reality interface so that the driller is able to control the rig without being on the rig site.

The communication part is the main link between a driller and a rig; it is supported via the interface. Old communication tools, which are introduced at the beginning of this thesis shall be removed and are replaced by a completely new communication technology. The idea behind this is the advancement to reach rig automatisation, which will eliminate the need for immediate personnel on the rig floor.

Hardware

As already mentioned above, a future DsD is planned in a completely new way by using state-of-the-art technologies. These technologies are already in use in other technical divisions like the car industry, but not integrated in any drilling technologies at the moment. Due to this fact, the reliability of these technologies has already been widely tested in all different kinds of applications.

The following part covers all the needed hardware to support the development of a DsD 2k30.

Virtual reality

The main idea behind is a replacement of all different kinds of displays by virtual reality. Visualization of data and interactions with the rig should be integrated interactively. To enable the possibility of a virtual reality environment of a rig, a 3D camera system could be used to operate the rig anywhere in the world.

Oculus rift

These glasses provide the possibility of a rig floor without a driller's cabin and a driller. Due to the design of a 3D visualization of a rig floor it is possible to provide a communication tool to support the driller rig interface. This interface is used to observe all activities and interact with the rig.

Figure 32: Oculus rift developer kit 2 with an additional motion sensor (http://www.oculus.com/blog/announcing-the-oculus-rift-development-kit-2-dk2/: seen: 20.11.2014)

Motion sensor

Motion sensors are used together with virtual reality glasses to track the driller's view. This feature provides a very suitable interaction between driller and rig. The various motion sensors are either hardware or software based.

Hardware

- Accelerometer
- Gyroscope (rotation per second)

Software

- Gravity (3D gravity measurement)
- Linear acceleration (3D acceleration measurement)
- Rotation vector sensor (orientation of the device/glasses)

These motion sensors are located on the glasses and provide information of the driller's viewing direction to the software. As a result, the software provides an interaction between driller and rig. Further information and area of application of its functionality is delivered in the software part of the future driller's display.

In general, nowadays motion sensors are already included in visual reality glasses.

3D input device

State-of-the-art input devices are able to replace knobs, buttons and joysticks. These common input devices could be replaced by 3D technology due to the development of intuitive input possibilities. There are two options to interact with the rig via the hands.

Cyber gloves

This technology is in the development phase since over 20 years. Due to this fact, the sophistication and the reliability is quiet high. The developed industrial design of these devices can be seen below. The cyber clove is able to track all motions of an arm, a hand and fingers. The communication between the device and the software is supported via wireless LAN.

The big advantage in comparison to the leap motion technology is that the gloves can be designed to deliver feedback. With this possibility, the action of grabbing something visually can be simulated by force feedback.

Figure 33: Cyber glove III represents one out of the two possibilities to introduce 3D input technology. http://www.cyberglovesystems.com/products/cyberglove-III/overview , seen on: 20.11.2014)

Leap motion

Leap motion is a small device which is able to track both hands and all 10 fingers without using a glove. The big advantage of leap motion is the non-usage of wearable sensors like in the glove technology. This feature supports simplification of rig operation control.

Figure 34: Leap motion demo which indicates the capability of tracking hands and finger motions.

To provide interactions between a driller and a rig, leap motion sensors can be combined with virtual reality glasses. This would enable motion tracking of hands and fingers to interact with "Oculus rift" visual information.

3D camera

A 3D camera is needed as an optical scanning of the rig floor. With this process, the system can catch all rig floor devices (iron roughneck, drill pipe, top drive and so on) and generate a 3D model. The working principle of the camera is a 3D scanner.

Communication tool

Nowadays, a typical communication tool on the rig site is supported via an internal telephone. This is used to communicate with the company man and various service companies. A communication between the driller and responsible engineers in the offices is not supported. Due to this fact, the communication tool of the DsD 2k30 does not only provide communication with different personnel on the rig site but as well with engineers, located in the offices.

For further development of a communication tool, a voice-command system can be integrated. With this system, the driller-rig interface is created via voice command in both directions. Voice control is based on the principle of voice recognition and already widely used in telecommunication. Further developments are also introduced in aircraft cockpits and are called “direct voice input”.

Camera monitoring system

Due to the idea of rig automatisation, a camera monitoring system is essential to observe all the operations during a drilling process. Nowadays, it is common to observe the draw works, top drive, monkey board and sometimes the shale shakers. This monitoring system can be integrated into virtual reality visualization.

Software

This chapter describes how to use the already introduced hardware to develop the DsD 2k30. The main aim is to combine various devices to enable a driller-rig interface, which introduces the 21th century on the rig floor.

One of the goals to control the rig intuitive is the usage of a 3D virtual model in assistance with the capability of 3D motion tracking and voice recognition.

The observation of overall rig operation is the second aim. This one is based on the idea of early drilling problem detection. Drilling problems should be indicated with introduced key drilling parameters and a fingerprinting mechanism. This information should be provided to the driller interactively in a virtual 3D model.

3D model

To make this possible, a 3D model of a rig, especially of the rig floor, is needed. The 3D model is developed by using a 3D camera system including software, which models the rig floor digitally. This 3D model forms the basis of the DsD 2k30. All the different tools like the iron roughneck, slips, top drive and so on, are modeled and integrated into a 3D system. The drill string as a major component is also included in the system. As a result, the entire tools are indicated on the head up display (HUD) virtually.

In addition to that the all hardware control units used to steer and monitor all rig operations are getting replaced by using a forward looking digital version of them. As a result there is a huge possibility of remodeling a system from scratch on. For example the idea of using little symbols of mud pumps in the HUD to control the flow rate or a top drive symbol to control the RPM of the drill string.

Functions

One of the main work tasks of a driller are monitoring and controlling the rigs machinery and operations parameter.

The possibilities of controlling all the machines, which are used during various operations, are already described in previous parts of this thesis. The monitoring of all parameters either geological or operation-dependent is currently done via a geology data system and mud logging system systems.

To simplify controlling a rig, essential parameters (key drilling parameters) can be used to operate three main rig machineries (draw works, top drive and mud pumps).

Control

The first main aim is controlling the rig by using hardware, which is formerly introduced in combination with a 3D model provided via software. The driller should get all relevant drilling information in front of his eyes due to his view movement. The movement of the head can be tracked via motions sensors, which are introduced in the hardware part. If the driller is looking at - for example - an iron roughneck, the HUD display should indicate this tool and display it digitally in the HUD.

Figure 35: The principle of object identification of the system should work as shown in this picture

The idea behind this is to control the entire tool by using hands or voice control. To simplify the interface between the driller and the rig little symbols of tools are available in the view of a driller for interactions.

Iron roughneck

To make up or break connections, most of the time an iron roughneck is used. Due to the indication of an iron roughneck on a HUD relevant information about the tool like connection torque can be shown. The activation of the iron roughneck is done via the 3D input devices like leap motion and cyber gloves. On the basis of the advanced functionality, the control of the rig can be done interactively. The iron roughneck can be steered virtually to make or break up connection. At the very moment of the virtually steering process the real iron roughneck makes the same movement. Due to this functionality, a connection - for example - is conducted by pulling the iron roughneck to the drill string. A rotating movement via the hand controls the opening and closing process. Further possible applications will be described in the lower sections.

In addition of controlling the movement of the iron roughneck, the main important parameters of the device are shown directly next to it - like required and applied torque.

Slips

Due to the work flow of making or breaking up connections, an additional tool is needed to release the hook of the drill string weight. To make this possible, slips are used to hold the weight of the drill string. The activation of slips can simply be done by just clicking on them or using the voice command system for activation.

Mud system

As already discussed, mud pumps control two essential parameters of drilling operations. These two parameters are highly dependent on the SPM, which is manipulated by the driller. A higher SPM results in a higher the flow rate and the pump pressure. A newly developed system could be capable of controlling a mud system by adjusting flow rate interactively via the HUD. This could be done via adjustment of a bar next to the mud pump, which controls the flow rate.

Next to the mud pump symbols, a load pump symbol can be also added to control these pumps. By just tabbing on the symbol the load pump can be activated.

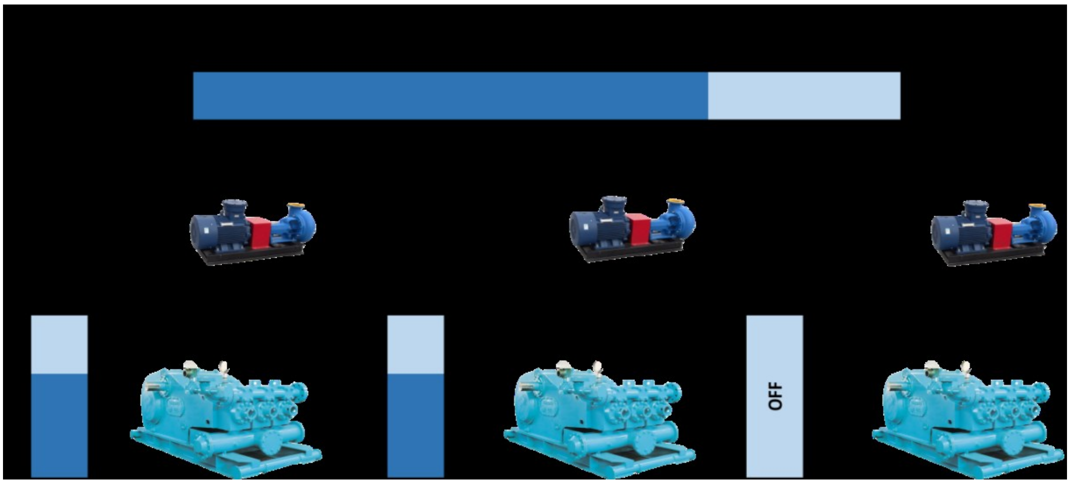

Figure 36: The new control system of the mud system is a combination between observation and controlling the system. The clear arrangement paired with the intuitive interaction simplifies the driller rig interface.

Top drive

The top drive controls two parameters of rig operations. The first one is RPM to enable rotational movement and the one, which is measured at the top drive, is torque. Torque is a result of the drill string rotational movement and the resulting normal forces on the borehole wall or the bottom of the well. To control the top drive in the introduced system, there are three possibilities; the activation of the steering input can be started either by looking up to the top drive, visually activating the top drive symbol (located next to the mud pump symbols) or using voice command. Both of the visual illustrations are used to display the current operation parameters and provide the possibility of changing the rpm of the top drive. The input process provides the same interaction possibilities as for the previous tools.

Figure 37: Indicates the turning direction including the RPM and torque reading.

Draw works

The draw works is used to move the drill string up or down. Due to this fact the draw works controls hook load and WOB. WOB and hook load are directly related to each other. WOB is calibrated value of the driller (set zero: bit at bottom, pump rate and rpm at drilling condition). An advanced system should be capable of re-setting and calculating WOB automatically.

The movement of the pipe string is done via pointing manually at the drill string and pushing the string down or up. The same motion is already widely used for example in the mobile phone business to scroll up or down. The current weight of the string and the WOB is displayed via the HUD next to the drill string. A “conventional” graph like the “Martin Decker” can be integrated into the virtual display as well.

Monitoring

Safety

The big advantage of rig automatisation is the non-requirement of personnel on the rig floor during most of the time. Due to this fact all processes of rig automatisation consider no personnel on the rig floor and are therefore designed thusly. As a result, no one is allowed to enter the rig floor at various operations to provide an elevated safety standard this can be provided via barriers.

Early drilling problem detection

Referring to a previous part of this thesis, early drilling problem detection by simplify information to the driller is important to optimize the drilling process and to improve the interface between driller rig. The current design of the driller's display, which is already developed, cannot be transferred directly into the HUD display configuration. But still, to be able to provide this feature, some adaptation can be integrated into the new system.

The system can be based on the simulation of torque, hook load and pump pressure as well as considering the fingerprinting mechanism of hook load and active tank volume. The information of simulations can be displayed like a gauge design in a restrained way. As long the simulated and measured value of e.g. hook load remains close, the gauge is displayed in the background. The displayed values are the current values. If there are any changes in trend, this information gets enlarged and alterations in the trend are shown over a period of time. This could be done in the same manner like it is has already been done in the first version.

Failure report

Over a longer period of rig operation, different kinds of failure are recorded and presented to the driller. All these failures are prioritized depending on their impact and/or importance. Nowadays most of the failures can be neglected. An advanced system as it is planned in this section should be able to accurately define only the important ones.

These major failures have to be presented to the driller in a clear and intuitive way. The information is given at the location of their occurrence. For example: a pump failure is indicated by a red marked pump symbol with additional information on the failure.

Drillers Window

This tool is already introduced at the driller's display 2.0 to optimize drilling operation and increase ROP. An implementation of this idea into the DsD 2k30 is highly recommended.

The design of the information chart has to be developed along the testing phase of the 2nd version of the driller's display, which is presented in the chapter above.

Camera system

State-of-the-art drilling rigs already provide a good amount of cameras to observe all rig operations. All working areas, which are involved in the works of a driller, have to be monitored to improve the HSE standard. The interactions of the system with a driller are designed with intuitive handling.

This mode of operation can also be applied for all different kinds of cameras placed on the rig floor, positioned next to the shale shakers, mud pumps, draw works, mud tanks and so on.

Hardware

The main idea of the driller's display is to support the driller through information to identify drilling problems early. The required application of the display itself is the ability of displaying a transmitted video stream. The display of Version 1.1 and 2.0 should not provide any direct input possibilities to the driller. As a result of these configurations, the hardware of the driller's display should be designed as a Thin Client. A Thin Client does not provide high system requirements and suits perfectly for the allocated functions.

The data processing by the software is planned to be done on a server located in a field container. Further information about the two different types of setups including data transport possibilities and power supply are given in the Appendix.

Conclusion

A simplification of visualization of early drilling problem detection by using real time drilling data is one major steps to improving the interface between driller and rig.

Two companies, which are working on the technological front, are already demonstrating early drilling problem detection with reliable results. But both of these developed systems neglected one major aspect and this is the interface between driller and rig displaying their warnings in a straightforward way directly to the driller.

To establish early drilling problem detection system on the rig site a Driller's Display (DsD) with software running in the background is introduced. Early warnings of drilling problems with only a few drilling parameters is based on the usage of key drilling parameters by the drillers since decades to monitor and control drilling operations. The occurrence of early drilling problems can be detected by comparing expected values against actual measured ones to determine any trend changes. Due to this fact a simulation is used to calculate expected values of the three main parameters. Next to the simulation a fingerprinting chart is introduced, monitoring recurrent operations and monitoring effects on hook load and active tank volume during making and breaking connections. The software of the DsD uses only surface sensor data to provide a more reliable data source than downhole data.

After the first draft versions of the displays, the first test version was used to determine the simulation reliability of the three key drilling parameters and the Fingerprinting Chart. Technological immaturity of the used ANN the simulation of torque and hook load requires further research. Simulation of pump pressure can be used in further development phases without any major changes because of the already advanced development. Also the Fingerprinting Chart showed confident results. This is tested via Version 1.1.

The specification of the DsD 2.0 is a look into the near future. This version introduces new models like a drilling window, a communication tool and hook load & torque model; but also uses models of previous DsD versions. The new models have not been developed until now. One major difference between the already existing version of the Driller's Display and the future concept is the differentiation of the graphical user interface for the different operations of drilling, tripping and due to the fact of different required information of the various operations.

The idea of providing the driller with trends of the key drilling parameters to monitor rig operations was very well received on the rig site. Another idea of using the DsD as a communication tool between driller and responsible personnel was developed together with various drillers to improve decision making during early drilling problems.

In order to achieve a simplification of early drilling problem detection simulation issues of hook load and torque have to be overcome to establish trend analysis between measured and expected values. A field test can be done to test the systems capability of early drilling problem detection and to receive feedback from drillers for further development.

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Appendix

Driller's Interview Protocol

Driller's Interview		
[Pick the date]	09:00 (MEZ)	RAG Rig E-200
Type of meeting	Interview / Discussion	
Meeting lead	Stephan Weichselbaum	
Participants	Driller's RAG Rig E-200	
What kind of information is important for a driller during operation?		
Recap		
The driller uses mainly the Martin Decker plus pump pressure and the torque reading of the top drive to observe rig operations		
Detailed information supported by the rig monitoring system and the mud logging system are used additionally and only from time to time to get an detailed view of current operation		
Indication process of drilling problems?		
Recap		
Key drilling parameters are used to observe rig operation.		
Any unexpected changes of these parameters alarm the driller and the driller is using additional detailed data supported by a mud logging company.		
Major Drilling Problems are discussed with the tool pusher, company man and sometimes also drilling engineer		
What kind of sensor warning systems is available?		
Recap		
A sensor warning system is governed by the rig monitoring system.		
System limits can be either adjusted by the driller or are already pre-adjusted with specific warning signs.		
How are these warning signs used?		
Recap		
Warning signs which are adjusted by the driller himself are much more considered than pre-defined warning signs.		
Especially warning signs colored in yellow. These are ignored most of the time. Only red warning signs are taken serious		
Requirements of a new system? (ANN simulation of Hook load, torque, pump pressure; Finger Printing Charts are available)a		
Recap		
Information in a straight forward looking way. Data has to be shown in a clear way to the driller, to enable the possibility of a driller to interpret the presented data.		
Simulation data of Hook load, torque and pump pressure can be displayed in both ways. Depth based and time based. To determine the better approach both systems have be tested.		
The system has to be as reliable as possible. Systems which greats uncertainties will be not used probably by the drillers		
What kind of features are on the wish list of a driller?		
Recap		
Communication tool between driller and the responsible personnel of the operator to improve decision making process during the occurrence of drilling issues.		

Rig sensor system above ground

Hook load sensor

"The hook load is the sum of all forces acting on the drill string that are suspended on the hook" (Schlumberger, 2014). These forces include the weight of the drill string in drilling fluid, mechanical and hydraulic frictional forces including sheave friction on surface, possible restrictions, wellbore problems etc.

The measurement of the hook load is done by load cells or tension anchors. The function principle is based on the measurement of the steel cable tension. Due to the development of the rig sensor system over the past decade, there are various locations for the load cell.

- Old technique:

  from the tension in the deadline

- New technique:

  load cell at the crown block or directly in the top drive

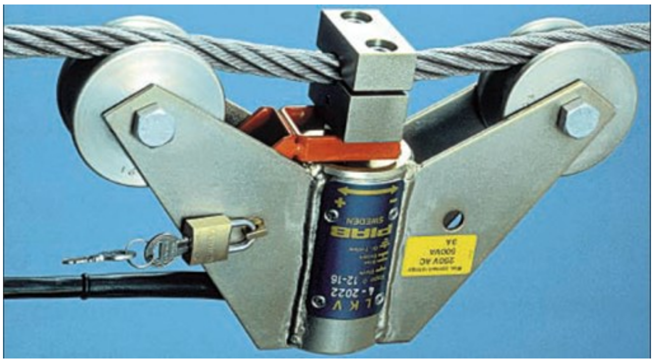

Figure 38: Load cell to measure the hook load. This picture shows a typical tension anchor, based on the old technique but commonly used (http://kwintgroep.nl/: seen: 3.8.2014)

Pressure sensor

These sensors monitor surface pressure (standpipe pressure). The measuring instrument is the differential pressure transmitter. This device senses the difference in pressure between two ports and emits a signal, representing that pressure in relation to a calibrated range. The used differential pressure transmitter is based on electronic data transmission. The measuring principle measures every differential pressure (“d/p”) between a high and a low port (1).

The pressure sensors are located after the mud pumps and measure the stand pipe pressure. This pressure is needed to provide a mud flow through the circulation system at a certain rate.

A changing stand pipe pressure the constant flow rate can be an indication for upcoming drilling problems.

Flow in calculation

These sensors provide information about the fluid flow rate into the borehole. With these data calculations for drilling fluid hydraulics, well control and cuttings lag time can be calculated.

The most common method to determine the flow out of a mud pump is to calculate strokes per minute with a given liner size, considering pump efficiency. A change in liner size requires an adjustment of the calculation.

Flow out sensor

The measurement of the flow, out of the wellbore can be determined by using two different types of sensors.

The commonly used flow paddle operates by measuring the resistance of a paddle in consideration of the angle between the fluid flow and paddle, and converts it directly into a flow rate.

Today, ultra-sonic sensors are used more and more. The flow rate is determined by measuring transit time between the sensor

Figure 39: Mud outflow tracking sensor on the RAG Drilling Rig E200. The measurement of the outflow is based on the principle by calculating the flow rate, using the ultra-sonic transit time sensor.

and the surface of the mud at the outflow line shown in the Figure 41 (1).

Both of these sensors need to be calibrated to calculate the signal into flow rate.

The combination of flow in and out data is used to determine unplanned active volume changes by checking flow return.

TQ and RPM sensor

The TQ and RPM sensor can monitor the revolutions per minute (RPM) as well as the rotary torque. The torque sensor is located at the top drive, around the main power cable. The measurement principle is to measure a magnetic field, which is produced around the cable; this is commonly referred to as the "Hall effect". Next to this system a strain-gauge technique can be used to measure the applied torque by measuring the change in elective resistance. Calibration of this measurement is done by considering the gage factor of the transducer and amplifier module. With information if excitation voltage and gain including an accurate measurement of micro strain torque can be measured in an accurate way. The measurement of rotational speed is similar to a proximity sensor which is used for mud pumps (1).

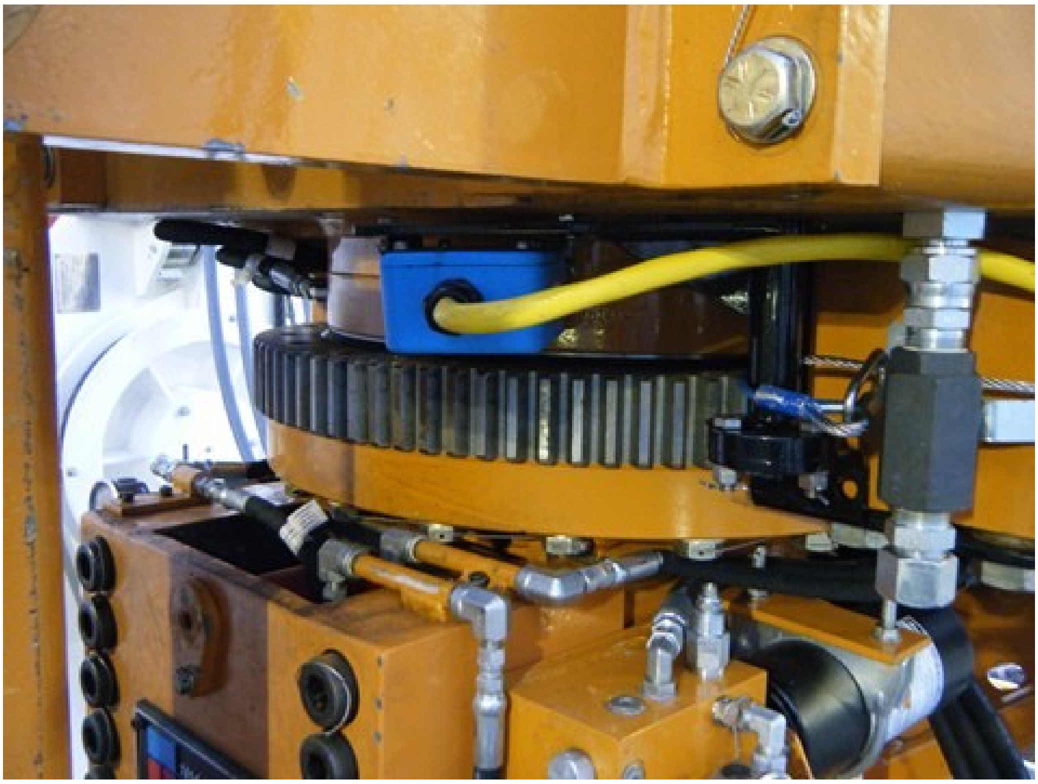

Figure 40: Drill Monitor sensor: rotational and torque measurement (www.rigsmart.com: seen on: 24.10.2014)

Pit monitor sensor

The pit monitor sensor surveys the ultra-sonic transit time between the sensor and the mud level. These sensors are located above the highest possible mud level in a tank. The volume of the mud tank is calculated by using the transit time measurement. These sensors are employed to attain exact volumes in tanks. On a rig there are two tank systems. One part of the tank system is used to store and mix up drilling mud. Active tanks are the second mud system used for circulation. Active tanks are the trip tank, shaker tanks and the main active tank system on a rig site (1).

Due to the ultra-sonic transient time principal, there is a restriction for measurement by foam occurrence on the surface.

One reason is to know fluid levels of various tanks which are calculated into tank volumes.

Types of Drilling Problems

1. Stuck pipe

1.2. Cutting bed build-up

Cutting bed build-up is an excessive cutting accumulation due to improper borehole clean-up. It's a major problem especially for inclined wells with a higher inclination than 35 degree up to horizontal wells. In a deviated well, cuttings tend to settle down at the low side of the well bore. This accumulation of cuttings in the lower part of the wellbore can either result in a cutting avalanche or accumulation of cuttings during the POOH of the drill string.

1.2.1. Key indicators of cutting bed build-up:

- Wellbore with a higher inclination than 35 degree
- Increase in torque and drag, which can be detected by comparing actual measured values with expected one generated by using for example a torque & drag model in combination with various predicted friction factors.

The highest possibility of occurrence is while drilling and tripping out of hole. Mostly cutting bed build up occur during pulling out of hole (POOH) out of the reason of cutting accumulation above the bit (6).

1.3. Borehole instability

The two main types of borehole instability are:

- Hole closure
- Collapse

1.3.1. Hole closure

This is a drilling problem, which involves hole-size reduction over time. This process can be a result of a creeping mechanism due to the pressure of the overburden or clay swelling due to improper mud inhibition.

1.3.2. Collapse

Borehole collapse occurs when the drilling-fluid pressure is too low to maintain the structural integrity of the drilled hole. The associated problems are pipe sticking and possible loss of well (6).

1.3.3. Key indicators of borehole instability:

- A smaller wellbore diameter due to borehole instabilities results in a larger contract area around the drill string with an increase of torque compared to a predicted one.
- Increase in hook load during POOH or decrease of hook load during RIH in comparison to expected hook load

1.4. Key seating

Key seating is one of the main causes of mechanically stuck pipe. Key seating occurs, when a drill string is constricted into the inner radius of the wellbore. This is a result of a side force due to doglegs (6).

Mostly long drilling runs can cause key seating. Reaming trips are used to optimize wellbore conditions.

This drilling problem mostly occurs during drilling through shales.

1.4.1. Key indicators of key seating:

- An jumping increase in hook load during POOH or jumping decrease of hook load during RIH in comparison to expected hook load (6 et. al.)

1.5. Differential sticking

This drilling problem occurs when the internal pressure of the mud in the wellbore is higher than the formation pressure shown in Figure 43. Hence, the pipe is pressed onto the borehole wall. The intensity of this drilling problem increases the more circumferences and length of the pipe is in contact with the mud cake (6).

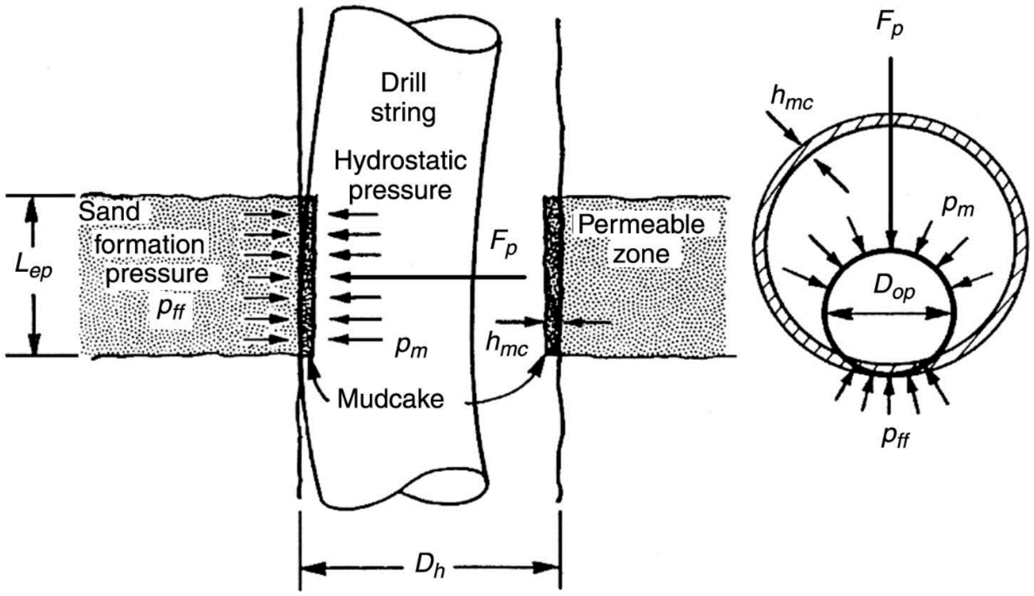

Figure 41: Differential pipe sticking is an effect due to the pressure difference between the borehole and the formation. (Glendasmith (2012) online: http://petrowiki.org/File%3ADevol2_1102final_Page_434_Image_0001 : seen on: 09.09.2014)

1.5.1. Pipe sticking force

The mechanism of pipe can be influenced by various parameters. These parameters can be used to release a stuck or sticking pipe.

- Reduction of the thick mud cake results in lowering the friction force at the borehole wall.
- Unnecessarily high differential pressure
- Low lubrication mud cake; this can also result in a too high friction coefficient

To minimize the sticking process at the formation of occurrence, special drill collars with spiral grooves and external upsets can be employed to minimize the area of contact. Consequently, the pipe sticking force can be reduced to the proportion of the area in contact (6).

1.5.2. Key indicator for differential sticking

- Increase of hook load and especially peak hook load at the beginning of the drill string movement due to the function of overcoming the static friction
- Uninterrupted drilling fluid circulation and no pressure spikes.

2. Volume control

2.1. Kick

A Kick is a flow of formation fluids into the wellbore during drilling operations. The kick is physically caused by the pressure in the wellbore being less than that of the formation fluids, thus causing flow (16). The main cause of a kick is a too low ECD in correlation to the pressure of a formation. With a wellbore pressure lower than the pressure of the formation, there is a possibility of formation fluid entering the wellbore. It is crucial to detect a kick as early as possible and prevent an uncontrolled increase of flow into a wellbore.

One of the factors, which control a kick, is the permeability and porosity of formation rock. A high permeability provides a good formation fluid inflow over a short period of time.

2.1.1. Causes of kicks

Kicks occur due to the pressure difference in the wellbore. Most of the operations in the well are done with hydrostatic pressures above the formation pressure which is called overbalanced. To provide higher pressure in the wellbore, several parameters have to be considered:

- Insufficient mud weight
- Swabbing
- Improper hole fill up during tripping operation
- Mud losses (6 et. al.)

2.1.2. Insufficient mud weight

Wrong pore pressure prediction is one of the main causes of a kick. To prevent a kick, a number of abnormal pressure indicators can be used to estimate the pressure of a formation. Two quantitative methods of several others are observing the rate of penetration (ROP) and the d exponent.

2.1.3. Swabbing

Swabbing can happens during a too fast movement acceleration of the drill string which creates a swab pressure. This pressure is negative and reduces the hydrostatic pressure at the bottom of the well. This reduction of pressure is a potential cause for a kick. Swabbing is affected by several factors:

- Mud properties
- A too high pipe pulling speed during POOH as well as a too high acceleration of the drill string
- Undersized clearance as a result of a too small diameter relation between wellbore wall and drill string components.

2.1.4. Improper hole fill up during tripping operation

Improper wellbore fill-up is one of the main causes of a kick during tripping operation. During tripping out operations, the mud level in the well is going down. As a result, the hydrostatic pressure in the wellbore is decreasing and nearing pore pressure. To prevent this process, the well has to be filled properly.

Currently several method are used to control a proper hole fill-up. Each of these measurements has to be accurate in order to detect a kick. The measurement of the used mud volume by using a centrifuge pump is not very exact. Instead, greater accuracy can be achieved by measuring the volume of the trip tank. This type of measurement is the most common one to observe the pumped down mud into the wellbore. The trip tank can be placed above the top of the well, which provides a gravity-induced flow into the wellbore. With this figuration, the wellbore is filled up automatically during the whole operation. Another measurement is done via the calculation of the volume by the pump strokes. The well is filled periodically with the mud pump. A device is calculating the volume of the mud and automatically stops the pump, when the well is filled-up properly (6).

2.1.5. Key indicator of a kick:

- Increase of active tank volume
- Unexpected hook load increase as a result of a decrease of buoyancy due to an increase of formation fluid or gas in the wellbore
- A drilling break can be an indicator of a kick and is identify as an increase in rate of penetration during drilling. Depending on the bit being used and the

formations being drilled, a formation, even if sand, may sometimes drill slower rather than faster. (17)

2.2. Mud losses

It is an uncontrolled flow of drilling fluid into the formation. Mud loses can results in a partial loss, some return or a complete loss without returns to the surface (11).

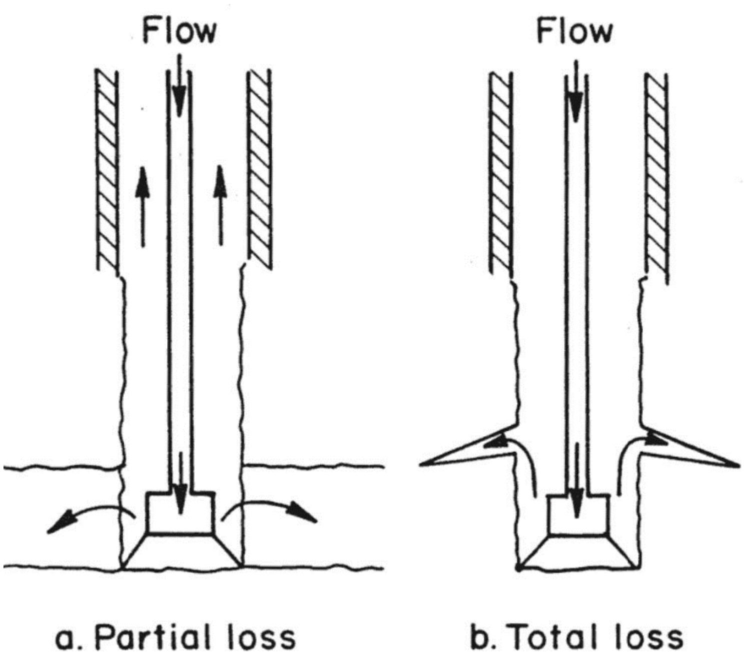

Figure 42: This figure gives an overview about the difference between a partial loss of drilling fluid (left) and the total loss of drilling fluid (right). (http://petrowiki.org/images/0/05/Devol2_1102final_Page_439_Image_0001.png (left), http://petrowiki.org/File%3ADevol2_1102final_Page_439_Image_0001.png#filehistory (right): 08.09.2014)

2.2.1. Causes of mud losses:

- ECD too high and/or low formation pressure
- Formations which are naturally fractured have a high permeability or are very cavernous.
- Due to too high pressures in the wellbore, fractures can be induced

2.2.2. Induced fractures:

The main cause of fracturing is excessive wellbore pressure, which is a result of too high flow rates or tripping too fast, in turn originated from a way too high ECD.

2.2.3. Cavernous formations:

Primarily, this drilling problem occurs in limestone formation causing a fast and maybe total mud loss. This drilling problem is very hard to control and seal off.

2.2.4. Prevention of mud losses:

Often, it is not possible to avoid a formation with high permeability and low formation pressure, fractured and cavernous thief zones. To lower the risk of mud losses, some precaution can be taken:

- Maintain a proper mud design with a good mud weight
- Low amount of cuttings in the drilling mud
- Minimize annular friction pressure losses
- Setting casing to protect weak formation
- Updating formation pore pressure and fracture gradients for better and accuracy during drilling operation (6 et.al.)

2.2.5. Key indicators of mud losses:

- Decreasing active tank volume
- Differences between the flow in and flow out of the wellbore

2.3. Ballooning

Ballooning is a natural effect or phenomenon, occurring during drilling operation, when drilling fluid is lost into the formation. This happens, when the pumps are running and the ECD exceeds formation pressure and micro fractures are generated. The vice versa process is e.g. during tripping operation without circulation or during a flow check, whereas the formation gives mud volume back to the system (6).

2.3.1. Prevent ballooning

One of the key procedures to prevent ballooning is to manage the ECD. This can be done by observing and controlling the ECD. Another important key parameter is to establish a well selected BHA to manage pressure losses.

2.3.2. Key indicators of ballooning:

- Increase and decrease of active tank volume, due to an in and out flow of mud through the formation

Artificial Neuronal Network

Definition of an ANN

An ANN is a model, which is based on the idea of the structure and function of a biological neural network (Figure 46). The ability of a human brain, capable to complete machine learning in addition to pattern recognition, is provided by the structure of the central nervous system (8).

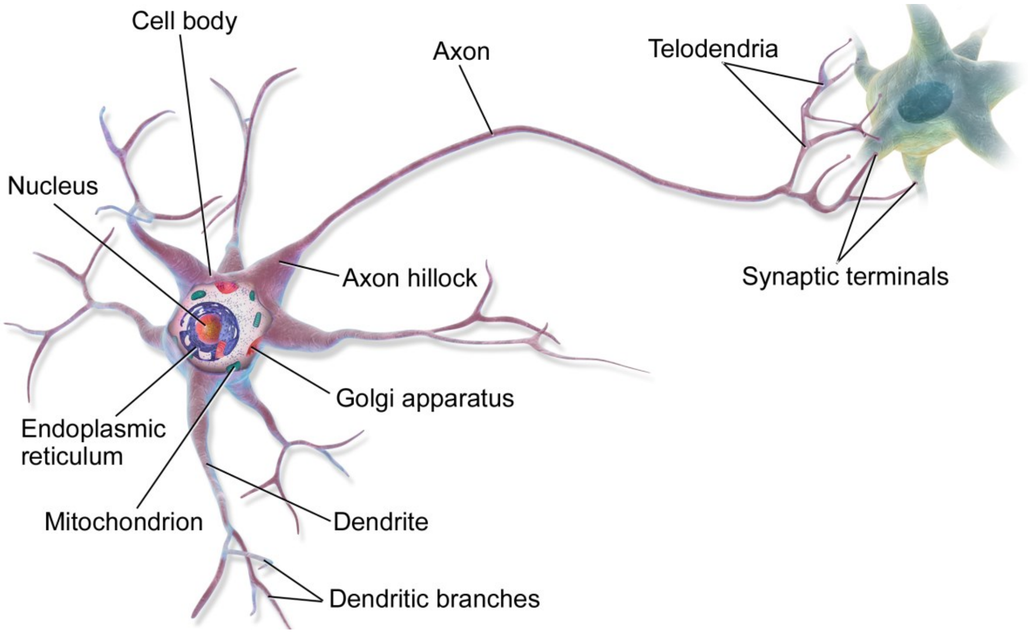

Figure 43: This figure shows a detailed overview of the construction of a neuron. (http://upload.wikimedia.org/wikipedia/commons/1/10/Blausen_0657_MultipolarNeuron.png seen on: 25.08.2014)

The central nervous system is built out of nodes. These are also called “neurons” or “processing elements”. All of these neurons are linked together. The communication between the neurons is done via connectors. These connectors provide a one-way data connection of local data. The neurons are able to receive signals (data) through synapses, which are located on the dendrites of a neuron. This signal can either activate the neurons or get side-stepped by the axon to the next neuron and thus might activate this one.

As obvious from Figure46, a neuron is very complex. To use this paradigm for an algorithm, the neuron has to be modeled in a very simple way. The computer neuron consists of multiple possibilities to input data like a synapse. The activation of a computer neuron is driven by the “weight” of the signal, which is controlled by a mathematical function. The weight is controlling the strength of each connection. The activation of a neuron generates an output signal. An ANN is constructed by using many of these neurons.

The output of an ANN is driven by adjusting the weights. Caused by the amount of neurons in an ANN, it is impossible to find the adequate weights of an ANN. As a result of that, the system uses an algorithm to adjust the weights. This process is often specified as “learning” (8).

Principle of operation

For the usage of an ANN, the neurons are split up into layers. The first layer includes the input neurons. These neurons forward their information to the multi intermediate layers “hidden layer”. At the end, several output layers provide the output of an ANN.

For the usage of ANNs a data processing computer is needed. This device provides the possibility of using an algorithm to run an ANN.

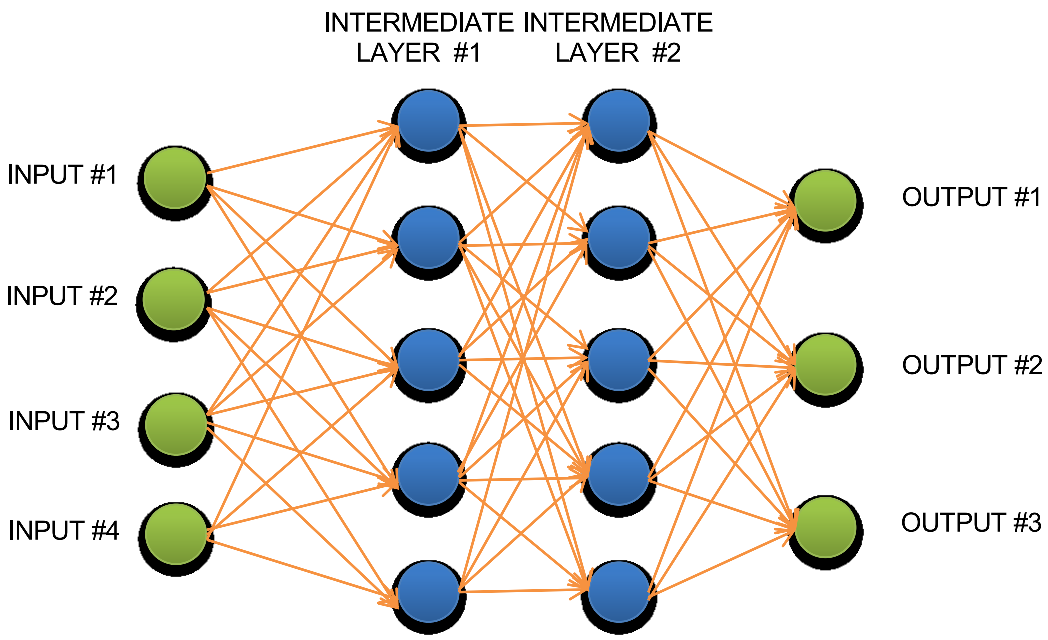

Figure 44: This figure gives an overview on the working principle of an artificial neuronal network (ANN) with the various layers, which are connected by one way connectors.

Learning

The learning process of an ANN is a process completed by adjusting the weights. The weights are defined as parameter values, which are used for the simulation.

Various learning algorithms are available:

- Error correction learning
- Hebbian learning
- Competitive learning
- Memory based learning
- Boltzmann learning

The main reasons of the learning process are to achieve a pattern association and pattern classification to identify the number of output values.

Quality characteristics

Various attributes are controlling the quality of an ANN simulation output.

- Generalization

  The generalization has a higher margin of error for the combination of a too small number of example patterns and a too complex system. There is also a process tending in the opposite direction called over fitting which is described below.

  To find an ANN, which has the perfect size, highly depend on the design weights, bias, nodes and layers.

- Over-fitting

  The characteristic of over-fitting is generated during a bad generalization process. It occurs if the number of parameters in an ANN is much higher in comparison to the used samples during the training process.

- Curse of dimensionality

  This problem occurs due to the usage of high dimensional vectors. This can be a major issue due to the principle of vector format usage in ANNs. The main issue occurs due to the dimensionality increase, as a result the increase of volume rises as big as the data becomes spares.

- Feed forward and Back propagation

  The back propagation is the most powerful and effective model, which is easy to learn for complex model and multi-layer networks. The typical back propagation model consists of one input layer, one output layer and at least one hidden layer. Theoretically, the system is not limited within the amount of hidden layers, but normally a maximum of three hidden layers is used. Each of these layers, as it is shown above, is interconnected with each other.

Configuration file of the driller's display


```
<?xml version="1.0"?>
<configuration>
        <configSections>
            <section name="Database"
type="System.Configuration.NameValueSectionHandler"/>
            <section name="UnitConversionSection"
type="FingerprintsPlot.Configuration.UnitConversionSectionHandler,
          FingerprintsPlot, Version=1.0.0.0, Culture=neutral,
PublicKeyToken=null"/>
            <section name="DrillerDisplaySettings"
type="System.Configuration.NameValueSectionHandler"/>
        </configSections>

        <Database>
            <add key="Server" value="bhp-landClone.tde.at"/>
            <add key="PTS_Schema" value="pts_rt"/>
            <add key="Username" value="root"/>
            <add key="Password" value="sys"/>
        </Database>


      <appSettings>
            <add key="ProjectTimeZone" value="+01:00"/>
      </appSettings>


      <!--Use symbole "x" as the original value.
                        Example: Convert a channel hkldav from kg to ton
                              ChannelName ="hkldav" DisplayName = "ton"
formula = "x / 1000"
                        Example: Convert a channel prespumpav from pa to
psi
                              ChannelName="prespumpav" DisplayName="psi"
CalculationFormula="(x / 1000) * 0.1"
                  -->

       <UnitConversionSection>
             <UnitConversions>
                  <!--add ChannelName="prespumpav"   FromUnit="Pa"
      ToUnit="psi" CalculationFormula="(x / 1000) * 0.14503"/-->
```

```xml
            <!--add ChannelName="prespumpsim"   FromUnit="Pa"
      ToUnit="psi" CalculationFormula="(x / 1000) * 0.14503"/-->
            <add ChannelName="prespumpav" FromUnit="Pa"
      ToUnit="bar" CalculationFormula="(x / 100000) "/>
            <add ChannelName="prespumpsim"     FromUnit="Pa"
      ToUnit="bar" CalculationFormula="(x / 100000)"/>
            <add ChannelName="posblock"        FromUnit="m"
      ToUnit="cm"  CalculationFormula="x * 100"/>
            <add ChannelName="hkldav"          FromUnit="kg"
      ToUnit="ton" CalculationFormula="x / 1000"/>
          <add ChannelName="hkldsim"           FromUnit="kg"
      ToUnit="ton" CalculationFormula="x / 1000"/>
            <add ChannelName="tqav"            FromUnit="J"
      ToUnit="Nm" CalculationFormula="x"/>
          <add ChannelName="tqsim"       FromUnit="J"
      ToUnit="Nm" CalculationFormula="x"/>
        </UnitConversions>
   </UnitConversionSection>

      <DrillerDisplaySettings>
            <add key="ScenarioID" value="426"/>
            <add key="ProjectID"  value="428"/>
            <add key="StreamType" value="raw"/>
            <add key="Resolution" value="10000"/>

            <add key="FirstChannelActual" value="hkldav" />
            <add key="FirstChannelSimulated" value="hkldsim" />

            <add key="SecondChannelActual" value="tqav" />
            <add key="SecondChannelSimulated" value="tqsim" />

            <add key="ThirdChannelActual" value="prespumpav" />
            <add key="ThirdChannelSimulated" value="prespumpsim" />

            <add key="FourthChannelActual" value="flowinav" />

            <add key="StartTimestamp_ms" value="1411121642000"/>
            <add key="EndTimestamp_ms" value="253402243200000"/>
            <add key="WatchingWindowSize_min" value="20"/>
            <add key="TriggeringThreshold" value="1000000"/>
            <add key="MaxNumberOfFingerprints" value="10"/>
      </DrillerDisplaySettings>

      <runtime>
            <assemblyBinding xmlns="urn:schemas-microsoft-com:asm.v1">
                  <dependentAssembly>
                        <assemblyIdentity name="EntityFramework"
publicKeyToken="b77a5c561934e089" culture="neutral"/>
                        <bindingRedirect oldVersion="0.0.0.0-5.0.0.0"
newVersion="5.0.0.0"/>
                  </dependentAssembly>
            </assemblyBinding>
            <gcAllowVeryLargeObjects enabled="true"/>
      </runtime>

      <startup>
        <supportedRuntime version="v4.0"
sku=".NETFramework,Version=v4.5"/>
    </startup>

</configuration>
```

Hardware

Setup

To realize the driller's display and improve the driller's rig interface, a system set-up has to be planned and presented.

For testing the system, two different system set-ups are planned to improve the testing phase and minimize the footprint of the system during the testing phase onsite:

- Office test setup
- Rig setup

Office test Setup

The main reason of the office set-up is to test the reliability and trustiness of the Driller's Display. The goal is to achieve a version of the driller's display, which can be used onsite.

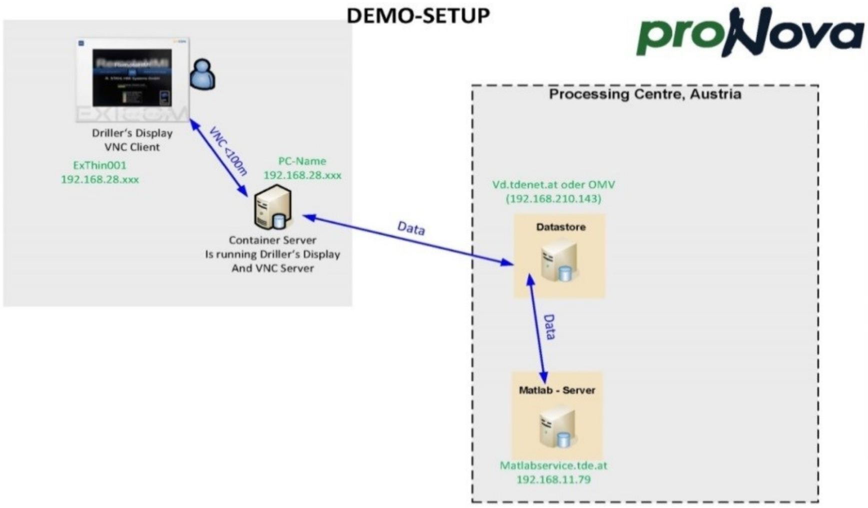

Figure 45: Data transfer concept of the office test setup created by Markus Summer (ProNova Advanced Drilling Solution ADS)

The system structure is constructed with a data base, to provide data for the testing phase. This data is processed via a Matlab Server to simulate the hook load, torque and pump pressure in connection with Fingerprinting Chart of hook load trend and flow back of the mud. This information is then transferred to the container server, which provides the running system of the driller's display. The visualization of the driller's display is done by a Thin Client.

The testing phase of the office test set-up runs by using real time drilling data. With this testing phase, the reliability of the system can be tested to the limit before using the system on a rig site.

Rig Setup

The setup for the rig installation is split up into two parts. Both of these parts are able to process real time drilling data. One data processing system is operated on site and the second one is operated in the “Data Centre Austria” of Think and Vision. Due to this configuration of the whole system, quality control is able to ensure a proper output of the Driller’s Display.

The rig setup has three main functions. The first one is the acquisition of rig data by collecting them via the data format WITS. The second aim is to process the rig data by the ANN and the Fingerprinting Chart. This information for early drilling problem

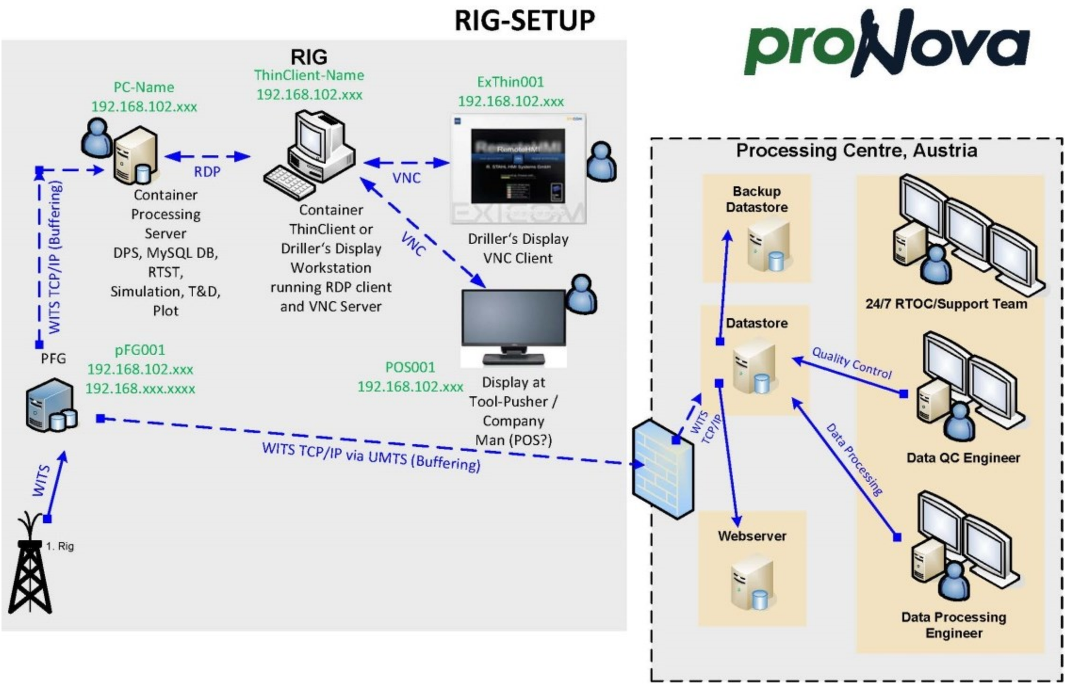

Figure 46: Data transfer concept of the rig setup to provide the driller’s display created by Markus Summer (ProNova Think and Vision)

detection is shown as the third aim via a thin client on the rig floor and various offices on the rig site.

As mentioned above, the quality management is provided by a processing Centre in Austria. The data transfer is provided via WITSML TCP/IP and the first step is to store the received data. To ensure the availability and secure the real time drilling data, a backup data store is available. Next to the processing of real time drilling data onsite, another processing mechanism is done at the Processing Centre, by a data processing engineer to ensure an error free simulation. This process is also assisted by a data quality control engineer. Both of these processing servers are working with the same software. Based on this principle, an error free simulation can be thusly assured.

Data transfer possibilities

The main aim of data transfer for the Driller's Display is to deliver real time drilling data for the processing server to support the simulation process of the driller's display. The second aim is to transfer information of the driller's display in a video format into the driller's cabin and into the tool pusher's and the company man's office.

Due to new technologies, two different types of data transfer are possible. Based on reliability, the conventional solution of data transfer via cable is considered to be the preferable application. Next to this possibility, a wireless data connection option is also considered as a solution for an advanced development phase.

Cable

The data connection can be done by two types of cables.

- Ethernet CAT5 <100m
- Fiber optic <2km

The main difference between Ethernet cables and fiber optical cable is the function of transferring data. Ethernet is working by using electric signals. Fiber optic ones are working with transfer of light.

Due to the working principle of Ethernet cables, the data transfer is vulnerable to electromagnetic interferences. This risk can be minimized by using "shielded" cables. The likelihood of an appearance of electromagnetic fields on the rig site is marginal. Fiber optic cables are insusceptible to interferences, since they do not conduct electricity.

A decade ago, the speed of data transfer for Ethernet cable was much lower than for fiber optic cables. Due to the development of the Ethernet technology, the connection speed increased close to the same data rate.

The big advantage of an Ethernet cable to a fiber optic cable is the robustness. The fiber optic cables are not susceptible for re-installation for every rig up and rig down.

The required length for a driller's display data cable is a length of about 75 meters. Due to this length, the bandwidth differs between these two cables. The fiber optic solution transmits twice as much information than the Ethernet cable.

WLAN

A wireless local area network (WLAN) is a computer network to connect two or more devices to each other without a cable connection. The most common used WLAN standard is based on the IEEE 802.11 standard.

A wireless signal is generated via a current pulsation in a copper wire, which is inside an antenna. This methodology generates a magnetic field around the antenna. This pulse radiates out in a circle via radio waves. Unfortunately, metal is a conductor of electricity. Due to this characteristic, a WLAN signal is absorbed by metal. This property of metal can be a big issue on site, which is completely constructed out of metal. To overcome this issue, the antennas have to be located in a field of vision of each other.

The big advantage of a WLAN connection is the autonomy of the device location. The location of the device has to be in the reception range of a WLAN router. The property of metal to absorb a WLAN signal lowers the size of the reception area dramatically.

To overcome these issues, a sophisticated and well-engineered WLAN rig mesh is needed to establish a reliable data connection. The main focus of attention is on an error free data transfer via WLAN. This can be achieved by considering two main points. The first one is the location of the WLAN antenna. These antennas have to be located outside of a container or rig floor, to have a direct view of each other. Due to the methodology on site, it is possible that various objects can mask the direct view of the antennas to each other. For this reason, at least 3 WLAN antennas are required to ensure perfect connectivity.

Energy supply

Next to the data transfer possibilities, the energy supply of the Driller's Display in the dog house has to also be considered due to the high requirements in HSE. The Explosion Zone 1 at the rig floor presents a challenge for energy supply. Due to this issue, the energy supply has to be provided via a cable, which provides energy from outside the explosion zones into the dog house. The display requires an energy supply of 24 Volts and 1.2 A.

Display

Due to the different explosion zones (EX-zone) on the rig, especially on the rig floor and the driller's cabin, special equipment is required in these areas.

As a result of the hazard areas and the difficult environment on the rig site, the following specifications have to be provided to establish a display.

The specific features:

- Thin Clients for modern network solutions
- EX zone 1
- Energy supply
- WLAN Connectivity or cable connectivity

For the driller's display, two individual possibilities of hardware are feasible.

Portable devices

The big advantage of a portable device for a driller's display is the size of the whole device. Due to the small design, it would be possible to place the driller's display anywhere in the dog house. As a result, the human-rig interface will benefit greatly.

The big disadvantage is the charging mechanism. This mechanism can only be provided by an "open" system. As a result, a continuous charging possibility cannot be provided. The company ATEX provides various possibilities of zone 1 displays with an energy supply via a fixed cable. Due to the high prices of these devices, portable devices are not the first option in the earlier test phases.

If the newly invented system shows a high success rate in early drilling problem detection and operates fortuitously in the dog house, a portable system could be considered.

Fixed install display

For the first application of the driller's display on site in the dog house, the fixed display is chosen. The main reason of this is the big advantage in price.

In the Appendix, the Stahl HMI system is introduced, which is intended for deployment the first tests in the field.

The big disadvantage of a fixed display compared to the portable system is the differences in size in conjecture with the positioning of the displays. The clumpy design and size of a fixed display restricts the usability and improvement of the driller-rig interface.

STAHL HMI systems

As mentioned in the passage above the fixed install display is the first choice for the first testing on the drilling rig. As a result the STAHL HMI system was chosen to provide the display for the drillers display.

Model: ET-536 15“(1024 x 768)

The needed technical parameters for the drillers display

LAN or WLAN connection

15” display size 1024 X 768

Ex zone 1

Additional technical option which can be useful

Touch screen

Further information of technical data is provided in the appendix.

Mounting option

STAHL is providing a case for the display. Size of the case:

Dimensions (W x H x D): 440 x 340 x 165 mm (17.32” x 13.38” x 6.5").

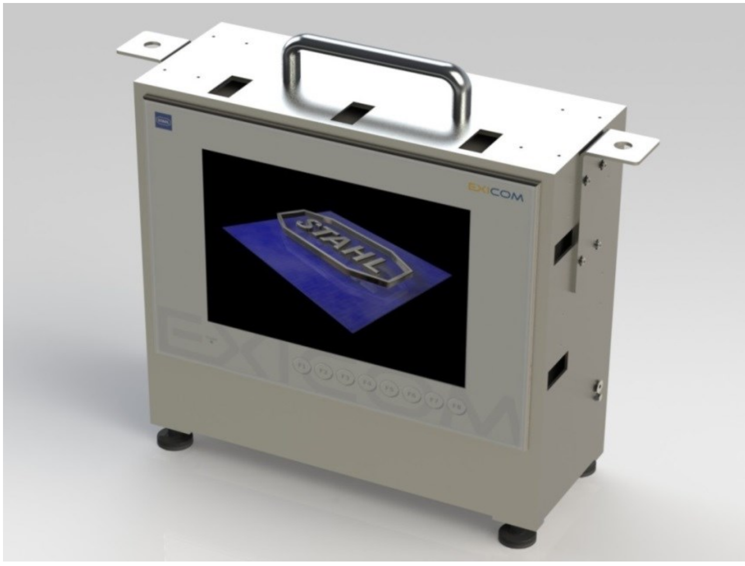

Figure 47: Example picture of a Stahl display, Model: ET-536 15" (1024 x 768) http://www.stahl-hmi.de/de/produkte-systeme/serie-500-thin-client-systeme/et-536.html, seen on: 25.11.2014)