AST

ADVANCED SOFTTORQUE

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Stick-Slip mitigation in general

1.1. What is “Stick-Slip”?

An oil-rig's top-drive is a multi-purpose controllable high power drive. During drilling the drill-pipe is the intermediate between a drill and the top-drive. A practical problem is so called `stick-slip' while drilling.
Experience shows that a relatively constant speed of the drill is optimal for effective penetration, low drill wear and good steering conditions.
At certain depths and depending on drill conditions, among others: friction on bit, drill speed and weight on bit, the drill bit can “stick” down hole while the drill-string keeps rotating. The drill-pipe acts as a torsional spring. Since the Top Drive does not recognize the “stick” of the drill bit, the rotation of the drill pipe continuous and the drill-pipe will wind up. As a result the torque in the pipe builds up. At a certain torque value the “stick” friction is overcome and the drill-bit suddenly increases in speed while the drill pipe “unwinds” itself. This suddenly increase in speed can damage the bit. Also steering rotary drilling operation is very difficult under “stick-slip” conditions.

“Stick-slip” is a common occurrence in drilling operations that can result in harmful rotational vibrations in the drill-string. When fully developed, stick-slip can cause the bit and BHA rotation to completely stop and accelerate up to 5-6 times the surface r.p.m.

“Stick-slip” can cause:

- damage to the bit;
- broken cutters;
- decreased rate of penetration (ROP)
- decreased bit life.

Furthermore, it can also damage other down hole components such as rotary steerable systems, and Measurement While Drilling devices (MWD). It can even cause down-hole motors to stall.

1.2. Recognizing when “Stick-Slip” is occurring

There are two clear stick-slip indicators for the driller:

1. **Large variations in surface torque.**
2. **Large variations in downhole RPM.**

The torque variations can be accompanied by “groaning” noise coming from the top drive. Characteristic for the slip-stick behavior is the saw-tooth behavior of the torque, which can go up to 50% torque variation. In Figure 1 is an example of the characteristic saw-tooth torque variations. This behavior can only be seen clearly when using data with at least 1-second sample time.

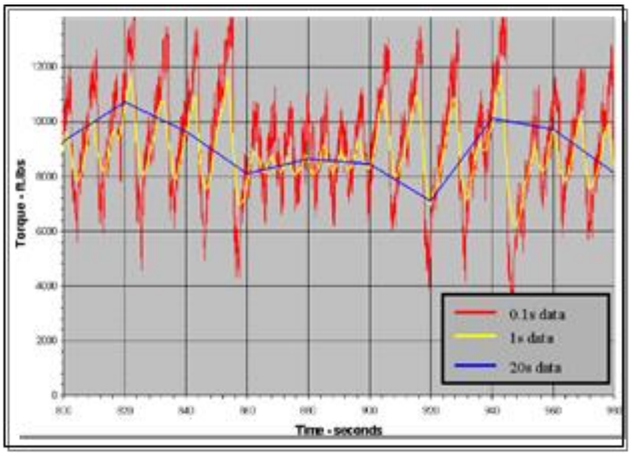


Figure 1: Torque variations due to stick-slip

1.3. How to reduce “Stick-slip”

Stick-Slip occurs at a rotary speed below a certain threshold value. The threshold value depends on system parameters such as design of the drill-string, mud, bit, BHA and weight on bit (WOB). The driller can reduce stick-slip by:

1. Increasing the rotary speed (RPM);
2. Reducing the weight on bit (WOB);
3. Add lubricants to the mud system;
4. Installing a Electroproject Advanced Softtorque (AST).

In Figure 2 at 21 seconds the AST system is switched on. Torque becomes smoother and speed variations are greater. This is typical when AST is active.

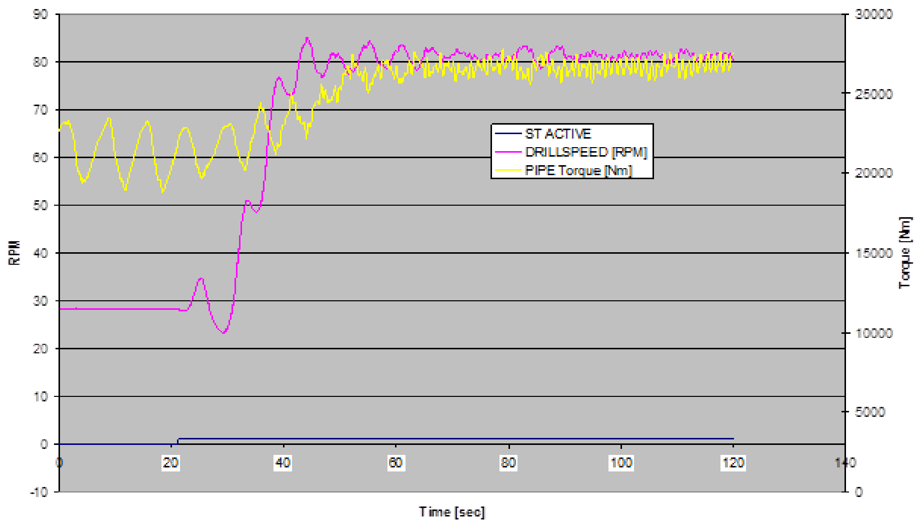


Figure 2: Activating Advanced Softtorque

In Figure 2 at 21 seconds AST is switched on. Torque becomes smoother and speed variations are greater. This is typical when soft torque is active.

2. Electroproject Advanced Soft Torque (AST).

In general the AST system is described below.

Depending on implemented drive system and the used controls for top drive, the functionality of the AST system and the used components could differ.

2.1. General System overview

The AST system is designed to be easily implemented in modern drive systems.
The AST controller is a standalone but RIG specific µ-processor based controller.

To implement the system the following hardware is required:

1. Touch panel to operate the system.
2. Industrial PC (IPC). The Soft Torque controller.
3. Additional PROFIBUS communication interface with variable frequency drive (VFD)
4. Ethernet communication between touch panel and IPC
5. If not already present, speed encoder at TOP DRIVE motor.

Fig 3. HMI, MP277 touch panel Ex zone 2 indoor   Fig 4. AST controller cabinet

The AST controller can be embedded in the rig TD as described in fig 5.

The use of a standalone controller as showed in Fig 5 has several advantages:

a. The controller can be implemented in all electrical AC TD's independent of brand.
b. The contractor/operator has the same type of controller for all his operations independent of the rig brand used.
c. The implementation of the system is not intrusive.
   Normally the configuration of the existing equipment, VFD and PLC, does not have to be changed.
d. The controller can be by-passed if necessary.
e. The controller can be transfer from one rig to the other if the TD's used are identical.

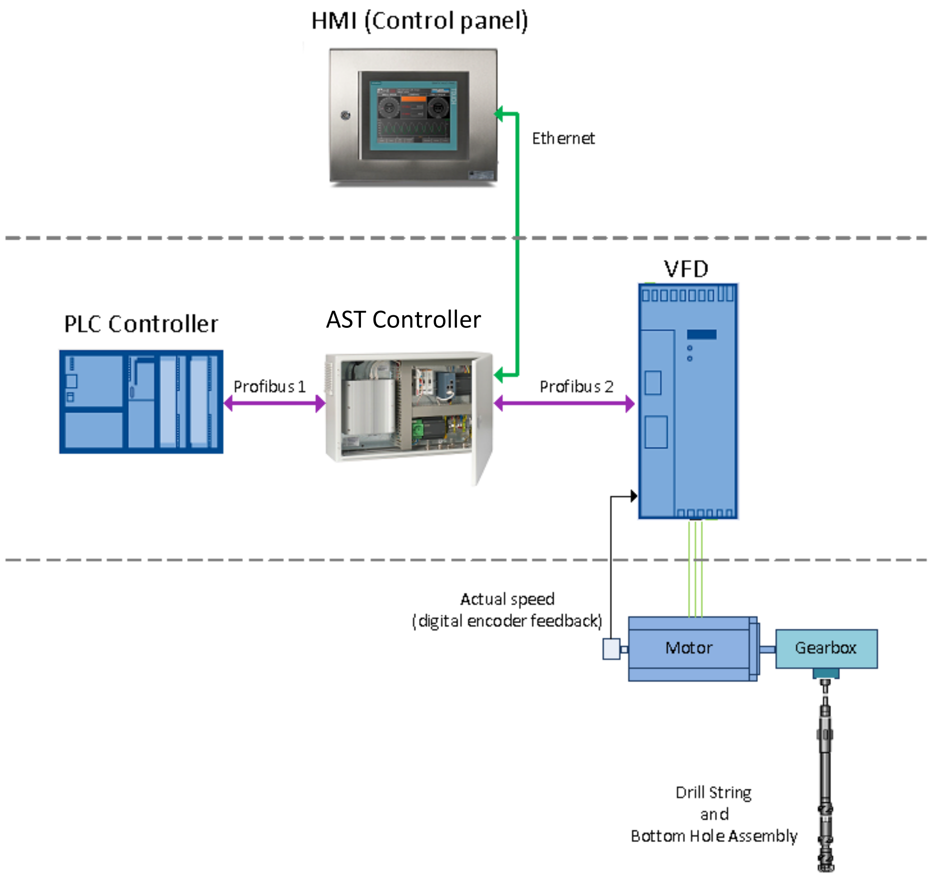


Figure 5: AST System overview

2.2. Principle of operation

Advanced Softtorque (AST) is Electroproject's (EP) newest implementation of soft torque technology. This technology aims to mitigate the negative effects of the frequently arising stick-slip phenomena in oil and gas well drilling. To do this the rotation dynamics of the (top)drive in the drilling rig is changed to **damp** the torsional vibrations in the drill string **such that the drill bit speed variations are minimized**.
The settings for the controller to achieve this minimum speed variations of the drill bit are automatic calculated by an embedded optimization program in the AST system.

Advanced Softtorque finds its strength in:

- Wide control frequency band to allow damping of all relevant torsion vibration modes of the drill string.
  This obviates the need to re-tune at different drilling depth as is needed for conventional Softtorque controllers (STRS technology).
  AST has proven in practice to deliver a better torsional vibration mitigation than traditional Softtorque technology specially in horizontal operations or when less stiff pipe is used like 4".
- Optimizations to minimize the downhole (Bit/BHA) speed fluctuations. Especially useful for directional drilling operations.

Below graph shows the performance of the AST system during the horizontal section of a drilling operation. The light blue line represents torque on surface. Ones the Softtorque system is switched on the torque values stabilize due to the mitigation of the drill string torsional vibrations.

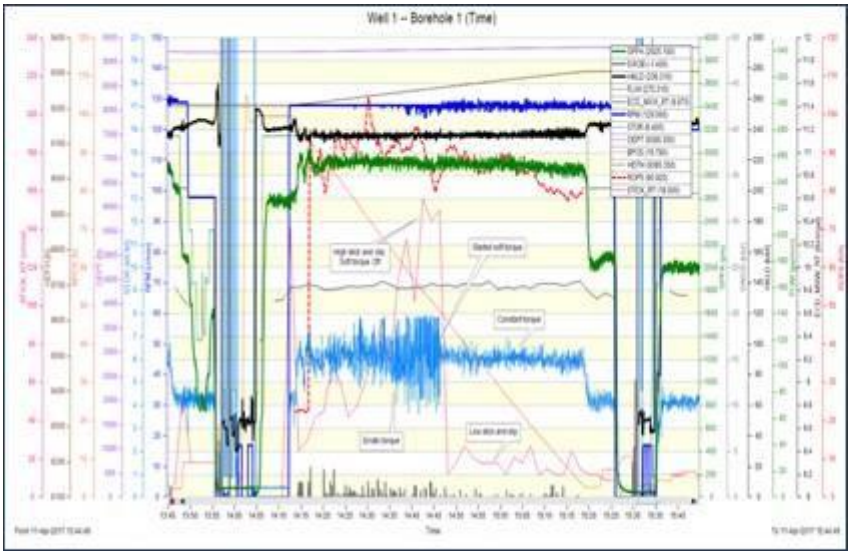


Figure 5: AST performance in an horizontal section.

The drill string forms the connection between the (top)drive in the drilling rig and the bit/BHA downhole. Stick-slip mitigation requires to keep the rotation speed of the bit/BHA end of the drill string as constant as possible i.e. zero or minimal speed fluctuations.

Conventional (top)drive control systems are designed to maintain a requested (driller's) drill string rotation speed independent of the (torque) load from the drill string and bit, under the false assumption that the bit/BHA rotation speed is always identical to that (visible) on the rig.

In reality, however, the drill string forms a flexible mechanical vibration system whereby, under circumstances, high bit/BHA speed variations can exist, leading to stick-slip in which the bit/BHA intermittently comes to a complete stall.

The above translates into the basic requirement for modern stick-slip mitigation:

How to adapt the (top) drive speed control system to minimize the bit/BHA speed variation under various (torque) load conditions?

To answer this question, we need to understand the nature of rotation vibrations of the drill string. This can be done by realizing that the torsion vibration is composed of a number of vibration modes (each with a distinct vibration frequency). Depending on drill string geometry, (top) drive behavior and loading one or more of such vibration modes may be more apparent than others, resulting in a specific speed and torque pattern along the length of the drill string.

A vibration mode may be **damped by extracting its vibration energy**. The top drive control system is the obvious instrument to do this. By allowing the speed control system some softening (i.e. speed variation) at the frequency of a particular vibration mode, it can be proven that vibration energy of that mode can be extracted (i.e. dissipated). This will then reduce or remove the particular vibration mode.

The conventional STRS (EPST) system is designed to focus only on the first mode (with the lowest frequency). Since the vibration frequency of the modes changes with depth STRS needed to be re-tuned after drilling every stand.
The advanced AST system however, is designed to focus on all vibration modes at the same time by means of its wide frequency band. As a result the AST system does not need continues tuning as a conventional system does.

The capacity of extracting vibration energy of a (top)drive over frequency is expressed by the “hummingbird control curve” of the respective soft torque system. See figure 6 on the next page.

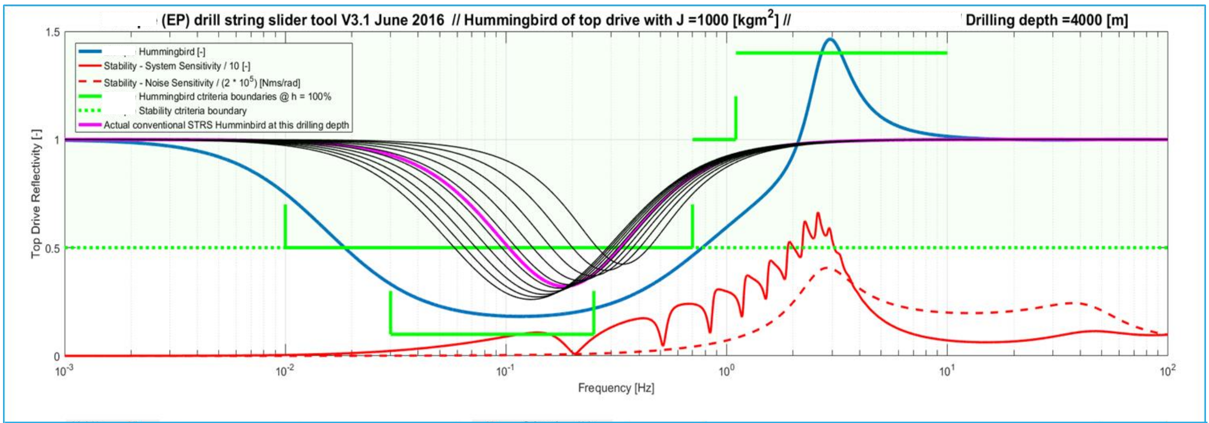
The Y-axis is formed by a normalized power scale (showing the amount of power that can be dissipated, were:

- 1 = no power can be dissipated torsional wave will be fully reflected.
- 0 = the full wave can be absorbed.

And the X-axis is formed by the torsion vibration frequency of a mode in [Hz].

The “hummingbird curve” thus indicates how much a vibration mode reaching the (top)drive can be dissipated by the (top)drive as a function of the mode frequency.
Top drives and their control systems reveal certain limitations (e.g. the magnitude of the mass moment of inertia and delays in the control system) which make it more difficult to damp a vibration mode at higher frequencies due to the decreasing stability of the (top) drive at those frequencies. Therefore, AST contains special developed techniques to minimize the effects of such limitations while guarantying safe stability margins of the (top)drive. They can be expressed by stability curves (System Sensitivity (red) and Noise Sensitivity (cyan)) together with the hummingbird curve (blue).

In figure 6, the blue line show the ability of the AST system to dissipate energy in a wide range of frequencies. The black lines show the predicted performance of a conventional Softtorque system. Each black line represents a set of tuning values. With a conventional Softtorque system multiple settings are necessary to cover a wide frequency spectrum.



AST properties:

- Shape of reflectivity curve is adaptable on operation.
- Stability algorithms take the drill string property's into account.
- Higher modi damping up to 3 Hz.
- Low TD excitation with minimum drill bit speed disturbance.

Figure 6: AST System Hummingbird

2.3. Speed and torque monitoring

On the touch panel, actual values of speed and torque can be monitored in real-time.
These values can also be monitored graphically in a trend display of 100 seconds.

2.4. Advanced data logging

The AST controller is programmed in an IPC (Industrial PC). The operating system is Linux.
The IPC also function as a data server for logging purposes, the AST-server.

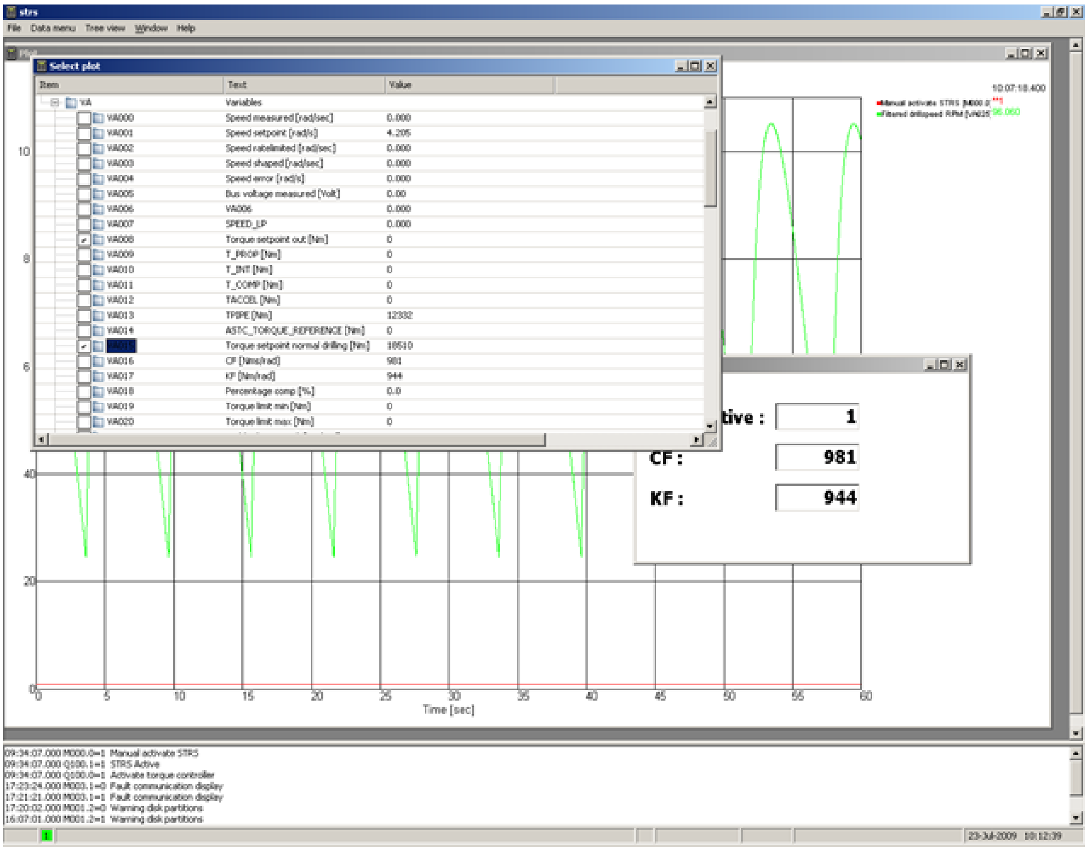


Figure 5: Screenshot ST log-data view program

The AST-server, stores the actual values of all inputs, outputs, variables, markers and parameters to hard disk. When the VFD is operating, the resolution of this log data is 5ms. Depending on the size of the applied hard disk(s), log data can be hold for months.

The log data can be viewed, exported and analyzed with a special EPST data-log view program.
The EPST data-log viewer can be installed on a Windows based PC.

2.5. Remote access

If the IPC is connected to a WAN network, logdata and status of the IPC can be remotely accessed. Even remote assistance and updates are possible.

If a connection has to be made between the AST network (IPC and touch panel) and another network, a specific TCP/IP setting has to be made. These settings can only be changed by Electroproject personal. The standard IPC TCP/IP configuration is stand alone but RIG specific with a DHCP server enabled.
Please contact us for other configurations.

2.6. AST off-line

Since the AST system is designed as a standalone but RIG specific controller the drill operation can continue if the AST system is off-line. Drill operation can continue with disconnected AST system.
If the AST system is turned off, the original control of the VFD is restored.