ElectroProject Soft Torque

- EPST
- Advanced Soft torque
- Auto Tune
- Z-Torque

Operation manual 3.3.2
Revision History

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Safety Guidelines

This manual contains notices you have to observe in order to ensure your personal safety, as well as to prevent damage to property. The notices referring to your personal safety are highlighted in the manual by a safety alert symbol; notices referring only to property damage have no safety alert symbol.

Qualified Personnel

The device/system may only be set up and used in conjunction with this documentation. Commissioning and operation of a device/system may only be performed by qualified personnel. Within the context of the safety notes in this documentation qualified persons are defined as persons who are authorized to commission, ground and label devices, systems and circuits in accordance with established safety practices and standards.

Prescribed Usage

Note the following:

**WARNING**

The EPST system may only be used for the applications described in this manual and only in connection with devices or components from other manufacturers which have been approved or recommended by Electroproject. Correct, reliable operation of the product requires proper transport, storage, positioning and assembly as well as careful operation and maintenance.

When devices or components from other manufacturers, which have been approved or recommended by Electroproject and which are connected with the EPST system, changes due to hardware or software updates possible malfunction of the system arise.

**IMPORTANT**

The EPST system will become RIG specific after commissioning.

Disclaimer of Liability

We have reviewed the contents of this publication to ensure consistency with the hardware and software described. Since variance cannot be precluded entirely, we cannot guarantee full consistency. However, the information in this publication is reviewed regularly and any necessary corrections are included in subsequent editions.
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1 Preface

1.1 Purpose of this manual

This operation manual is part of the Electroproject Soft Torque (EPST) documentation. The manual provides information and guidelines for the operation of the EPST system.

The manual is intended for drillers and engineers operating the EPST system. This manual has been derived from the standard EPST operation manual and supplemented with operation instructions for the use of EPST Auto Tune (EPST-AT), EP advanced soft torque (AST) and EP Z-torque functionality.

When EPST AT or AST is not activated, not all controls and screens are available as described in this manual.

If Z-torque is activated, automatically AST will be activated. Auto tune, BHA and drill pipe entry will not be available (see chapter 6).

1.2 Basic Knowledge Requirements

General knowledge in the field of drilling installations, electrical installations and automation engineering is required to understand this manual.

Off-shore installations:
Additional knowledge in the field of off-shore electrical installations and requirements are needed.

Explosion Proof- installations:
Additional knowledge in the field of off-shore installations and requirements are needed.

1.3 Position in the information scheme

This manual is part of the Electroproject Soft Torque (EPST) documentation. The information below presents an overview of the information landscape of EPST system.

- Technical request form.
  Provides needed technical data from top-drive system to start engineering of EPST system.

- Installation and mounting instructions.
  Provides guidelines for the installation and erection of EPST system.

- Installation Rig System On Paper (IRSOP) procedure.
  Provides guidelines for the commissioning and start up of EPST system.

- **Operation manual.**
- **Quick reference guide to EPST touch screen**

We trust that following these instructions, the EPST system will positively contribute to your operating results for many years to come.

We will be pleased to supply you with further information and assistance as regards installation of your EPST system.

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2 Stick-Slip mitigation

2.1 What is “Stick-Slip”?

“Stick-slip” is a common occurrence in drilling operations that can result in harmful rotational vibrations in the drill-string. Although the drill-string is continuously rotating at surface during the drilling operation, friction on the bit, bottom hole assembly (BHA) and/or drill-string itself can cause it to “stick” down hole. As rotation at surface continues and torque in the drill-string builds up, this ‘stick’ friction is suddenly overcome causing a sudden increase in speed (“slip”) as the drill-string ‘unwinds’ itself. 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.

2.2 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 behaviour is the saw-tooth behaviour 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 behaviour can only be seen clearly when using data with at least 1-second sample time.

Figure 1: Torque variations due to stick-slip
2.3 How to reduce “Stick-slip”

Stick-Slip only 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. Install Electroproject soft torque system (EPST) to reduce Stick slip.

Please note that EPST, is the first soft torque system specifically developed for AC top drives and modern DC drives. Soft Torque technology has been in use since the early ‘90’s.

Figure 2: Activating soft torque

In Figure 2 at 1332 seconds soft torque is switched on. Torque becomes smoother and speed variations are greater. This is typical when soft torque is active.
3 General

3.1 System overview

The EPST system is designed to be easily implemented in modern drive systems. The EPST controller is a standalone but RIG specific µ-processor based controller. It can operate without any interface with the RIG-controls.

To implement the system the following hardware is required (see Figure 3):
1. Touch panel to operate the system (HMI).
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.

One possible implementation example:

![Diagram of EPST System overview](image-url)

Figure 3: EPST System overview (extra profibus communication board example)

To make the controller work properly a fast connection between VFD and EPST controller is necessarily. In the block diagram above this fast connection has been made with a second profibus interface to the VFD.
Another most common implementation example:

Figure 4: EPST System overview (in-between original profibus example)
3.2 EPST options / modes

EPST has two options:
- Auto tune
- Advanced soft torque
- Z-torque (hybrid)

3.2.1 Auto tune option

An option that automatically estimates the tuning of EPST while drilling. Manual input of tuning is not necessarily.

3.2.2 Advanced soft torque option

The tuning of the controller will be made on based on an optimum drill bit speed response when the bit loses from a “stick to slip situation”. Depending on the whole system (top drive / drill string) a third tune parameter is introduced compared to normal EPST: “Comp”. Comp stands for “Compensation”.

3.2.3 Z-torque option

Z-torque is a recently developed soft torque control system by Shell. EP hybrid Z-torque uses its own advanced soft torque controller to achieve the same mobility as Z-torque. Z-torque settings are transferred in the background to AST settings. The controller mobility of Z-torque can be revered to a so called “Hummingbird plot”.

![Z-torque “Hummingbird Plot”](image)

3.3 EPST control and input

With the touch panel the EPST controller can be operated and speed and torque variables can be monitored.

The EPST controls consist of:

1. Switching Soft Torque (ST) ON and OFF.
2. Switching Soft Torque Auto Tune (AT) ON and OFF.
3. Enable normal, advanced soft torque (AST) or Z-torque control (ZT).
4. Manually entering the right settings for the tuning parameters \( K_f \) and \( C_f \) or \( H \) and \( 1/Z \) for Z-torque.
5. Alternatively calculation of \( K_f \) and \( C_f \) depending on BHA and Drill pipe specifications (not ZT)
3.4 Settings

The user settings can be found at the “Settings” screen on the EPST-HMI control panel. System settings can be accessed directly at the EPST-IPC and only need to be modified by the EPST specialist while commissioning.

**IMPORTANT**

The EPST system can only be used after been commissioned by an Electroproject EPST specialist.
3.5 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 120 seconds.

An adjustable filter time for all display values can be set in the settings screen to avoid aliasing of the sampled trend due to the communication speed between the touch panel and the EPST controller.

3.6 Advanced data logging

The EPST controller running on an IPC (Industrial PC) with Linux as operating system. The IPC also functions as a data server for logging purposes, the EPST-server.

The EPST-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 4ms (250Hz sampling). Depending on the size of the applied hard disk(s), log data can be held for months.

![Figure 6: Screenshot ST log-data view program](image)

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

If the IPC is connected to a WAN network, log data 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 EPST 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.

3.8 EPST off-line / bypassed

Depending on the implementation of the EPST controller the controller can be totally disabled or bypassed. This in case of a malfunction of the controller or to trouble shoot if there are problems with controlling the top drive.

3.8.1 Configuration with two profibus communication channels to the VFD

Since the EPST system is designed as a standalone but RIG specific controller the drill operation can continue if the EPST system is off-line in case of a configuration with two profibus communication channels to the VFD. Drill operation can continue with disconnected EPST system. If the EPST is turned off, the original control of the VFD is restored.

3.8.2 Configuration with EPST connected in between PLC and VFD

When the IPC controller is situated between the top drive control PLC and the VFD profibus communication, the EPST controller can always be physically bypassed by “skipping” the controller in the profibus network. See appendix “8.3 EPST connected in-between the profibus communication cable (bypass)”.

3.9 Unit system: metric or imperial.

The unit system can be changed in the “settings screen”

<table>
<thead>
<tr>
<th>IMPORTANT</th>
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<tbody>
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<td>A common cause of problems with operation is wrong data input.</td>
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<td>Wrong data input can be caused by the wrong choice of unit system.</td>
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4 Principle of operation EPST / AST

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 bit is optimal for effective penetration, low drill wear and good steering conditions.

At certain depths and depending on drilling 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. The large speed variations can damage downhole components, including the bit itself. Furthermore, stick-slip is known to decrease ROP by some 25%. Also steering rotary drilling operation is very difficult under “stick-slip” conditions.

The EPST system is designed to mitigate the stick-slip behaviour or enlarging the working envelope of the drilling process.

4.1 EPST HMI Control panel

Controlling the EPST soft torque system is done on a HMI touch screen. The available screens and controls depend on which EPST options are enabled:

- EPST Auto Tune (AT)
- EPST Advanced Soft Torque (AST)
- Z-torque

In the Figures and paragraphs are applicable to a EPST control system with the first two options are enabled! Z-torque will be described in chapter 0.

Buttons

Buttons are operated by touching the displayed symbol on the screen

WARNING

Accidentally touching the screen could activate unwanted functions.
To wipe the screen clean see chapter 5.6 (Clean screen function)
**Numeric input**

![Numeric key-pad](image)

0 – 9 = numeric input values

- =

= = Backspace

= Enter

ESC = Escape

Del = Delete

Ins = Insert

→ = move cursor to left

← = move cursor to right

Num = Toggle Numeric / Alphabetic keypad

The alphabetic keypad will not be described because no alphabetic input is required.

**Bottom section of the screen**

Depending on the version of the EPST control software and the available options, the below “screen selection buttons” will be present at the bottom section of each screen (see Figure 6).

![Bottom section of the screen](image)

By selecting one of the screen selection buttons the selected screen will be activated. The screens will be described in the next chapters.

**Upper section of the screen**

![Upper section of the screen](image)

**Alarm signal and button:**
If a warning is active the button “Warning if flashing” will be flashing.
By pressing the button, the warning screen will be opened. Active warnings will be displayed. See paragraph 7.3

**IPC time:**
The actual time of the EPST industrial pc (IPC) is shown. This is not the actual time of the HMI clock. This time is used with the log data and messages of the EPST IPC.
Info screen button:
By pressing on the “Electroproject Aandrijftechniek” logo the info screen of the EPST system is shown. The info screen gives the Electroproject contact data and some background information of the EPST system.

4.2 CONTROL: Activate EPST

Switching EPST ON and OFF is done by the "Activate EPST" button (toggle function) on the “Home screen”. The button is grey when EPST is not active and green when active.

![Activate EPST](OFF state)

If pressed “Activate EPST” EPST will be switched ON and automatically the “Next Kf / Cf” values will become active.

![Activate EPST](ON state)

If pressed “Activate EPST” EPST will be switched OFF.

Switching ON the EPST controller can be done “bump less” while the top drive is running. If the EPST controller is switched OFF the original speed controller of the variable frequency drive (VFD) become active again.

**IMPORTANT**

Make sure that the right “Next values of Kf and Cf” have been set. This can be done manually, by calculation with BHA and drill pip entries or automatically by EPST AutoTuning (EPST-AT).

EPST will be switched OFF automatically or cannot be switched on when:

- a communication error occurs between IPC and VFD;
- communication timeout between touch panel and IPC has been exceeded; See chapter 5.6 “EPST-time-out display”
- the drillers speed set point is less than the “Auto switch off speed, settable on HMI panel”. See chapter 5.6 “Auto switch off”.
- the VFD is switched off.
- The Kf / Cf settings are out of range.
4.3 Kf, Cf and Comp (AST) tuning parameters

The EPST controller is a speed controller tuned with the \( K_f \) (drive stiffness in Nm/rad) and \( C_f \) (drive damping in Nms/rad) values. If the EPST advanced soft torque option is enabled a third setting “Comp” is available.

Depending on the drill string and BHA configuration the tuning parameters \( K_f \) and \( C_f \) are calculated. EPST will be able to improve damping of stick-slip when the two tuning parameters \( K_f \) and \( C_f \) are on target or not too far from ideal values. Also drill speed needs to be above a threshold value. Compared to normal operation (EPST is not activated) the threshold speed value above which stick-slip cannot exist, is lower when soft torque is on.

**IMPORTANT**

When “Auto Tune with auto transfer” is not used or no AT option, \( K_f \), \( C_f \) must be adjusted each time the drill string configuration changes (e.g. adding a stand)! The comp value when the AST option is available is normally a constant value.

The EPST system has “Actual” and “Next” Kf, Cf and Comp settings for the EPST controller:

The Kf, Cf and comp values with the black background are the actual “used” values when EPST is active. These values cannot be changed directly. Each time EPST is activated by pressing on the “Activate EPST” button, the Next values will be copied to the actual values directly except when the next values differs to much with the actual ones.

There are four ways to specify the next Kf, Cf and Comp settings.

1. Manually input of next Kf, Cf and Comp values on the Home screen
2. Calculation with integrated BHA and drill string configuration. (BHA and Drill pipe entry screen)
3. Automatic calculation and activation by EPST Auto Tune algorithm (EPST-AT)
4. By the “Initialize AT” function on the “Home Screen”
When “auto tune” with “auto transfer” is selected changing the next tuning values on the main screen is not possible.

If correct settings are available in the next Kf and Cf values EPST can be activated with the “activate EPST” button. With auto tune and auto transfer selected activation of EPST may be blocked because the last tuning values estimated where expired. Wait before new AT values come up before enabling or switch auto transfer of to use manual input.

![Image]

When the next values differ more than the in the settings set percentage “Max. difference next and actual Kf/Cf” the next values will be coloured dark orange. Then, if the “Activate EPST” button is pressed a pop-up window will show:

![Image]

Figure 13: Pop-up when activating EPST (no AST option)

Possible reasons for a certain difference between the “old” and “new” values:

- EPST-AT has been switched off for a couple of stands. In the meantime the calculated Auto Tuning values are changed more than the last actual ones.
- EPST-AT has not been able to produce next Kf and Cf values for a while.
- After (re-) initializing the “Next Kf / Cf” values with the “Initialize-AT” button it is most likely that these next values are different than the actual ones.
- Wrong manual input or first time manual input
- Skipped manual input of new Kf/Cf values for a while
- Restart using EPST like starting a new hole.
- Change drillstring configuration.
The EPST controller continuously checks if the actual values of Kf and Cf are out of range. The settings are out of range if one of the following conditions is true:

- Cf < 500 or Kf < 250
- Cf > 20000
- Kf > 30 * Jtd

Where Jtd is the inertia of the top drive. (PA011 of EPST controller.

**Note. Chapters 4.3.1 until 4.3.2.3 are mentioned for Manually Input of Kf and Cf**

### 4.3.1 Manual input of Kf and Cf

Manual input of Kf and Cf is always possible when auto tune and auto transfer is not activated (AT option).

Entering the right settings must be done on the “Home” screen by touching “Next Kf and Cf" input fields.

If working with manual input of Kf and Cf a table must be provided with Kf and Cf values for each bit depth.

To make the EPST controller work properly the right Kf and Cf parameters must be entered depending on the bottom hole and drill string assembly configuration. This can be done by touching the input fields of the "Next Kf and Cf values" on the main screen and must be repeated after every stand. For input of Kf and Cf a data sheet must be available with the pre-calculated Kf and Cf values.

**IMPORTANT**

Soft Torque may be in the on state while changing the Next Kf and Cf values. Make sure when reactivating EPST by the “Activate EPST” button proper next Kf / Cf values are filled in.

When manual input of the next Kf/Cf values is desired switch both off the “AT-Auto transfer function” when enabled. Auto tune may be left on for special data analyses.

Kf and Cf values must be adjusted during drilling according to the drill depth to make the EPST controller work properly. Wrong settings can cause instability or no optimal performance of the system.

Ask for new data sheet if drill string or BHA configuration is changed and no auto tune or HMI calculation is used.
**Example part of Kf and Cf sheet that can be provided:**

<table>
<thead>
<tr>
<th>Total Measured Depth (along hole)</th>
<th>Tuned values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total MD [m]</td>
<td>Kf [Nm/rad]</td>
</tr>
<tr>
<td>1800</td>
<td>6188</td>
</tr>
<tr>
<td>1829</td>
<td>6046</td>
</tr>
<tr>
<td>1857</td>
<td>5909</td>
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<tr>
<td>1886</td>
<td>5776</td>
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<td>1914</td>
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<td>1971</td>
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<td>5290</td>
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<td>4965</td>
</tr>
<tr>
<td>2114</td>
<td>4863</td>
</tr>
</tbody>
</table>

This table is unique for each top-drive, drill string and BHA configuration.

**Procedure manual input Kf and Cf:**

1. Check if correct Kf and Cf table is available for the current configuration.
2. Select Home screen.
3. Select “Next Kf” input field (press at the Next Kf numeric field).
5. Depending on total measured depth (MD) fill in the right Kf value (see example).
6. Before pressing enter button check if the entered value at the Kf field is correct.
7. Confirm value by pressing enter button.
8. Enter the new “Next Cf” value, same procedure as “Next Kf” (step 3 to 8).
9. EPST controller is now ready to be (re-) activated.

**Note:** If the EPST controller was still activated while changing the next Kf/Cf values, EPST must be first deactivated and activated again to make the new Kf/Cf values active! The next values are transferred to the actual ones by reactivating EPST.

**Example for selecting Kf and Cf values:**

A new stand is inserted.
Current total MD = 1975 meter.
The next total MD in the provided table is 2000 meter.
The corresponding values of Kf and Cf in the provided table are Kf = 5290 and Cf = 2422.
Enter these values in the corresponding input fields at the “Home” screen.
Before activating EPST again, check if values on the touch panel are correctly entered.
### 4.3.2 Calculation with BHA and DP entry

Alternatively, the EPST controller can calculate the values of $K_f$ and $C_f$. For this calculation the configuring of the bottom hole assembly (BHA) and the drill string data has to be inputted in the EPST. The input of data and calculation is done on the “BHA-entry” and “Drill Pipe-entry” screen (for a detailed description see chapter 4.3.2.1 and 0).

The drill pipe entry screen does have a total of five different drill pipe parts to configure. Item one is the lowest (connected to the BHA) and must be first selected. A pipe part can be added by selecting a pipe name from the database and enter the TOTAL length of the stands. Just adjust the length of the highest pipe part item (connected to the top drive) each time a connection has been made and then recalculate the $K_f$ and $C_f$.

### 4.3.2.1 BHA (Bottom Hole Assembly) Entry screen

Alternative to the manual input of $K_f$ and $C_f$, the EPST controller can also calculate the values of $K_f$ and $C_f$. For this calculation the configuring of the bottom hole assembly (BHA) and the drill string data has to be inputted to the system. The input of data and the calculation of the tuning parameters is done on the “BHA-entry” and “Drill Pipe-entry” (see chapter 4.3.2.2) screen.

![BHA Entry screen](image)

The BHA entry screen has a maximum of 5 items to enter. Obviously, in practice, a BHA will have more components. The most significant components in the BHA, in terms of weight and length, **MUST** be entered; such as HWDP and / or DC. The length of smaller components, like the bit, motor, stabilizers, MWD and jars have to added to the main components in the BHA when using the BHA entry screen.
For the first four items four parameters should be entered:

1. **Material.** → “No Item”, “Normal” or “Non-magnetic”
2. **Outer diameter.**
3. **Inner diameter.**
4. **Length.**

The outer, inner diameter and length can be entered by selecting it’s numeric input field. Because of the huge variety of BHA components there is only a standard drill pipe database implemented in the EPST system. HWDP or normal DP’s can be selected in item 5. The rest of the BHA components must be configured at items 1 till 4.

By lumping the BHA into four major items the BHA entry can be simple and it is not necessary to maintain a large data base. The BHA items must be entered from the bit up! Item one is closest to the bit! Unused items will not be included in the calculations. It is recommended to always use the four available items to input the BHA, to make the tuning as accurate as possible.

**Material:**

The settings for material are:

1. Normal.
2. Non-magnetic.
3. No-Item.
   
   If “No item” is selected as material this item will not be part of the calculation of $K_f$ and $C_f$.

**Outer diameter, inner diameter, Length:**

Fill in the sizes of the configured BHA items.

Note: The unit system can be changed in the “settings screen”.

The fifth item is meant for selecting a standard heavy drill pipe from the predefined database. Select the used heavy drill-pipe belonging the BHA. Add all used lengths of the BHA HWDP’s and fill it in the length field of item five.

HWDP’s can also be used as a part of the drill string. Add these HWDP’s on the drill pipe entry screen.

**BHA Calculations:**

The calculation of $K_f$ and $C_f$ can only be started after the drill pipe has been configured at the “Drill Pipe Entry” screen.

**IMPORTANT**

Once drilling has started with a certain BHA configuration, the entries on this BHA entry screen don’t have to be adjusted anymore.
Note: The units of diameter and length can individually be changed on the settings screen (m / inch):

![Figure 15]

4.3.2.2 Drill Pipe Entry screen

![Figure 16: Drill Pipe Entry screen just after calculation]

The drill pipe entry screen does have a total of five different drill pipe sections to configure.

Item 1 is the lowest (connected to the BHA) and must be entered first. In case this drill pipe section runs all the way to surface, items 2, 3, 4 and 5 will remain unused.

Pipe name and ID field:

The EPST controller has a database of pre-defined DP selections. This database contains definitions of regular normal DP’s and HWDP’s. The DP database will continuously be updated to the need of our customers. When needed the database can be updated but only can be done by an EPST engineer.

The moments to update the database are before or during the Installation & Commissioning and during maintenance.
Available pipes in HMI version …V80DP (STRS_Tuning_Master_Version_V80_June_2015) are:

<table>
<thead>
<tr>
<th>DP No.</th>
<th>Display name</th>
<th>Display name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3 1/2” DP - 9.50 lb/ft - NC38</td>
<td>31 5 7/8” DP - 23lb/ft - GT-Type2</td>
</tr>
<tr>
<td>2</td>
<td>3 1/2” DP - 13.30 lb/ft - NC38</td>
<td>32 5 7/8” DP - 26lb/ft - GT-Type3</td>
</tr>
<tr>
<td>3</td>
<td>3 1/2” DP - 15.50 lb/ft - NC38</td>
<td>33 5 7/8” DP - 26lb/ft S-135 XT57</td>
</tr>
<tr>
<td>4</td>
<td>4” DP - 11.85 lb/ft - NC46</td>
<td>34 5 7/8” DP - 46.18lb/ft S-135 XT57</td>
</tr>
<tr>
<td>5</td>
<td>4” DP - 14.00 lb/ft - CYX105-120</td>
<td>35 6 5/8” DP - 25.20 lb/ft - FH</td>
</tr>
<tr>
<td>6</td>
<td>4” DP - 14.00 lb/ft - XD105</td>
<td>36 6 5/8” DP - 27.70 lb/ft - FH</td>
</tr>
<tr>
<td>7</td>
<td>4” DP - 14.00 lb/ft - G-109</td>
<td>37 6 5/8” DP - 27 lb/ft - GT-Type4</td>
</tr>
<tr>
<td>8</td>
<td>4” DP - 14.00 lb/ft S135 TT390</td>
<td>38 6 5/8” DP - 34 lb/ft - GT-Type5</td>
</tr>
<tr>
<td>9</td>
<td>4” DP - 14.00 lb/ft - NC40 (FH)</td>
<td>39 6 5/8” DP - 40 lb/ft - GT-Type6</td>
</tr>
<tr>
<td>10</td>
<td>4” DP - 14.00 lb/ft - GT-type1</td>
<td>40 2 7/8” HWDP - NC26 (2 3/8” IF)</td>
</tr>
<tr>
<td>11</td>
<td>4” DP - 14.00 lb/ft - G105 - XT40</td>
<td>41 3 1/2” - 2 1/16” HWDP - NC38 (3 1/2” IF)</td>
</tr>
<tr>
<td>12</td>
<td>4” DP - 15.70 lb/ft - HT38</td>
<td>42 3 1/2” - 2 1/4” HWDP - NC38 (3 1/2” IF)</td>
</tr>
<tr>
<td>13</td>
<td>4” DP - 15.7 lb/ft - NC40</td>
<td>43 3 1/2” - 2 1/4” HWDP - HT38</td>
</tr>
<tr>
<td>14</td>
<td>4” DP - 15.7 lb/ft IU G105 HT</td>
<td>44 3 1/2” - 2 1/4” HWDP - XT39</td>
</tr>
<tr>
<td>15</td>
<td>4 1/2” DP - 13.75 lb/ft - NC50</td>
<td>45 4” HWDP - NC40 - NC40 (4 FH)</td>
</tr>
<tr>
<td>16</td>
<td>4 1/2” DP - 16.6 lb/ft - NC50</td>
<td>46 4” HWDP - XT39</td>
</tr>
<tr>
<td>17</td>
<td>4 1/2” DP - 20.00 lb/ft - NC50</td>
<td>47 4” HWDP - NC40 - XT39</td>
</tr>
<tr>
<td>18</td>
<td>5” DP - 19.50 lb/ft - NC50</td>
<td>48 4” HWDP - HT38</td>
</tr>
<tr>
<td>19</td>
<td>5” DP - 19.50 lb/ft - G-105</td>
<td>49 4 1/2” HWDP - NC46 (4 IF)</td>
</tr>
<tr>
<td>20</td>
<td>5” DP - 19.5 lb/ft - VM105 - NC50</td>
<td>50 5” HWDP - NC50 (4 1/2” IF)</td>
</tr>
<tr>
<td>21</td>
<td>5” DP - 25.60 lb/ft - NC50</td>
<td>51 5” HWDP - HT50</td>
</tr>
<tr>
<td>22</td>
<td>5 1/2” DP - 21.90 lb/ft - FH</td>
<td>52 5 1/2” HWDP - 5 1/2” FH</td>
</tr>
<tr>
<td>23</td>
<td>5 1/2” DP - 21.90 lb/ft - HT55</td>
<td>53 5 1/2” HWDP - 5 1/2” FH (CB)</td>
</tr>
<tr>
<td>24</td>
<td>5 1/2” DP - 21.90 lb/ft - FH (CB)</td>
<td>54 5 1/2” HWDP - 5 1/2” FH VAM CDS</td>
</tr>
<tr>
<td>25</td>
<td>5 1/2” DP - 21.90 lb/ft - FH CDS</td>
<td>55 5 1/2” HWDP - XT54</td>
</tr>
<tr>
<td>26</td>
<td>5 1/2” DP - 24.70 lb/ft CYX105-120</td>
<td>56 5 1/2” HWDP - HT55</td>
</tr>
<tr>
<td>27</td>
<td>5 1/2” DP - 24.70 lb/ft XD 105</td>
<td>57 5 7/8” HWDP - XT57</td>
</tr>
<tr>
<td>28</td>
<td>5 1/2” DP - 24.70 lb/ft - S-135</td>
<td>58 5 7/8” x 4 1/4” HWDP -VAM VX57</td>
</tr>
<tr>
<td>29</td>
<td>5 1/2” DP -XT54 26.73 p/f (24.7p/f IEU)</td>
<td>59 6 5/8” HWDP - 6 5/8” REG Interdrill</td>
</tr>
<tr>
<td>30</td>
<td>5 7/8” DP - 23.4lb/ft S-125 VAM VX57</td>
<td>60 6 5/8” HWDP - 6 5/8” FH</td>
</tr>
</tbody>
</table>
To change or add a drill pipe touch the actual pipe type of the DP-entry that must be changed.

The above DP-entry “5” has no pipe selected yet. To add one, touch “No Pipe” to open the DP database pages. The database page with the actual selected drill pipe opens. In this case its page 1 with “no pipe” selected:

Browse with the “Previous page” and “Next page” buttons to the page (4 pages) the desired drill pipe is listed. When touching the new DP entry this pipe will be directly selected and the DP database will be closed automatically.

DP-entry “5” with selected pipe:
Total length:
When switching ON the EPST system for the first time during a drilling process the existing pipe configuration needs to be inputted. Start to fill in the lowest (connected to the BHA) pipe part and fill in the total length of the corresponding pipe by using the numerical keypad.

Drill pipe entry length:
Each time a connection has been made the length of the concerning drill pipe entry must be adjusted. This can be done by touching the "Length" field of the current drill pipe entry and fill in the right length or by means of the "+" button. If the "+" or "-" buttons are used to adjust the drill pipe entry length, the right actual "One pipe stand" length must be set up correctly. This can be done by touching the "one stand" field in the current drill pipe entry row.
If applicable a new drill pipe entry must be added by selecting a pipe name at the next not used drill pipe entry row.
The "+" and "-" buttons is a tool to adjust easily a drill pipe entry length each time a stand is added. The mean length of the used stands must therefore be filled in the "One stand" length field.

Calculate:
If the settings of the BHA have been altered at the BHA entry or the settings of the drill pipe have been changed the “calculate” button starts blinking. This indicates that a calculation of the Kf and Cf values has to be made. Just press the “calculate” button to recalculate the Kf and Cf values.

Transfer:
If the calculated values differ from the current values of Kf and Cf, the “transfer” button starts blinking. Press the transfer button to copy the calculated values to the current (active) values of Kf and Cf.

**IMPORTANT**

Soft Torque must be in the off state before changing the Kf and Cf parameters.
Wrong settings can cause instability of the system.
The current values of Kf and Cf on this screen are the same values showed on the home screen.

### 4.3.2.3 Procedure for Kf and Cf calculations with BHA an Drill pipe calculation

See also paragraph 4.3.2.1 and 4.3.2.2.

**New configuration:**

1. Select Home screen
2. Switch EPST OFF
3. Select BHA Entry screen
4. Fill in BHA settings at the BHA entry. See paragraph 4.3.2.1
5. Select Drill Pipe Entry screen
6. Fill in (existing) Drill pipe settings at the Drill Pipe entry. See paragraph 4.3.2.2
7. Press calculate button
8. Press orange transfer button
9. Select Home screen
10. Activate EPST
Connecting new stand:

1. Select Home screen
2. Switch EPST OFF
3. Select Drill Pipe Entry screen
4. If applicable a new drill pipe entry must be added by selecting a pipe name at the next not used drill pipe entry row
5. If necessary adjust length of one stand by using numerical keypad
6. Press “+” button or adjust the length field to add a stand length to the drill pipe entry with the highest number.
7. Press “Calculate” button to calculate new Cf, Kf and length values.
8. Press “Transfer” button to make new calculated values active.
9. Select Home screen

4.3.3 Automatic calculation and activation by EPST Auto Tune algorithm (AT option enabled)

EPST-AT is a new developed Soft Torque Auto Tune algorithm patented by Electroproject.

EPST-AT differs from other auto tune algorithms because it really identifies the drill string and BHA while the drill string is rotating. Although soft torque is mainly used to mitigate “stick slip” it is proven that soft torque has a positive effect on the drill process even if there is no stick slip! EPST-AT can be used when there is no stick slip in contrast to other soft torque auto tune algorithms.

EPST-AT analyses high resolution measured top drive data (torque / speed) while operating the top drive. It provides automatically the tuning parameters (Kf / Cf) for the EPST Soft Torque controller. With EPST-AT there is no need to manually enter these parameters or configure the drill string and bottom hole assembly at the EPST control panel!

The EPST-AT algorithm analyses measured drill data in blocks of ten minutes. If the first block contains “usable” information in the data it can estimate the tuned values of Kf and Cf. If there is not enough information in the data, it takes another block or more to identify the Kf and Cf values.

To enable auto tune, select the “Auto tune (AT)” button on the settings screen:

Auto tune not enabled: Auto tune enabled:

NOTE

When the button is not shown on the settings screen, the EPST auto tune option is not enabled. Then also the “Auto transfer” and “Initialize AT” buttons will not be available on the home screen.
The EPST auto tune exists out of two algorithms:
- Auto initialize while EPST is not activated
- Auto tune while drilling with EPST activated

When auto tune is enabled both algorithms run in the “background” and try to estimate initial and auto tune values of $K_f$ and $C_f$.

To **automatically use** these estimated values the next time EPST is reactivated the auto transfer function must be selected on the home screen:

**Auto transfer not enabled:**

**Auto transfer enabled:**

The “auto transfer” function cannot be switched on when auto tune is not enabled on the settings screen!

The auto initialize algorithm will estimate initial values that can be used as “start values” for the auto tune algorithm. Once the auto tune algorithm has estimated $K_f$, $C_f$ and $Comp$ values and these values are not expired, these values are used.

When the auto tune algorithm values are expired, the initial values will be used.

As long as the auto initialize algorithm is not able to estimate values and the auto tune values are expired, EPST activation is not possible. To manually calculate initial values so EPST can be activated select the Initialize button on the home screen. See paragraph 4.3.3.2 for description of this function.

**NOTE**

Note: Keep in mind that if stick slip is present or the ROP is too high (too less data for the auto tune algorithm available), the EPST-AT algorithm is not capable to produce $K_f$ and $C_f$ auto tune values at a regular basis! If no new $K_f$ and $C_f$ values are estimated the init values will be used. When optimal performance is needed, consider manual calculation with the BHA en DP entry screens.

4.3.3.1 **Procedure for using EPST with auto tune function enabled**

1. Check on the settings screen if “Auto Tune” and on the home screen “AT-Auto Transfer” are enabled.
2. When initial values or auto tune values are available EPST can be activated. If not, wait a few seconds or use the “Initialize-AT” button on the home screen.
3. Start using EPST by activating it with the “Activate EPST” button on the home screen. After a short time the “AT-Active” indicator will appear meaning that the EPST-AT algorithm is working in the background.
4. After minimal 10 minutes drilling with EPST-AT the first estimated values will appear in the “Next Kf/Cf” fields on the home and auto tune screen. If this happens, also the green “AT-NV” will be appear on the home screen.
5. Deactivate or let EPST switch off automatically when adding a new stand.
6. After adding a stand, start drilling and activate EPST again. If the next values of $K_f$ and $C_f$ were in range of the actual ones (set on the settings screen with the “Max. difference next and actual Kf/Cf” setting), the next values estimated while drilling the previous stand will be used automatically as actual values.
7. Go to step 4.
4.3.3.2 Initializing EPST-AT

Use the “Initialize AT” button to calculate new start values for the EPST-AT. Because EPST-AT can only produce EPST tuning values when EPST is activated, Kf and Cf “start values” must be calculated to begin EPST with.

If no other start values for EPST are present, use this button.

When pressing on the “Initialize AT” button a pop-up screen will appear:

![Pop-up window to Initialize EPST settings.](image)

**Figure 20**

Fill in the approximately actual depth of the drill bit and press enter. After pressing “Accept measured depth” start values will be calculated and used as “Next Kf and Cf values. When EPST is activated these values will be used as “actual Kf and Cf values”.

```plaintext
Fill in the actual measured depth to initialize auto tune:
```

0 [m]
The shorter the measured depth, the higher the next Kf and Cf values will be. If the entered depth is too low, the calculated next values of Kf and Cf will be out of range. A fault will be generated: "Kf/Cf settings out of range" after trying to activate EPST.

Because the maximum Kf value is top drive independent a minimum depth for the initialization button cannot be given (Kf max is ten times the inertia of the top drive).

$300 < Cf < 15000$ and $300 \text{ Kf} < 10 \times Jtd$.

Try to increase the initialization depth till the above criteria meets.

## 5 Screens of EPST HMI touch panel

In this chapter all EPST HMI screens will be described.

### 5.1 Home screen

This is the “start-up” screen of the EPST HMI control panel.

On this screen an overview of the system is shown.

Gauges and trends with actual drill speed and pipe torque are shown.

Changing the display values from **metric** to **imperial** can be done at the “settings screen”.

![Figure 21: Home screen](image-url)
### Speed gauge

The speed gauge gives the value for the actual drill speed of the TOP DRIVE (TD) in rpm.

### Torque gauge

The torque gauge gives the value for the actual pipe torque applied at drill pipe. Tmax displays the actual Torque Limit.

### SSI “Stick slip indicator”

The value displayed by the stick slip indicator is the measured peak-peak torque ripple on the pipe torque. The red graphical bar has a 0-40 kNm scale. The lower the showed values the better.

### “AT-active” and “AT-NV” indicators

The green “AT-active” indicator will show up when AT and EPST is activated and the AT algorithm is estimating Kf an Cf values.

The green “AT-NV” (Auto Tune New Value) indicator will show up when the EPST-AT algorithm has found a the first new value after activating EPST.

### “Auto Tune” button

The Auto Tune button enables the EPST auto tune algorithm. When EPST is activated, Kf and Cf values will automatically estimated for the current drill string.

### “Initialize button”

Next Kf an Cf values will be calculated by input of measured depth. Use only when starting EPST with auto tune enabled for de first time of a new hole!

### Trend display

The trend display shows the time related graph of drill speed and torque.

For a better indication of speed and torque choose the TREND display. See chapter 5.2

The time scale (x-axis) is fixed. The graph shows the last 120 seconds.

The trend display does have “auto scaling” of Y values. The scaling is only adjusted when the signals does not “fit”.

The scaling can be reset on the “Trend screen”. See chapter 5.2
5.2 Trend screen

The trend graph shows three magnitudes:

1. **Actual Drill speed at TD**
   
   \[ n \text{ (drill speed at TD)} = n \text{ (motor)} / \text{gear ratio} \]

2. **Actual applied torque**
   
   \[ T \text{ (TD)} = T \text{ (motor)} * \text{gear ratio} \]

3. **Actual pipe torque**
   
   Calculated pipe torque from EPST algorithm.

The trend graph of torque and speed has “auto scaling” of Y values. The scaling is automatically adjusted when the signals are out of range. The scaling can be reset by pressing the “Reset Y Scales” button.

The values are read from the EPST server every 0.5 seconds. To avoid a wrong interpretation of the signals (aliasing), a filter time for the displayed signals can be set at the “Settings screen”. A value of > 0.5 seconds is recommended.
5.3 BHA entry screen

The BHA entry screen has a maximum of 5 items to enter. Obviously, in practice, a BHA will have more components. The most significant components in the BHA, in terms of weight and length, MUST be entered; such as HWDP and/or DC. The length of smaller components, like the bit, motor, stabilizers, MWD and jars have to be added to the main components in the BHA when using the BHA entry screen.
5.4 Auto tune screen

The “Auto Tune” screen is only a status screen.

At the top of the screen there are three indicators:

EPST soft torque controller is active when green. Switching EPST on and off can be done on the home screen.

Note: EPST is also switched off (automatically) when the drilling speed setpoint drops below the setting “Auto switch off EPST level on the settings screen.

EPST-AT is enabled. This means that when EPST is enabled the auto tune algorithm tries to estimate automatically values for Kf and Cf. If a new values are calculated it will be showed in the “Calculated Kf and Cf fields”.

*Figure 24*
EPST-AT Auto transfer is enabled. When new values for Kf and Cf are calculated, these values will not only be shown in the “Calculated Kf and Cf fields” but will also be used as “Next Kf/Cf settings”. The “Next Kf/Cf settings” will be used as actual Kf/Cf settings the next time EPST is activated or reactivated.

If Auto Tune and “AT-Auto Transfer” are enabled, the driller only has to switch EPST on and off. Tuned settings for the EPST controller are automatically estimated and used.

5.5 Messages screen

On the messages screen system messages are displayed. There are four EPST-system messages (see chapter 7.3).

On the messages screen also panel specific messages are displayed (e.g. communication, system diagnostic). An explanation of panel specific messages will not be explained in this manual and can be found in “Simatic Wincc” manuals. [http://support.automation.siemens.com/WW/view/en/23337820](http://support.automation.siemens.com/WW/view/en/23337820)

Pressing the clear button clears the list of system messages.
5.6 User Settings screen

![Settings screen](image)

**Filter time signals**

Filter time for displaying torque and speed signals. To avoid aliasing of the displayed signals (especially in trends) a filter time greater than 0.5 seconds must be entered. To read out a mean value over a longer time, this setting can be set to a higher value.

**Auto switch OFF**

If the actual speed setpoint is less than the “Auto switch off speed”, or when the TD is switched off, EPST will be switched off automatically after the “Auto switch of time”. This function can be disabled by entering 0 seconds.

---

**WARNING**

EPST Soft Torque must be in the off state before changing the Kf and Cf parameters or when not in rotary drilling operation. Always check if EPST is switched OFF when there is no rotary drilling operation.

---

**EPST time-out display**

If there is no communication between the HMI control panel and the EPST-IPC, EPST will be switched OFF after the “EPST time-out display” time. This function can be disabled by entering 0 seconds (only disable when there are communication problems and EPST must be forced).
IMPORTANT

Note: This time should always be a minimum of 4 seconds.

Toggle system Units

Change over between [kNm]/[meter] and [k.lbf.ft]/[ft] units. Length, Diameter and Torque units can be changed independently.

Clean Screen Function

The screen will be blanked for 30 seconds to make it possible to wipe the screen clean without accidentally pressing buttons or changing values.

Exit runtime

If pressed, the running EPST control program will be shut down and the panel will return to its operating system (Windows CE). Settings of the touch panel itself can then be made.

WARNING

Be careful with the “Exit to runtime” function! When the EPST control program is terminated, EPST will be switched OFF after the “EPST time-out display” setting! Also changing settings of the panel itself (e.g. network settings) can cause a malfunction of the EPST control panel!
6 Z-torque

Background information.....

6.1 Selecting Z-torque as EPST control mode

Controlling the EPST Z-torque controller is done on a HMI touch screen. The available screens and controls depend on which EPST options are enabled and or activated.

Besides “classic” soft torque control (STRS) and Electroproject advanced soft torque control (EP-AST) also Z-torque can be selected as soft torque control controller.

To activate Z-Torque controller, select the Z-Torque mode” button (if option is available) on the settings screen. When activated, the “AST mode” and “Z-Torque” mode buttons are green:

![Figure 27: Z-torque mode selected as controller; set on “settings screen”](image)

The auto tune option (if visible) cannot be used with Z-torque and should therefore not be activated (grey button).

For description of common use of the HMI (numeric input / upper screen section ….) is referred to chapter 4.1.

**Bottom section of the screen**

With Z-torque control mode activated the below “screen selection buttons” will be present at the bottom section of each screen (see Figure 28).

![Figure 28: Bottom section of the screen (ZT option enabled)](image)

By selecting one of the screen selection buttons the selected screen will be activated. The screens will be described in the next chapters.
6.2 CONTROL: Using Z-torque as soft torque controller

If Z-torque is selected as the EPST control mode (see Error! Reference source not found.) switching Z-torque ON and OFF is done by the “Activate Z-torque” button (toggle function) on the “Home screen”. The button is grey when Z-torque is not active and green when active.

**Figure 29: Activate Z-torque button “OFF state”**

If pressed “Activate Z-torque” Z-torque will be switched **ON** and automatically the set Z-torque tuning values will become active.

**Figure 30: Activate Z-torque button “ON state”**

If pressed “Activate Z-torque” Z-torque will be switched **OFF**.

Switching ON the Z-torque controller can be done “bump less” while the top drive is running. If the Z-torque controller is switched OFF the original speed controller of the variable frequency drive (VFD) become active again.

**IMPORTANT**

Make sure that the right “1/Z” has been set before enabling Z-torque. To estimate the right 1/Z (admittance) value, select the most similar drill pipe with the “Z-torque 1/Z indicator” button on the “ZT settings” screen.
Z-torque will be **switched OFF automatically or cannot be switched on** when:

- a communication error occurs between IPC and VFD;
- communication timeout between touch panel and IPC has been exceeded; See chapter 5.6 “EPST-time-out display”
- the drillers speed set point is less than the “Auto switch off speed” (25 rpm = 2.5 rad/sec). See chapter 5.6 “Auto switch off”.
- the VFD is switched off.
- The hybrid KI / CI settings are out of range

### 6.3 H, t0 and Comp Z-torque setup

Before activating Z-torque it is important to setup the controller once. Settings that can be made on the “ZT settings” screen are:

- 1/Z string admittance
- H
- t0
- Jcomp (% inertia compensation)

Visualisation and or judgement of the Z-torque control settings is helped by the recently developed “Hummingbird plot”. The plot as we use it shows how much of the energy coming from the drill string to the TD is reflected back into the drillstring. So it shows how much damping the TD control system has across the frequency spectrum.

- A value higher than 1 means that energy is amplified by the TD control system.
- A value lower than 1 means that energy is damped, absorbed by the TD control system.
- The name humming bird comes from the shape it generally has with a Softtorque system.

Typically example of a Hummingbird plot:

**Figure 31; Hummingbird plot**

- 1/H must match the characteristic admittance of the upper part of the drillstring.
- Higher value (maximum 1) for H gives “deeper” but narrower plot. Higher mode frequencies will be damped less.
- to sets the damping at real low (0 – 0.1 Hz) frequencies
- Jcomp set the inertia compensation level

For a detailed explanation see “EPZT_Tuning report_i1.pdf”.

---

**Z-torque** + **Auto tune** + **Advanced Soft Torque** + **Z-torque**

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All settings can be set at the Z-torque settings screen:

On the Z-torque settings screen the 1/Z, t0, H and Jcomp setting scan be set. The Z-torque settings will be activated the next time Z-torque is switched on except for the H value witch will be active immediately when Z-torque is active (on the fly).

Also the equivalent EPS-AST settings are showed. These settings are actually used by the internal EP-AST controller to act like a Z-torque controller. Besides the standard ZT-torque controller also internally the “EP X-shift” control is active to “shift” the “head” of the humming bird plot to a higher frequency. This will dampen the higher mode string oscillations more than standard Z-torque.

6.3.1 1/Z; Admittance setting

In principle Z-Torque has to be setup once during the well before starting to use it. The driller has to choose the upper section of the drill string as the typical admittance of the drill string. The best admittance fit will be when upper drill pipe is more than 1500 m homogenous drill pipe. When shorter and or not a homogeny upper drill string is used an impedance mismatch causes the controller not to function optimal. For a relatively short or not homogenous drill pipe manual calculation of the 1/Z value is advised. Another option would be using EP-AST (see also this manual).

To estimate the typical 1/Z value, press the “Z-Torque 1/Z indicator” so a reference pipe can be chosen out of the build in pipe data base. (See Figure 18 on page 25 for the drill pipe selection screen.)

Once chosen a “reference drill pipe” for the upper drill pipe section a 1/Z indication will be given:

With 5 ½ "HT55 selected as above, 1/Z indication (estimation) is "497". This value must be filled in the 1/z field:
6.3.2 Slow loop integration time

The slow loop integration time $t_0$ does influence how fast the top drive speed drillers set point is achieved or in other terms what the damping is for ferry low frequencies ($< 0.15$ HZ). This setting may be adjusted in case it takes long before the top drive speed will return to its set value after a stick slip event that has been mitigated.

Typical values:
- Relative short string $<$2500m) 2 seconds
- Medium string length 2500 - 4500m) 4 seconds
- Relative long string $>$ 4500 6 - 10 seconds

When set to 4 seconds it will cover most of the drilling circumstances. See also “Figure 33 Influence different settings”.

6.3.3 Jcomp; Percentage of top drive inertia compensation

Z-Torque (but also EP AST) requires compensation of top drive inertia. When the Z-torque control system is commissioned, the top drive inertia is estimated. By setting a certain amount of compensation it seems that the low frequent (0-1.2 Hz) torque and speed waves traveling through the drill pipe are seeing a top drive with a lower inertia than without Jcomp and therefore damping of these frequencies can be done more effective.

The maximum amount of compensation is influenced by:
- the Z-torque control loop delay witch has been measured at the commissioning,
- Compensation makes the controller also more dynamic and therefore it needs more power / braking power when mitigating stick slip. When limited power and or braking power available, the inertia compensation cannot be set that high.
- Quality of speed measurement signal
- Performance an accuracy of the VFD closed loop torque controller

When commissioned, the maximum compensation has been set. A typically value of Jcomp is 60 to 70 %. When the top drive already has a relatively low inertia of itself, les compensation will be required for optimal performance. Jcomp causes the right side of the hummingbird plot “hole” to go to the right.

6.3.4 H; damping at mid frequency of Humming bird

In the plot below the influence of the H setting can be seen

![Figure 33 Influence different settings](image)

When H is increased (maximum is 100%), the hummingbird plot becomes “deeper” but also narrower.
To get a good overall damping for all frequencies we should say a typical setting of 26% will perform the best if also higher mode frequencies disturb the drilling process and must be damped. If there is only one low frequency is showing up (first frequency mode) a higher value of H might perform better.
7 Maintenance

7.1 Trouble shooting guide EPST system

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<th>Cause</th>
<th>Counter measure</th>
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<td>VFD trip (F082)</td>
<td>One of the 2 Communication board profibus (CBP) fails.</td>
<td>- Power ON IPC?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Check profibus status lower slot card in VFD, all 3 Led’s should flash.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Check measure screen on IPC</td>
</tr>
<tr>
<td>No value (#####) on</td>
<td>Communication failure between IPC(switch) and HMI</td>
<td>- Power ON IPC?</td>
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<td>touch panel (HMI)</td>
<td></td>
<td>- Check cat5 cable</td>
</tr>
<tr>
<td>drillers cabin</td>
<td></td>
<td>- Check message screen on IPC</td>
</tr>
<tr>
<td>HMI not working</td>
<td>Power supply missing</td>
<td>check power supply and correct voltage for HMI</td>
</tr>
<tr>
<td>ST switches off</td>
<td>Communication lost with IPC for more than 4 seconds</td>
<td>- Check cable connectors CAT5</td>
</tr>
<tr>
<td>sometimes</td>
<td></td>
<td>- Check routing of CAT5 cable, avoid noisy routing near noisy cables (power/motor cables)</td>
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7.2 Procedure: Disabling the EPST system

The EPST system can be disconnected from the VFD, after which the VFD can be operated normally without soft torque feature. There are 3 ways how to disconnect the EPST controller. This depends on how the EPST system is connected to the original TD system. The EPST controller can be connected:

1. to the 2nd profibus connection of the VFD (see also annex 8.2)
2. in-between the profibus communication cable (see also annex 8.3 and 8.4)
3. to the TD system by controlling the analog I/O signals (see also annex 8.5)

Follow the corresponding procedures below to fully disable the EPST system:

1. EPST is connected to the 2nd profibus connection of the VFD
   a. Make sure EPST is switched off on the EPST control panel.
   b. Disconnect the purple cable (profibus) from the Beckhoff Master module in the EPST controller cabinet.
   c. The VFD drive will trip.
   d. The VFD can be reset on the VFD panel (OP1S) with the reset button.
   e. The VFD will continuously give Warning A91 (CB Alarm).
   f. If not sure EPST was switched off when disconnecting profibus from VFD, restart the VFD by disconnecting 24V control power (operator panel of VFD will be blank).
   g. After power on the drive will operate normally with this alarm on.

2. EPST is connected in-between the profibus communication cable
   a. Make sure EPST is switched off on the EPST control panel.
   b. Make sure TD is not operate
   c. Disconnect the purple cables (profibus) from the Beckhoff Master and Slave modules in the EPST controller cabinet
   d. Connect these 2 connectors to each other and set the switches on the connectors as indicated on the drawing from Annex 8.3
e. It could be that the VFD gives a communication error. The VFD can be reset on the VFD panel with the reset button
f. EPST controller is now disconnected and TD system will operate without.

NOTE:
When installing the EPST system back again don’t forget to set the switches on the profibus connectors as indicated in the drawing from Annex 8.4

3. EPST is connected to the TD system by controlling the analog I/O signals
   a. Make sure EPST is switched off on the EPST control panel.
   b. Make sure TD is not operate
   c. Disconnected the communication connector
   d. Connected the bypass connector
   e. It could be that the VFD gives a communication error. The VFD can be reset on the VFD panel with the reset button
   f. EPST controller is now disconnected and TD system will operate without
7.3 System Warnings

If the text "Warning if flashing" in the upper section of the screen is flashing an EPST system warning is active. To open the warning screen press the button "Warning if flashing". An overview of warnings is shown. Actual warnings are blinking red.

Figure 34: ST Warnings

1. Warning Disk Partitions
   Not applicable.

2. Warning from Calculation Drill Configuration
   Calculation of drill string configuration can’t be executed (check BHA and drill string configuration).
3. **Warning Kf/Cf Settings out of range**

   If Kf or Cf value is too high or too low an out of range error will be generated. Check if Kf and/or Cf values are correct inputted.

   The EPST controller continuously checks if the actual values of Kf and Cf are out of range. The settings are out of range if one of the following conditions is true:

   \[
   \text{Cf} < 300 \text{ or } \text{Kf} < 300 \\
   \text{Cf} > 15000 \\
   \text{Kf} > 10 \times Jtd
   \]

   Where Jtd is the inertia of the top drive.

4. **Fault Communication Display**

   When flashing, a communication timeout between the control panel and the IPC is active. Check “EPST time-out display” settings in settings screen chapter 5.6 or check wiring.

5. **Fault watchdog**

   No profibus communication between EPST-IPC and VFD. Check if VFD is powered up or check wiring.
# Annex

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8.5 EPST connected to the TD system by controlling the analog I/O signals
8.6 Quick Guide manual input Kf and Cf

EP soft torque controller
Quick guide manually input Kf and Cf

EPST ON/OFF

Only switch ON EPST in drilling operation mode
Switch OFF EPST before drilling will stop.
For instance in case of adding new stand
ON/OFF can be done by touching the screen button in the “Home screen”

Gray = OFF
Green = ON

Warning: While adding a stand EPST must be switched OFF to avoid rotation because of external pipetorque.

CHANGE Kf and Cf

Kf or Cf values must be adjusted during drilling according to the drill depth!
Check if Kf or Cf values according to the drill depth are corresponding as listed in the Kf or Cf data sheet.
Entering the right settings must be done on the “Home” screen of the touch panel by touching Kf or Cf value fields.
Select Kf or Cf value; enter correct value by using numerical keyboard on screen. Enter “J” to save new value.

NOTE: Preferably change Kf value first
8.7 Quick Guide using EPST with Auto Tune ENABLED.

**EP soft torque controller**

**Quick guide EPST Auto Tune**

When starting a new hole or on a new depth, only once you have to initialize EPST AT

- Press ‘Initialize AT’
- Press on the ‘actual depth’ box
- Fill in actual depth of bit, confirm with enter
- Press ‘Accept measured depth’
- Check on the ‘Settings’ screen if ‘Auto Tune’ and ‘AT-Auto Transfer’ are active (green)
- Press ‘Home’ for home screen
- When drilling is started activate EPST AT by pressing ‘Activate EPST’
- ‘Activate EPST’ will become green (green is active)

When values are out of range a screen will popup

- Compare Kf and Cf with ‘Shell Kf/Cf calculation list’ if within – or + 20% press ‘Accept’ otherwise cancel and fill in Kf and Cf manually. (See Operation Manual)

When adding a stand

- Switch off EPST before drilling will stop by pressing the green ‘Activate EPST’ button
- ‘Activate EPST’ will become gray (gray is off)
- When drilling is started activate EPST AT by pressing ‘Activate EPST’

**Grey = OFF**

**Green = ON**

Warning: While adding a stand EPST must be switched OFF to avoid rotation because of external pipetorque.

---

**CHANGE of Kf and Cf**

While drilling with ‘EPST’ activated and ‘Auto Tune’ enabled, new “Next Kf and Cf values” will show automatically on the home screen together with the green text “AT-NV”.

Calculation of new values will last for at least 10 minutes! If drilling while “stick slip” or heavy torque variations are present, estimating new Auto Tuning settings will take (much) longer or will even not be available for the next stand.

**NOTE:** Preferably change Kf value first