DYNAMIC POSITIONING CONFERENCE
September 17-18, 2002

Control Systems

DP Performance and Incident Analyses

Nils Albert Jenssen

Kongsberg Simrad AS (Norway)

Øyvind Hauge

Kongsberg Simrad AS (Norway)

Introduction

Much can be gained by systematically analysing the DP performance of vessels. Such analyses can both reveal “hidden problems” in the total system (including power generation and thrusters) as well as improve the operational procedures. Fuel consumption and wear and tear may be reduced by using the DP control system in a more optimal way; by setting appropriate control strategy, gain levels, etc. By incorporating results from systematic performance analyses into the operational procedure, good savings may be obtained. Such analyses are not very often carried out in a systematic manner. Deep knowledge on hydrodynamics, control theory as well as the actual design of the DP control system is advantageous, but not absolutely necessary. What is a necessity, however, is good data facilities which can give the analyst full insight into the vessel behaviour, the operator actions and the control system.

What has been said about performance analyses also applies to incident investigations. But, this topic is generally a more complicated detective’s task.

Methodology

The methodology of performance- and incident analysis is very similar. The challenge is to find plausible reasons causing particular vessel behaviour. Such analyses require deep understanding of both vessel hydrodynamics and DP system control algorithms.

The vessel itself is exposed by not measured disturbances e.g. originated from waves. But, disturbances in this context may also contain vessel anomalies or imperfections e.g. bad operating thrusters in the sense that they do not respond as specified. Vessel response is measured, but the observed response will generally be corrupted by noise or even disturbances which completely twists the real response. The DP system itself may have software or hardware errors, which may produce improper thruster commands. Such bugs may also be characterised as “unknown disturbances”. See Figure 1.

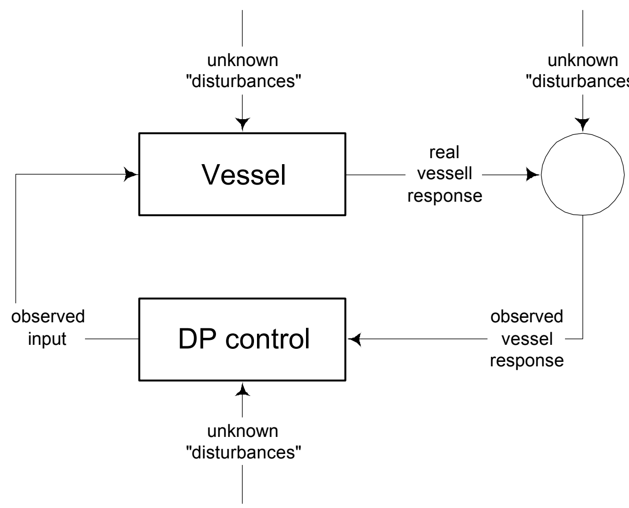


Figure 1 The analysis context

In the analysis hypotheses with respect to these “unknown disturbances” must be established and tested against recordings. Unfortunately many hypotheses may seem plausible having only a limited set of recordings available. A theorem from science theory states; given a finite set of observations, an infinite number of theories may be produced matching these observations. In more practical sense we need as many different observations as possible to test our hypotheses. Especially internal data from the DP control is crucial, and matching these with observations of vessel response and operator actions.

However, it is often too difficult to see all aspects of cause and effects due to the feedback structure of the "process". In such situations a simulator is a very good tool to help assessing correctly. Such a simulator must model the vessel quite accurately and use the real DP system software for control.

Data logging

The data logging functions available for the Kongsberg Simrad SDP systems are incorporated in a separate History Station with recording and reviewing facilities. See Figure 2.

In our context the data logging serves the following objectives:

- DP performance evaluation and system optimisation (requiring operational and system-specific data for a specific time period).
- Incident analyses (all data for a short period of time synchronised with alarm and warning history and operator actions).

The History Station can service both a stand-alone DP system and an Integrated Automation System.

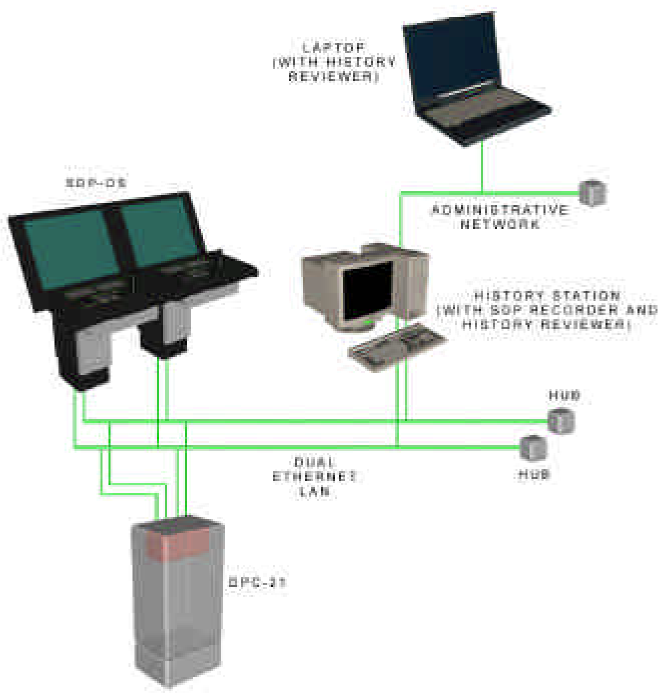


Figure 2 Data recording set-up

Data Recorder

The Recorder is a tool for recording and managing history data. It can access all information channels in the DP system, and stores variables and events to a History Database. Stored data are organised in user-specified logging Sessions, defined according to a library of Session Templates. This makes it manageable to identify and work with selected parts of large amounts of historic data.

The Recorder offers the possibility to interactively start and stop tailored Sessions, in order to satisfy the needs for different tasks. Selected parts can be extracted from any Session, and exported for further analysis on other computers.

Recording covers:

- SDP variables (measurements, control signals, internal variables, etc.)
- Alarms, warnings and system info (in the following denoted events)
- Operator actions

History Reviewer

The main use of the History Reviewer is to allow the analysis of data and events related to performance during specific operations and abnormal system states.

Data retrieval and display:
- Access to time-series databases
- Access to event databases including filtering according to event attributes
- Time series and events can be synchronised and scrolled together
- Bookmarks can be used for easy and quick time navigation in trend and event views

The History Reviewer facilitates in-depth analysis of data from different sources, which can be brought together in one or several views. Events from the same period of time can be displayed in tables within the same picture, and synchronisation of all data and events is accomplished.

Performance and incident analysis

The analyses described in this paper all originate from hypothetical scenarios produced by a simulator. There is no link to any real vessel or historical incident. The cases are meant as illustrations of the mental process of carrying out such analyses. Due to space limitations all considerations can not be dealt with, especially with respect to setting up alternative hypotheses and proving the one to be most correct (if any).

Case 1: Badly tuned thrusters

This case may be representative for a situation after major maintenance has been carried out on CPP thrusters, changing the thruster characteristics without doing a similar modification of the DP control software.

The typical footprint of such cases is that current estimated by the DP changes significantly as the vessel is rotated. Typically we may also observe that station keeping accuracy often is remarkably different after a heading change. Similar symptoms may, however, also be observed when the wind or current load on the vessel is modelled incorrectly. But these errors tend to give fixed changes in estimated current direction after a turn. This is not necessary the case for thruster modelling errors.

Looking at Figure 3 and Figure 4 it is highly probable that the behaviour is a result of improper thruster tuning. We can deduce this from the observation that the direction of the estimated current tends to converge towards its original value. Moreover, the observation also tells that these modelling errors must be quite evenly distributed to many of the thrusters.

If the thruster modelling error is only applicable to one direction, e.g. main propellers or some tunnel thrusters, it may be much more difficult to make assessments regarding the governing cause. The different potential causes will produce different dynamic responses event though the stationary results may be quite similar. To further investigate these possibilities it may be necessary to reproduce the conditions in a simulator and use that for hypothesis testing.

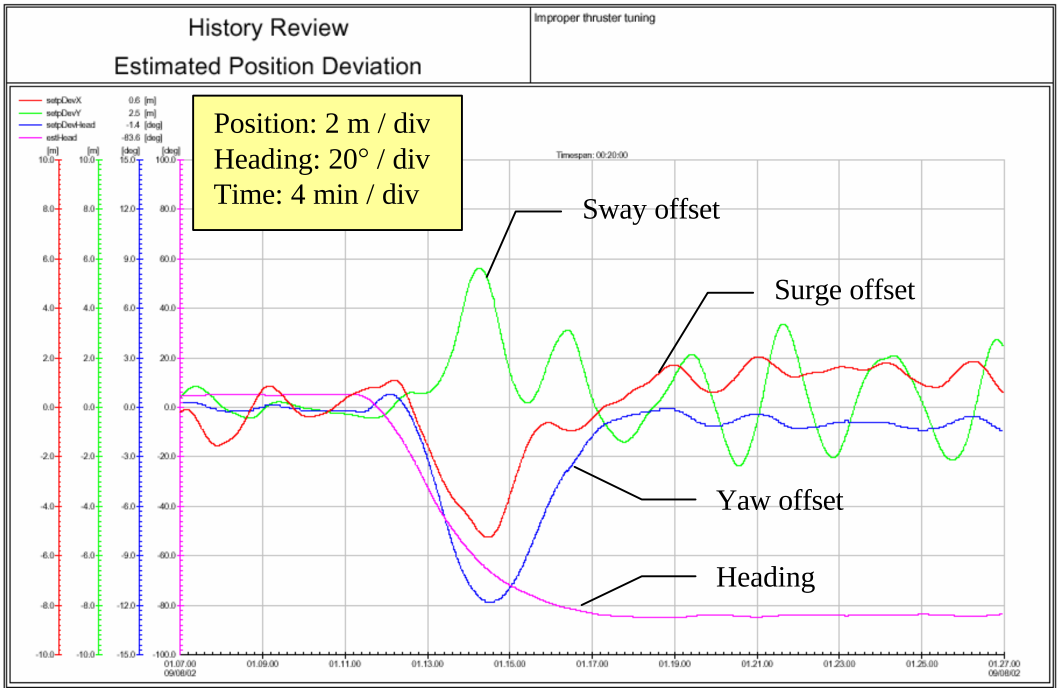


Figure 3 Station keeping; heading change 90°

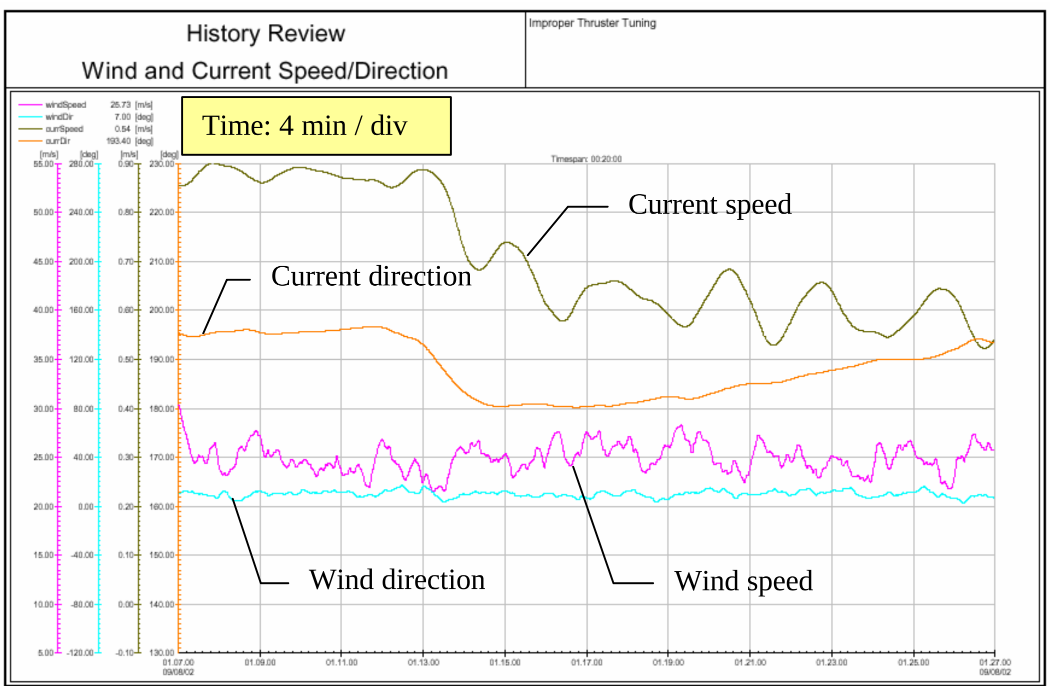


Figure 4 Wind and current

By analysing the thruster setpoint – feedback trends (not shown) no abnormality is observed. Hence we conclude that thrusters must have been boosted up or de-rated by modifying the rpm.

The difficult question to answer is how much the rpm has been changed. This can only be revealed from acceleration experiments using as few thrusters at a time as possible since we do not know anything about the real sea current.

The weather condition in this simulation case is close to zero waves and zero current. Assuming zero waves and current a likely response to the heading change is simulated in Figure 5. We see that excursions are quite smaller (2 meters versus 6 meters). By experimenting with thruster characteristics of the “real” thrusters (in the simulator) and keeping the DP settings unchanged a similar plot as Figure 3 can be derived by increasing the thruster rpm about 20%. This will not give any full proof, but at least a clear indication.

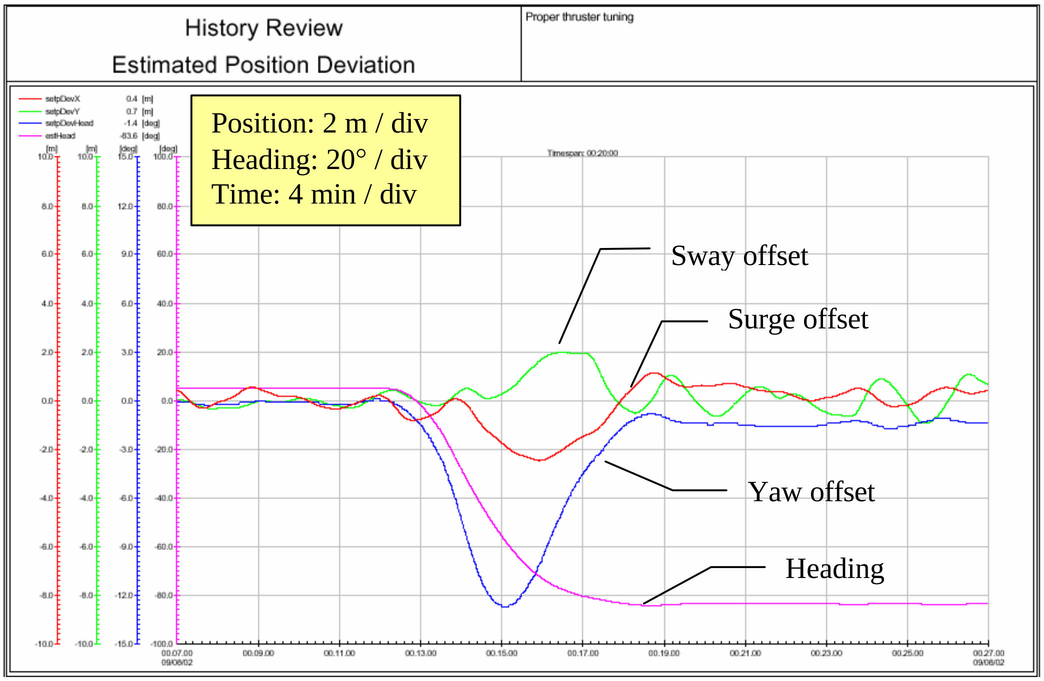


Figure 5 Simulated heading change

Case 2: Loop current

In this case the current condition changes from 0.2 m/s (direction 10°) to 1.5 m/s (direction 90°) over a period of 15 minutes. Wave (2 m Hs, direction 20°) and wind (18 m/s, direction 30°) conditions were fixed. Figure 6 shows the excursion as the loop current builds up.

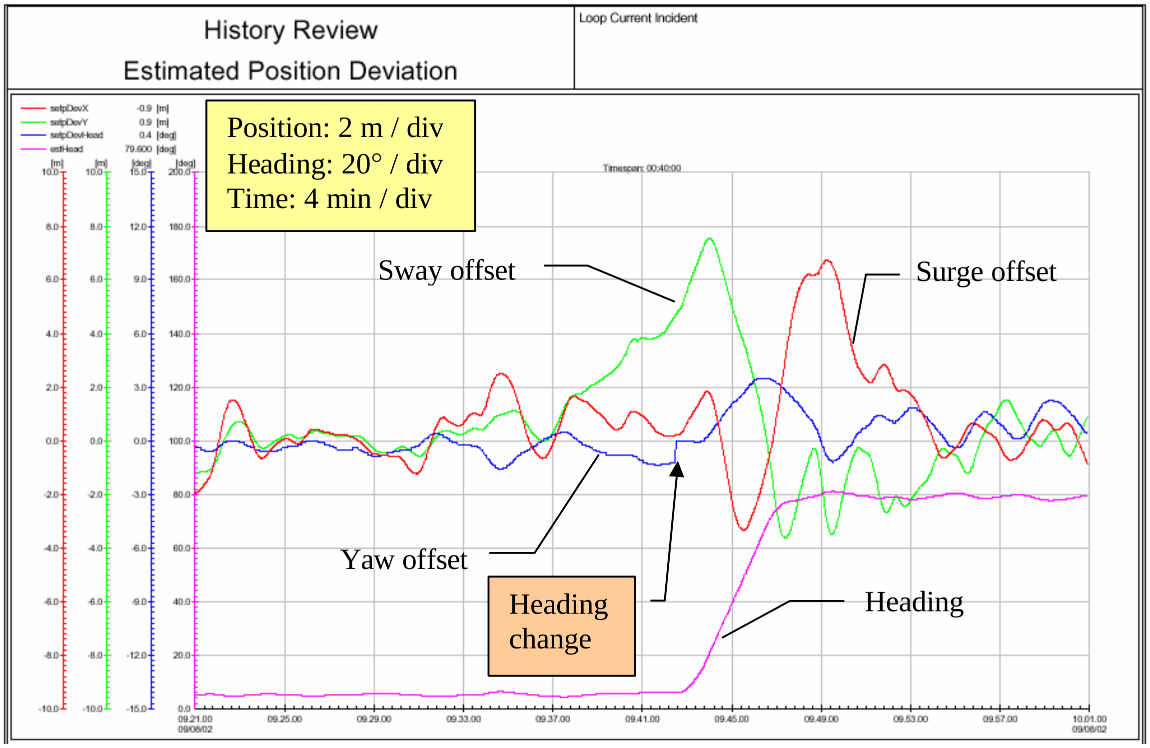


Figure 6 Station keeping

The above plot also shows that the operator has changed heading towards the current when he recognised the threat, trying to avoid a large drift-off.

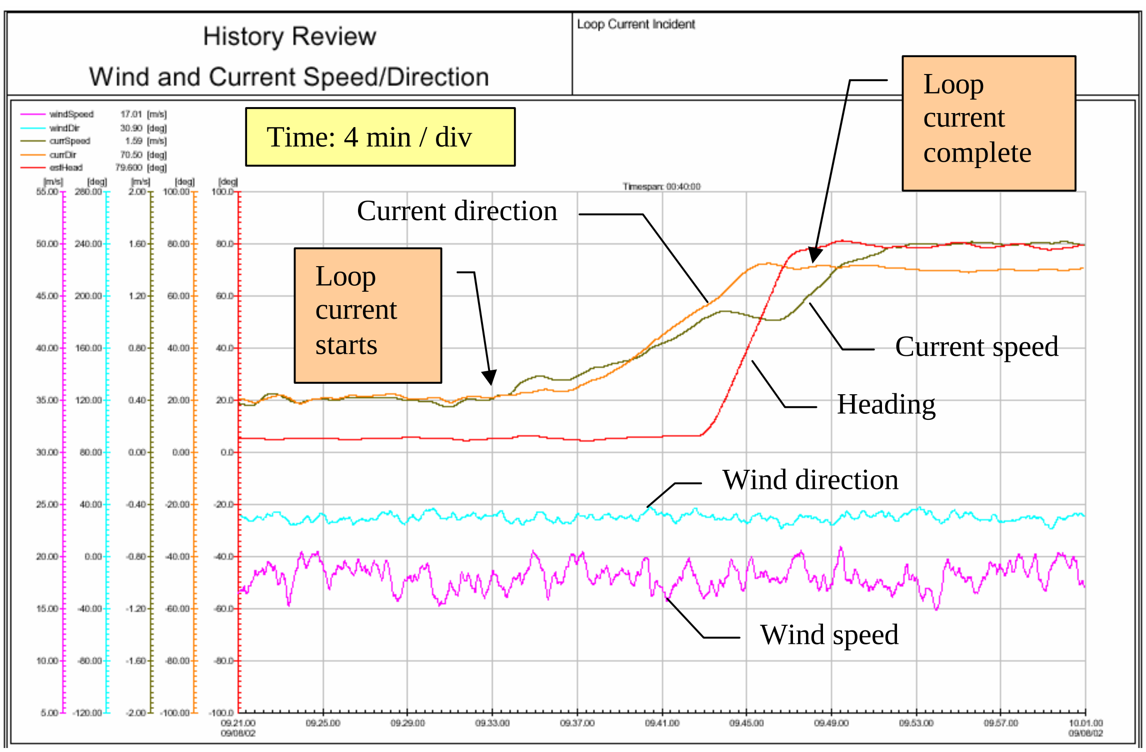
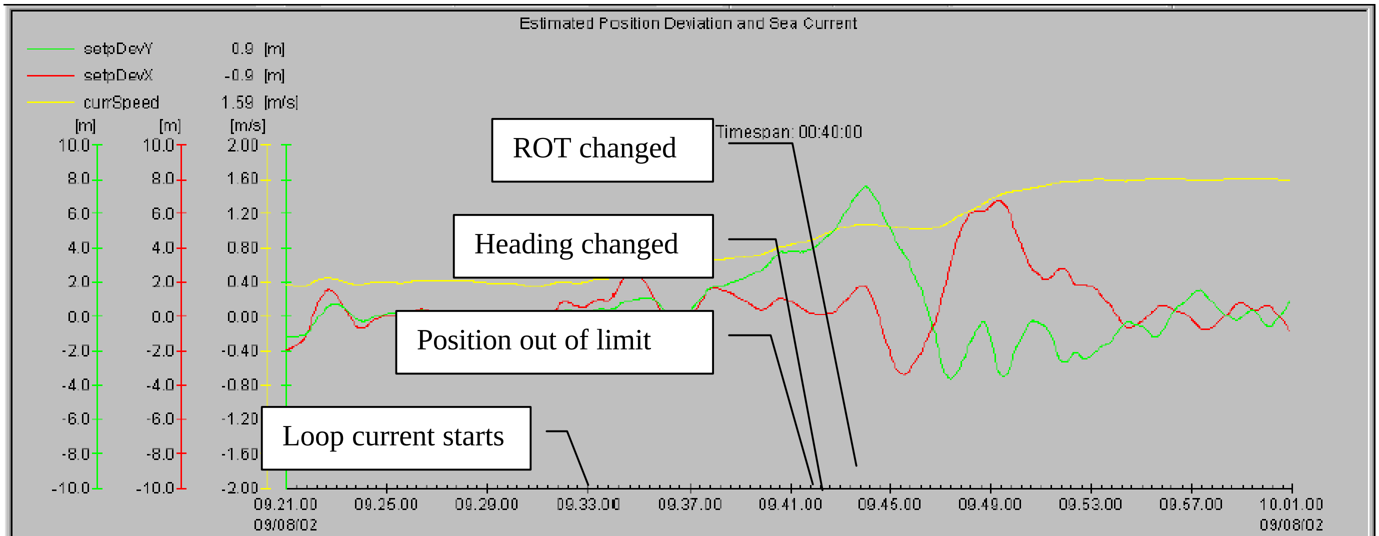


Figure 7 Wind and current

As can be seen from Figure 7 the loop current is estimated quite accurately, but it is impossible for the DP to track the changing current exactly, hence this temporary drift-off. Immediately after the operator prepared for changing the heading he got warnings about high thruster forces (above 80 %). The drift-off is amplified due to insufficient thrust (due to prioritising heading) as a result of the commanded heading change, see Figure 8.



Time	Name1	Name2	Event text	OrigStation
09/08/02 09.41.58	A	4.045 4.000	Position out of limits	A
09/08/02 09.42.12			OpDlg:Dialog entered <Heading>	OS2VIEW
09/08/02 09.42.14	A	80	Thruster 3 high force	A
09/08/02 09.42.14	A	80	Thruster 4 high force	A
09/08/02 09.42.14	A	80	Thruster 5 high force	A
09/08/02 09.42.15	A	80	Thruster 1 high force	A
09/08/02 09.42.15	A	80	Thruster 2 high force	A
09/08/02 09.42.30			Dialog:Page <0> applied <Heading>	OS2VIEW
09/08/02 09.42.42	A	surge sway	Insufficient thrust	A
09/08/02 09.42.46	A	4.045 4.000	Position out of limits	A
09/08/02 09.43.03			OpDlg:Dialog entered <Heading>	OS2VIEW
09/08/02 09.43.20			Dialog:Page <1> applied <Heading>	OS2VIEW
09/08/02 09.43.32	A	surge sway	Insufficient thrust	A
09/08/02 09.44.11	-	surge sway	Insufficient thrust	A

Figure 8 Alarms and operator actions

The figure above shows firstly that the operator has been warned about bad station keeping performance. Very quickly, 15 seconds after he prepares for changing the heading and executes the command 18 second after that. In this case the operator reacted very quickly to the 'Position out of limits' warning. But we see from the plots that loop current started as much as 9 minutes earlier. An experienced operator might have reacted earlier by observing the changing current, Figure 7, which should be visible after about 6 minutes, or from the increased thrust level, Figure 9. But as we can see from the plots, the build up is very slow. In retrospect when all data are available everybody may be the expert.

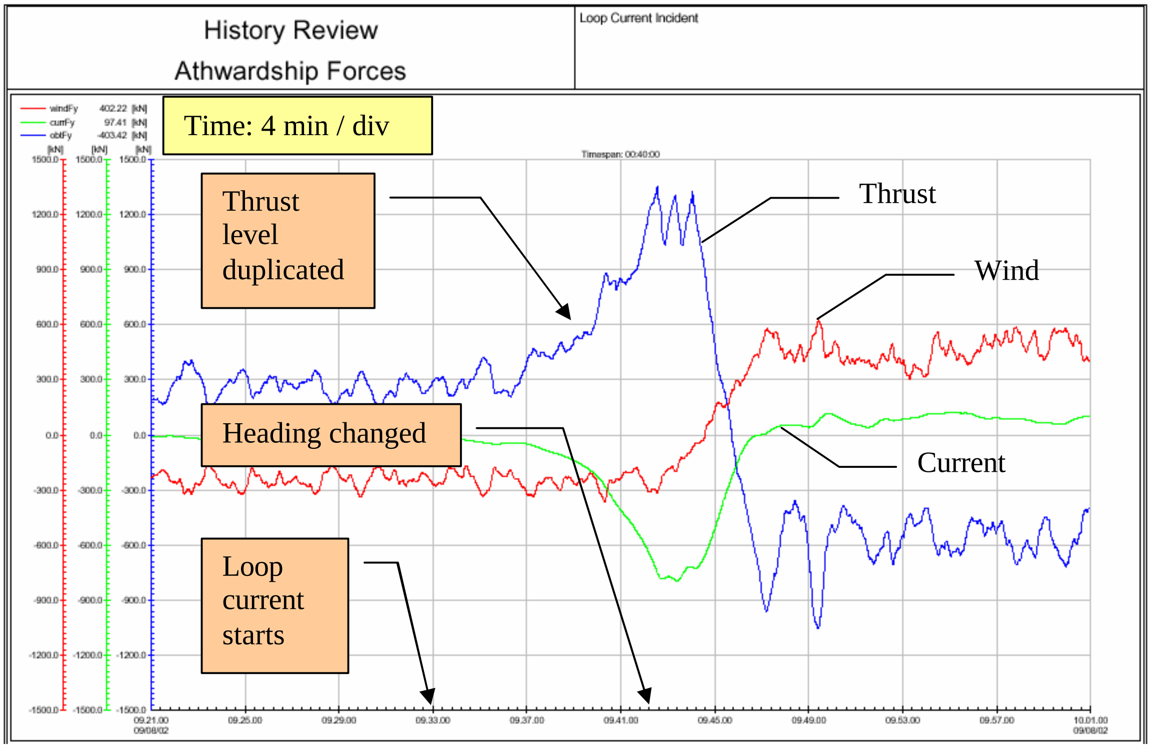


Figure 9 Lateral forces

Case 3: A position reference system problem

Most drive-offs are caused by reference system failures. Most reference system problems are normally sorted out automatically by the DP system itself, but unfortunately the operator may need to take action from time to time sorting out ambiguity type of problems.

During the incident the reference system view on the DP screen looked as shown in Figure 10 to Figure 12. In this case two DGPes and one acoustic system are in use.

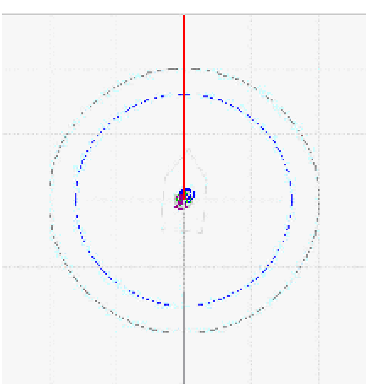


Figure 10 Initially

All normal.

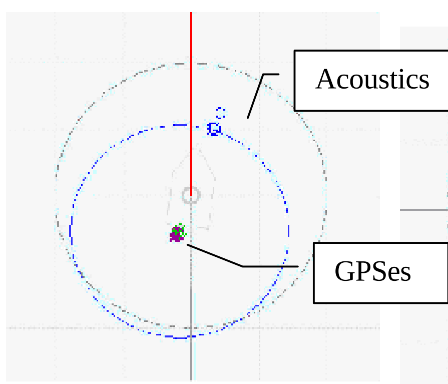


Figure 11 After a while

Reference systems drift slowly apart

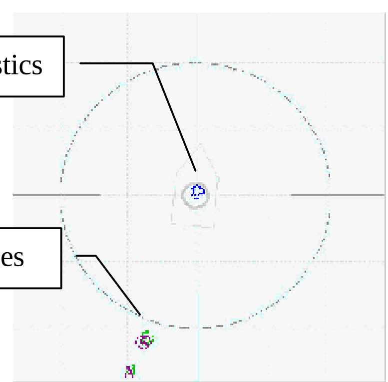


Figure 12 Finally

Operator has deselected both GPSes

Initially, Figure 10, each reference system provides the same position with approximately the same good accuracy. After a while, Figure 11, we see that the GPSes still follow each other where as the acoustics seems to diverge. We see that the estimated position (centre of display) between the GPSes and the acoustics and somewhat closer to the GPSes since they are in majority.

There may be many reasons why the reference systems diverge from each other:

- e.g. ionospheric noise may be experienced as a short term drift
- the acoustic transponder (in SSBL mode) is e.g. being dragged on the seabed and hence experienced as a slow drift
- the acoustics may lock to a "false target" providing a more or less fixed position
- the GPSes may "freeze"

In order to find out what is really happening we need look at the raw position readings, Figure 13.

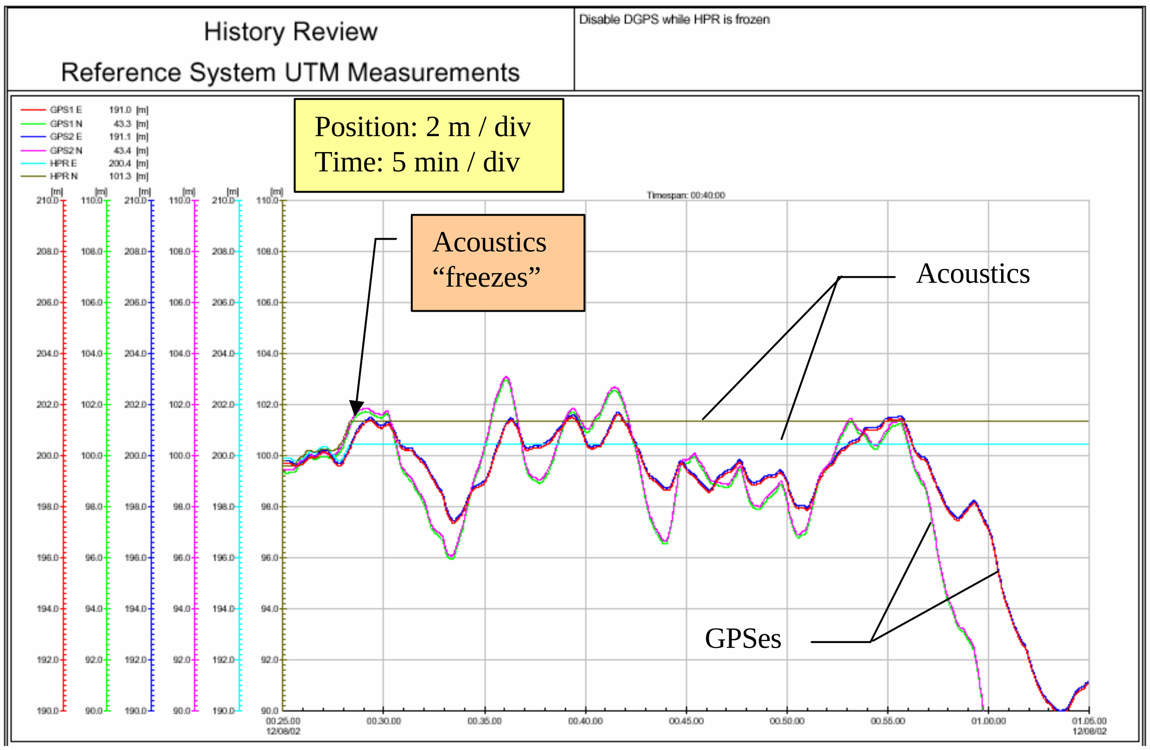


Figure 13 Reference system inputs

From the figure we clearly see that the acoustics "freezes" producing an almost fixed output to the DP control system. It is obviously varying sufficiently to fool the "freeze" test incorporated in the error detection mechanism of the DP.

However, the operator, who has some experience with GPS and scintillation phenomena, assesses this to be consequence of ionospheric disturbances. He therefor chose to deselect the two GPSes since they both behave identical. As discussed above a fully plausible cause according to his limited observations.

The system seems to work quite normally. The DP system is still capable of doing station keeping. The operator is, however, alerted now and then as shown in Figure 15. The station keeping deteriorates as soon as the acoustics "freeze" and 'Out of position limits' warnings are issued quite quickly after acoustics occasionally being rejected for a short period of time. In Figure 15 an alarm coming on is marked with an "A", and going off by a "-" in the 'Name1' field. When the acoustics is rejected, the estimated position is force to follow the GPSes. The recorded motion is therefor not real but a result of the signal processing.

The situation is stable, nothing dramatically is happening until the operator deselects the GPSes, Figure 14. The GPSes are still recorded to facilitate post mortem analysis.

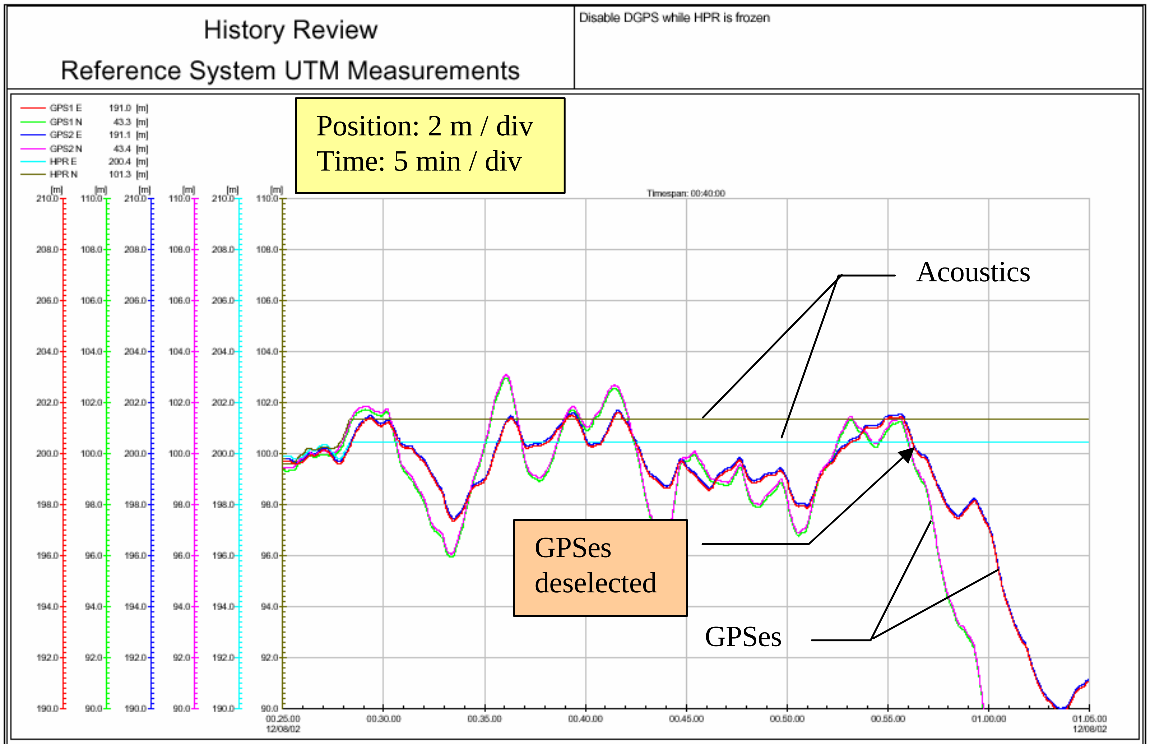


Figure 14 Reference system inputs

It is worth while noting the "ideal" behaviour of the vessel as presented by the Kalman filter when using a "frozen" reference system, Figure 15. When looking at the applied thruster forces, everything seems very normal, Figure 16. Unfortunately the vessel is drifting off slowly, about 2.5 meters per minute. The drift-off velocity will depend on the weather condition.

The drive-off behaves therefor like a slow drift-off.

What could the operator have done differently?

> *Given a finite set of observations, an infinite number of theories may be formulated matching these observations*
>
> *Look up more information, don't just hang on to old "truths"*
>
> *Don't overreact, the DP system itself often knows best*

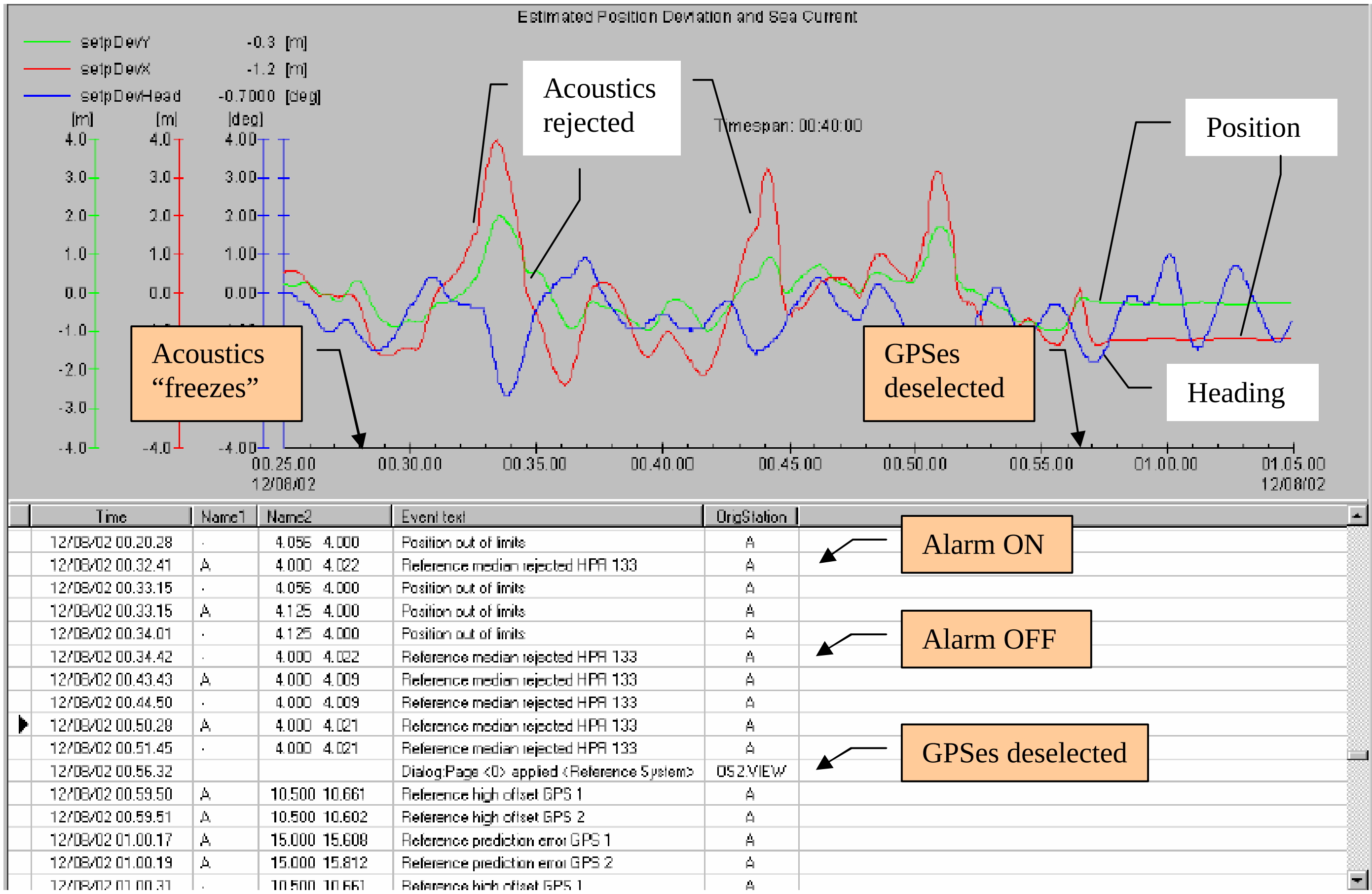


Figure 15 Alarms and operator actions

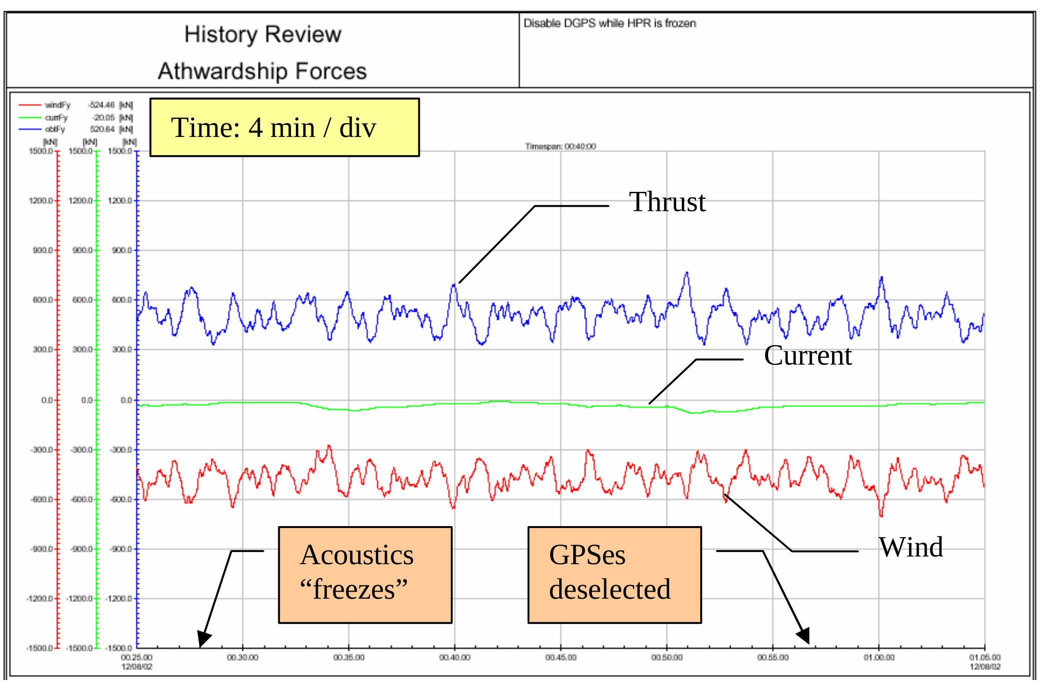
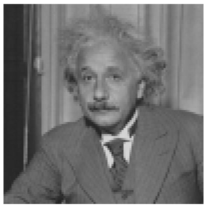


Figure 16 Lateral forces

Concluding remarks

There is a large potential in utilising systematic performance analyses. Results can be used to tune the DP system to fit its purpose in a better manner, and operational procedures improved. Both performance and incident analyses may be quite complicated to carry out. Deep knowledge of hydrodynamics and DP control is definitely a great advantage as we can see from some of the examples. There may always be another explanation compatible with the observations. Therefor, to find out what is really going on good data recording and retrieval facilities are mandatory. A vessel and DP simulator is a very valuable tool when testing hypothetical causes for an observed behaviour.

Who said life should be easy? So, let's at least make it interesting. No super-brain required.



In Norway there is a saying; "The least clever [1] farmers get the biggest potatoes". I am not so sure any more, mine are good for nothing.

[1] The original word means both 'least skillful' and 'most foolish'