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Improved DP Performance in Deep Water Operations Through Advanced Reference System Processing and Situation Assessment

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Improved DP Performance in Deep Water Operations Through Advanced Reference System Processing and Situation Assessment

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ABSTRACT

The paper focuses on some reliability aspects of DP operation in deep waters. It describes the necessity to utilise the best properties of each type of reference system availbale. Further some safety/reliability aspects of DP based operations are discussed, and a DP capability- and drift-off analysis toll is described.

INTRODUCTION

DP systems play a more and more important role in deep water operations. The DP performance is generally focusing more on reliability of the overall operation rather than on accuracy in station keeping. This implies that the performance of both the vessel and its different kinds of equipment (like power plant, thrusters and auxiliary systems) as well as the DP system and its reference systems and sensors must be taken into account when assessing the performance. It is of major importance to the DP operators to be aware of the effects of possible equipment failures in order be able to take advance actions.

Kongsberg Simrad has been addressing this as part of a research program, “Reliability of DP operations”, together with Shell, Statoil, Norsk Hydro and Saga. Some of the main topics covered have been:

- Reference system processing
- On-line DP capability analysis
- On-line drift-off analysis in case of equipment failure

REFERENCE SYSTEM PROCESSING

In deep waters far away from any fixed installations the availability of different types reference systems are quit limited. So far only DGPS, LBL acoustics and the Simrad HiPAP are available as reliable reference systems. In the very near future also combined DGPS and Glonass systems will become available.

The DGPS system is quite accurate, but is corrupted by coloured noise (man made low frequency, SA) which can not be filtered, the noise level is, however, quite satisfactory. The LBL acoustic systems have very good accuracy, but the sound transmission in water and transponder delays to avoid sound collisions at the reception in the transducer, reduces the data rate of position fixes to the DP system quite dramatically compared to the general case in more shallow waters. The HiPAP has a good noise level whith close to white noise characteristics (high frequency). It can supply a higher data rate than an LBL system since only one transponder is used at a time. To get the best possible positioning, it is therefor necessary utilise the best qualities of each one. This can be done by using Kalman filtering techniques.

The Kalman filtering based DP controller used int the Simrad DP system is shown in figure 1. The main issue in the deep water context, is the model updating from

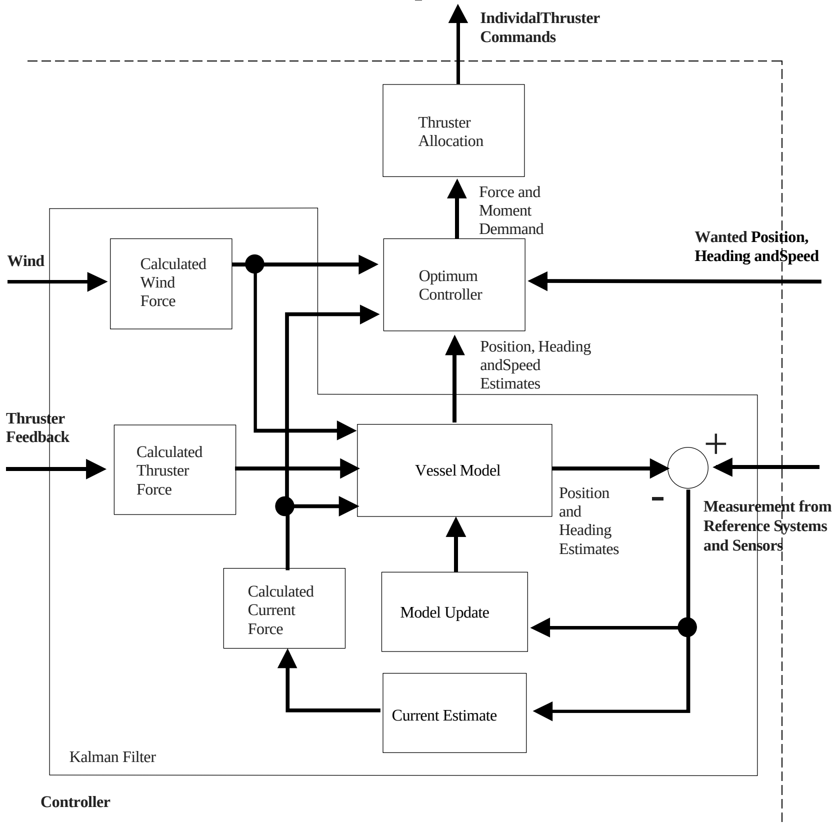


Figure 1 Kalman filter based DP controller

reference system readings.

When combining LBL acoustics with DGPS, the Kalman filter will stick to the DGPS since this system has low high frequency noise characteristics and the highest data rate. The LBL will be assessed as noisy. The situation is illustrated in figure 2.
To improve this, the knowledge of the noise characteristics of the two systems must be taken into account.

Solution:

- Utilise knowledge of nature of reference systems
    - Quality figures from reference systems
    - Monitor high frequency noise statistics (fast fourier analysis, FFT)
    - Perform complete Kalman filtering calculations
- Kalman filter gains depending on
    - accuracy of position estimates
    - measurement noise
- Reference system mixing according to combination of
    - noise figures from reference systems
    - high frequency noise statistics

Some DGPS receivers can produce estimates of its accuracy in terms of variance of the position data. The quality figure is based on satellite geometry and validity of differential corrections. LBL acoustics may produce uncertainty ellipse according to the vessel position and geometry of transponder array as well as signal to noise ratio. Because the way of processing the data inside the HiPAP system, it may also estimate its own accuracy from internal measurements of the signal to noise ratio.

In the DP system the innovation signals, i.e. the difference between measurements and model prediction, are good measures of the accuracy of the reference systems (with respect to high frequency noise). By using FFT technique very sharp frequency cutting may be performed, and hence the high frequency component of the noiselevel (above 0.1 Hz) can be estimated. A typical FFT output is shown in figure 3.

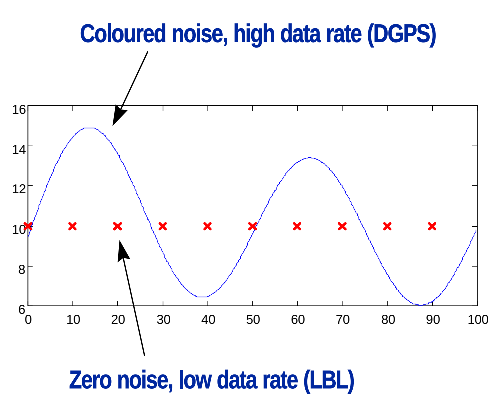


Figure 2 Coloured noise problem

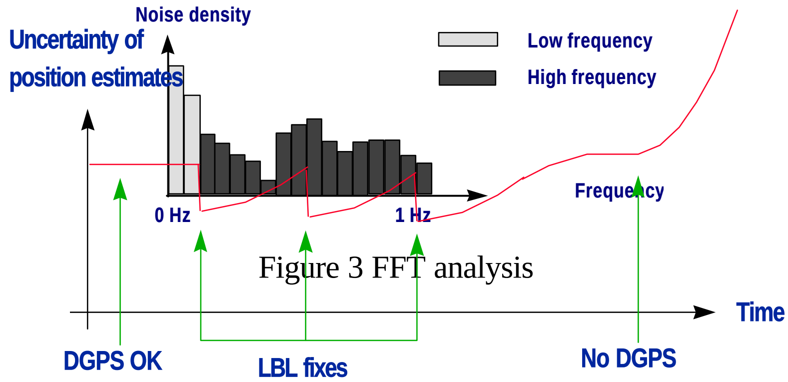


Figure 3 FFT analysis

Figure 4 Uncertainty as a function of time

By combining accuracy data from the reference systems themselves and the statistical analyses of the innovation signals a more complete picture of the quality of the reference systems may be derived.

The accuracy of the position estimate in the Kalman filter plays an important role in the DP controller. The accuracy of this estimate will be driven by the accuracy of the measurements. In addition there is an inherent inaccuracy of the mathematical model of the vessel which will decrease the accuracy if no measurements are received. To optimise the utilisation of the reference position fixes the estimated accuracy of the position estimates within the Kalman filter must therefor be taken into account. The Kalman filtering technique has a set of mathematical formulas for handling this, known as the Riccati equations.

Figure 4 shows a typical example where DGPS and LBL acoustics are combined. DGPS has its typical coloured noise characteristics (assumed time constant in this example). Initially DGPS is assumed to give OK signals, and the uncertainty of the position estimate will become steady. Each time an LBL fix arrives, the uncertainty of the position estimate is reduced because the accuracy of the acoustics is assessed to be better. The position uncertainty will, however, increase again because the DGPS accuracy is lower. At the end it assumed that no reference systems are giving OK signals, and hence the uncertainty of position estimate grows very rapidly because of inaccuracies in the vessel model. In the Kalman filter updating, gains are increasing by increasing uncertainty of the position estimate. When new measurements arrive at a later stage, high gains will be used until they converge to the stationary condition shown at time zero in the figure. LBL updates use high gain because of its good quality. DGPS gain is reduced due to its coloured noise characteristics.

The estimate uncertainty of the position estimate plays also an important part in error checking of position readings. The innovation signal for each reference system is compared to an accept limit derived from this estimated uncertainty of the position estimate. See figure 5. Hence the better the quality of the estimated position the tougher the failure limit, and vice versa.

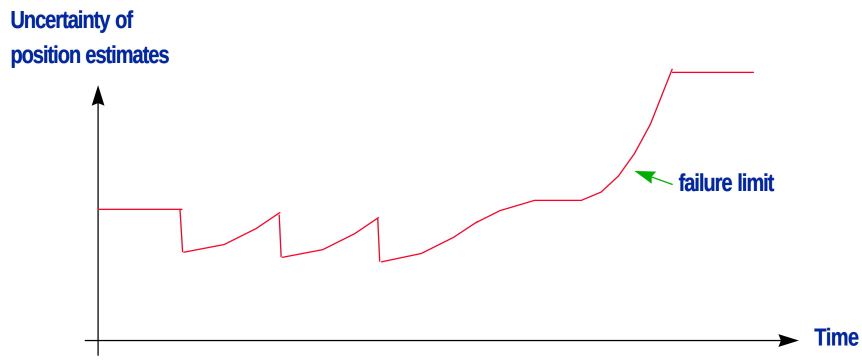


Figure 5 Prediction check limit

SITUATION ASSESSMENT

Some crucial questing in DP operations has always been asked:

- Is the vessel operating within its safety margins?
- What are the margins in case of equipment failures?
- Is it safe to operate if

  one or more thrusters fails?

  one or more generator fails?
- What is the optimal heading in case of equipment failure?

DP class 2 and 3 consequence analysis will tell whether it is possible to operate in present weather condition in case of thruster/power failures, but does not say anything about the safety margins.

DP capability studies are normally carried out as a part of the vessel design. But what happens as time passes? Are the capability figures still valid? Capability studies must be carried out on simulation models of the vessel. To cope with the uncertainties connected to “off-line” simulations a “DP capability tool” has been developed which takes into account:

- The tuned mathematical model of the vessel (found from sea trials)
- The actual implementation of the DP controller and thruster allocation logics
- On-line adaption according to measured versus expected thrust for doing station keeping

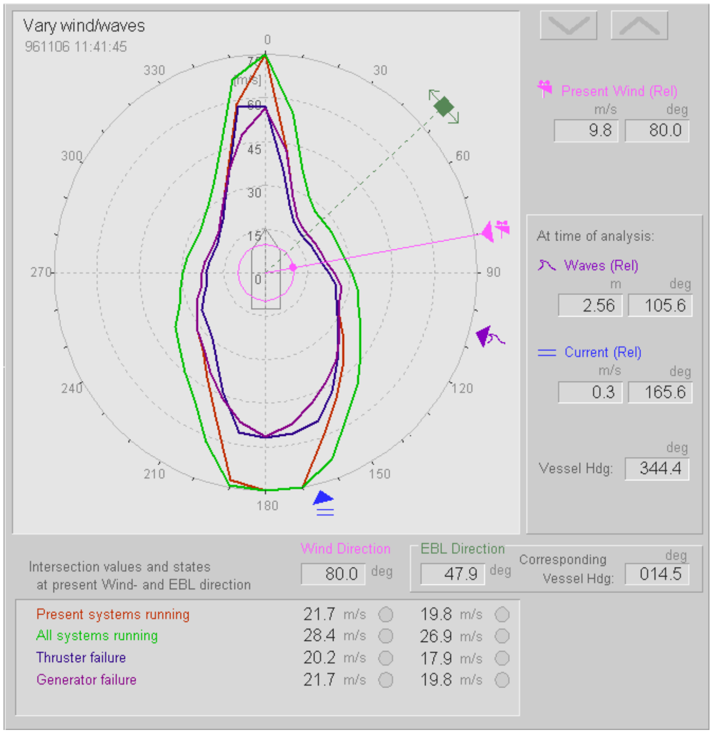


Figure 6 Capability plot

The capability plot, figure 6, may show maximum wind rosettes for the following scenarios:

- All thrusters and generators running
- Present number of thrusters and generators running
- Failure in a set of thrusters
- Failure in a set of generators
- Failure in a power bus

The force estimation takes into account wind, wave drifts, current and thrusters.

By using the plot the DP operator can at any time see how close to the limits the vessel is operating by watching the actual wind speed in the plot. The method includes a pre-programmed relation between wind speed and wave height. Hence extrapolation of wind beyond actual value also will influence the wave drift force.

The external force adjustment due to difference between observed thrust and forcasted is taken care of as illustrated in figure 7 showing measured and calculated thrust as a function of wind speed. The error force F_{err} is used to scale the calculations.

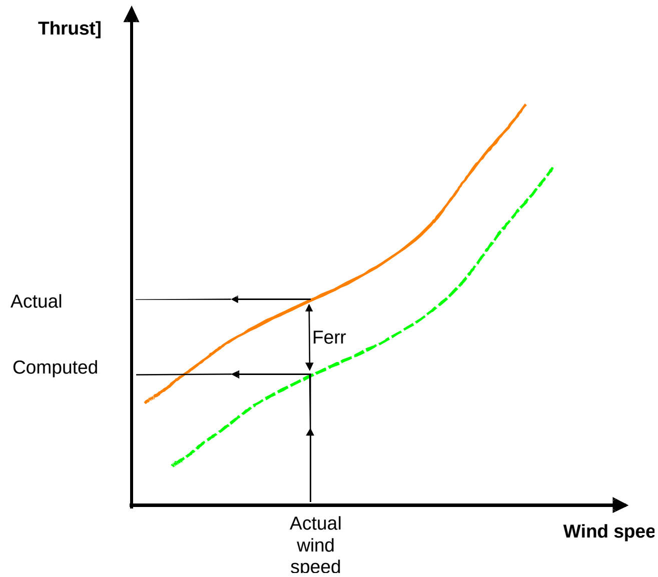
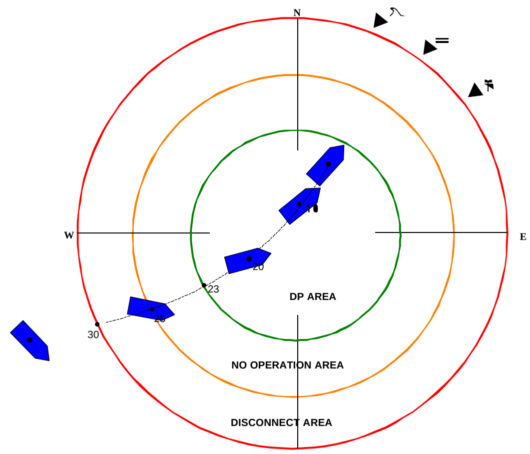


Figure 7 Thruster force vs wind speed

If the capability plot (or the consequence analysis) should indicate that a drift off will occur as a function of an equipment failure, the on-line drift-off analysis function can tell how the drift-off will take place.
The drift-off analysis uses the same mathematical models as the DP capability tool and simulates the different failure cases as indicated in figure 8 for a drilling operation.

The operator will get information on time elapsed to crossing each of the operational



limits, and may hence judge whether there will be time enough to terminate the operation safely or not. The tool may also be used for optimising the position setpoint in order to extend a time margin with respect to consequence of drift-off.

The operational boundaries are tailored to specific types of operations.

Figure 9 shows a typical setting for an intervention operation.

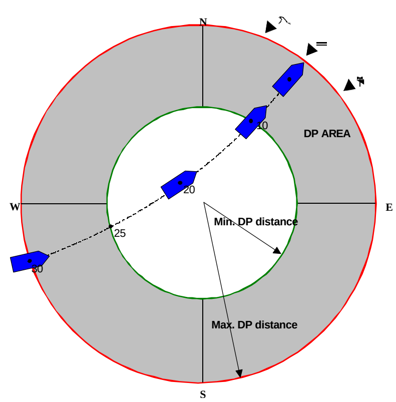


Figure 9 Drift-off pattern - intervention