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Operations

Tandem Loading and Drilling Operations Under Changing Environmental Conditions

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Abstract

Rapidly changing environmental conditions is one of the major challenges for many types of DP operations. Examples of such situations are tandem loading (FPSO to shuttle tanker) under change of the tidal stream in the English Channel, drilling operations under Gulf Of Mexico loop current situations and in general sudden wind speed and direction changes.

The presentation includes a review of the tandem loading operation under changing environmental conditions. The difference between offloading from FPSO's with and without active heading control is discussed. In the case of a heading controlled FPSO one of the tasks is to optimize the "combined" DP capability for both vessels. In the case of an FPSO with limited or no heading control, the shuttle tanker has to actively adapt its position and heading to the actual situation as dictated by the freely rotating FPSO.

An example showing a drilling vessel under a strong sea current situation is also included in order to highlight the similarities and differences between the drilling operation and the tandem loading operation. Advantages and limitations in the use of Online DP capability plots as an operator guidance tools is discussed as part of the presentation.

Weather Vane Principle

When loading offshore, it is possible to reduce the thruster/propeller force required to retain the vessel's position, relative to the offshore loading buoy, by utilizing the stabilizing effect of the wind and wave forces acting on the vessel's hull. In order to achieve this reduction in thruster force, the vessel's bow must always face the resulting environmental forces. Therefore the DP system includes a special Weather Vane mode for the loading operation.

The Weather Vane operation modes cause the vessel to act like a weather vane. The vessel is allowed to rotate with the wind and waves around a loading buoy. Neither the heading nor the position of the vessel is fixed. The heading of the vessel is controlled to point towards the loading buoy, while the position is controlled to keep a constant distance to the buoy. The Weather Vane principle is illustrated in the following figure.

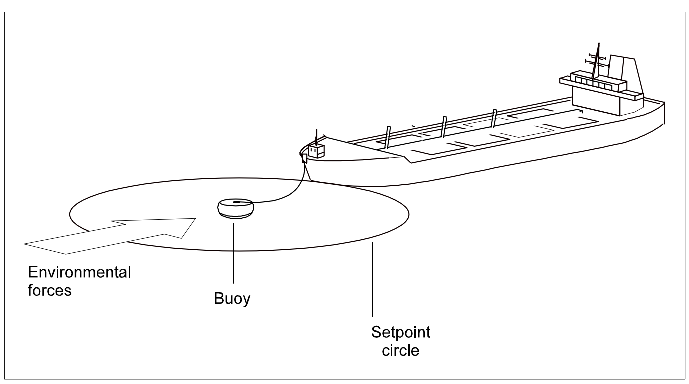

Figure 1: Weather vane principle

This kind of Weather Vane operation requires a minimum sideways holding force, and the available thruster capacity on the vessel is used for maintaining the correct distance and heading towards the buoy. In the sideways (sway) direction, the vessel position is not controlled; the vessel motions are only damped.

Predefined set-up for each loading buoy defines the maximum and minimum distance that the vessel may move from the buoy. The operator sets the wanted distance within these limits. The distance from the buoy is monitored and an alarm is given if one of the limits is exceeded.

Tandem Loading

For the tandem loading operation the loading buoy can not be treated as a fixed point. The FPSO / FSU will move significantly in the mooring system. Movements due to changes in the environmental conditions combined with periodical surge and fishtail movement will normally be experienced.

Safe distance between vessels as well as protection of the loading hose has lead to a number of criteria for ESD 1 (Stop pumping) and ESD2 / ERS (Emergency disconnect). The various aspects are illustrated in Figure 2, copied from ref. [1]. The inner green, yellow, red segment indicates the operational distance and the sector limits relative to stern of the FPSO, while the outer green, yellow, red "cone" indicates how much heading offset the shuttle tanker is allowed to have relative to a bearing that points directly to the stern of the FPSO.

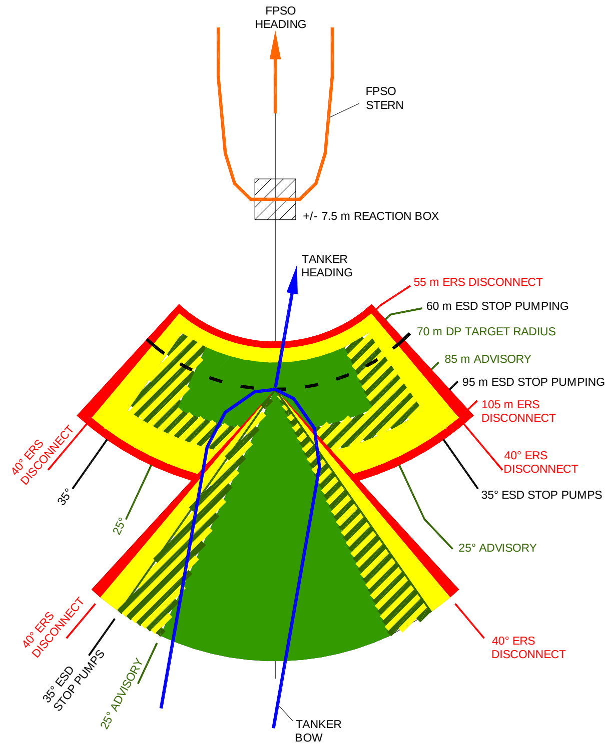

Figure 2: Station Keeping limits, ref. [1]

It is mandatory that the DP system is able to discriminate between the movement of the FPSO and the movement of the shuttle tanker. The DP model is constructed to allow a certain degree of FPSO surge movement without any adjustment of shuttle tanker position, ref. "Reaction box" in Figure 2 above. The reason for this is to increase overall safety, reduce power consumption and eliminate any potential "rubber band" effect due to relative movement of the two vessels.

However, on significant FPSO heading changes the shuttle tanker must adjust position and heading to follow the movement of the FPSO.

Shuttle tanker configuration for simulations

The configuration of the shuttle tanker used for the simulations in the following are:

- Vessel size: 263 m Lpp, 46 m width.
- Displacement: 90.000 tons (ballast), 160.000 tons (fully loaded)
- Thrusters:
  1 ea. 2200 kW tunnel thrusters bow
  1 ea. 2200 kW azimuth thruster bow
  1 ea. 2200 kW azimuth thruster aft
  1 ea. 10000 kW main propeller aft with rudder

Note that the thruster configuration for this vessel not is typical for a North Sea shuttle tanker.

FPSO surge movement

It is not sufficient with relative position reference systems alone for performing this DP operation, as the relative position reference system not is able to discriminate between the movements of the two vessels. Any kind of “Relaxed Control” can not be used either, as this might give a dangerous situation if the shuttle tanker is driven off position by wind / waves.

The error handling / voting of the absolute and relative reference systems must also be treated separately.

The difference between positioning purely on relative position reference systems and the “Tandem Positioning” with combined use of absolute and relative position reference systems is illustrated below. A surge movement with amplitude 4.5 meter and a period of 93 seconds was simulated at medium strength environmental conditions. The plot includes two graphs: Deviation from wanted distance and Total thruster force. The first five minutes clearly illustrates that the shuttle tanker not is able to keep a constant distance due to the rapid movement of the FPSO when using only relative reference systems. The last five minutes shows how thruster utilization and position deviation is stabilized when operating in correct “Tandem Positioning” mode.

Figure 3: Pure relative positioning compared to "Tandem Positioning" after 5 minutes

FPSO heading changes

Quote from ref. [1]:
”There are a series of passive weather-vaning, FPSOs in the central North Sea which currently have a good offtake safety record and have the merit of being simple with very little opportunity for FPSO equipment failure or operator error to cause a sudden loss of heading during offtake.

Experience suggests, however, that the use of passive weather-vaning FPSOs may be less attractive in areas where the wind, wave or current climate is significantly more severe. (E.g. the Atlantic frontier, or areas with very high currents). Offtake tankers by nature of their size, shape and thruster configuration have very limited ability to move sideways to follow the stern movements of a passive weather-vaning FPSO without getting seriously out of alignment, in these more stringent metocean conditions. It becomes more attractive to use active heading control on the FPSO to help damp out fishtailing and permit the offtake tanker to adopt an optimum heading to the prevailing conditions.”

These statements bring us on to the topic of changing environmental conditions, and its implication on the DP operation. Refer to the figure below, where a 90° heading change of the FPSO is illustrated. If the FPSO is changing heading with a rate-of-turn of more than 4°/minute, the shuttle tanker will have to move sideways at a speed of more than 1 knot, while continuously adjusting it’s heading towards the stern of the FPSO. As a shuttle tanker normally has limited sideways thrust capacity, it is a great benefit to the overall operation that the FPSO has active heading control in order to optimize the joint operation.

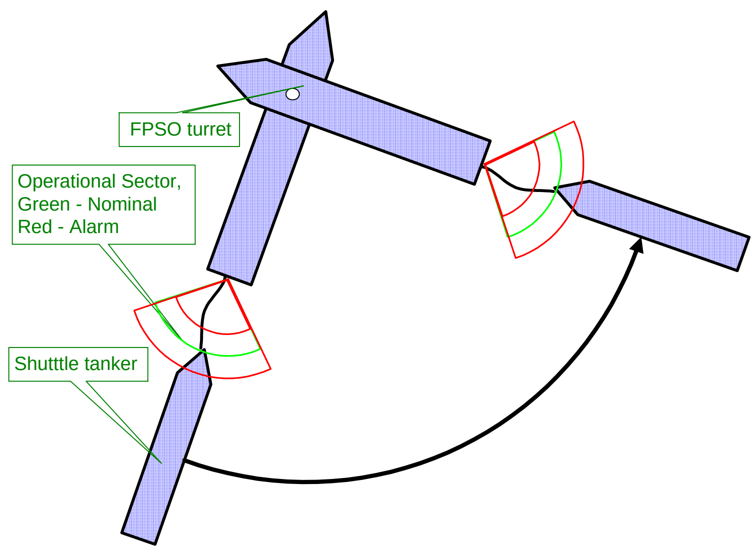

Figure 4: “Ideal” rotation of FPSO and shuttle tanker

The situation when the dominant weather forces for FPSO and shuttle tanker is different, for instance due to largely different draught, is illustrated in Figure 5. The result of this situation can be a violation of one or more of the alarm / disconnect criteria. The same will be the case if the shuttle tanker is unable to follow FPSO rotation speed.

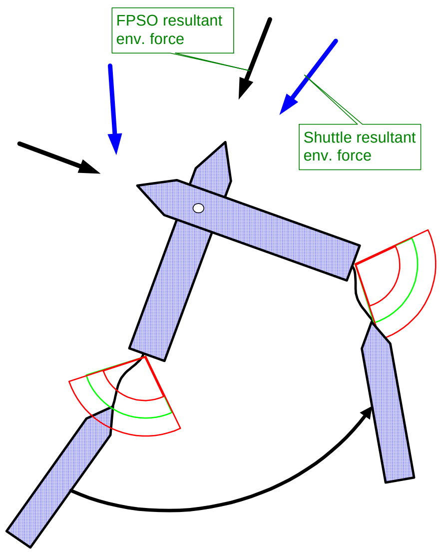

Figure 5: Rotation where shuttle tanker not is able to follow the FPSO

A simulation of a rather "common" situation in the North Sea is illustrated below. In calm weather conditions, where the tidal current is the dominating force a passively weather vaning FSU will rotate quickly when the tidal current changes direction. Heading changes of 180° in approximately 30 minutes has been experienced. Figure 6 below shows that the shuttle tanker is able to follow this rotation by applying sideways thrust. This operation can not be performed in standard weather vane mode.

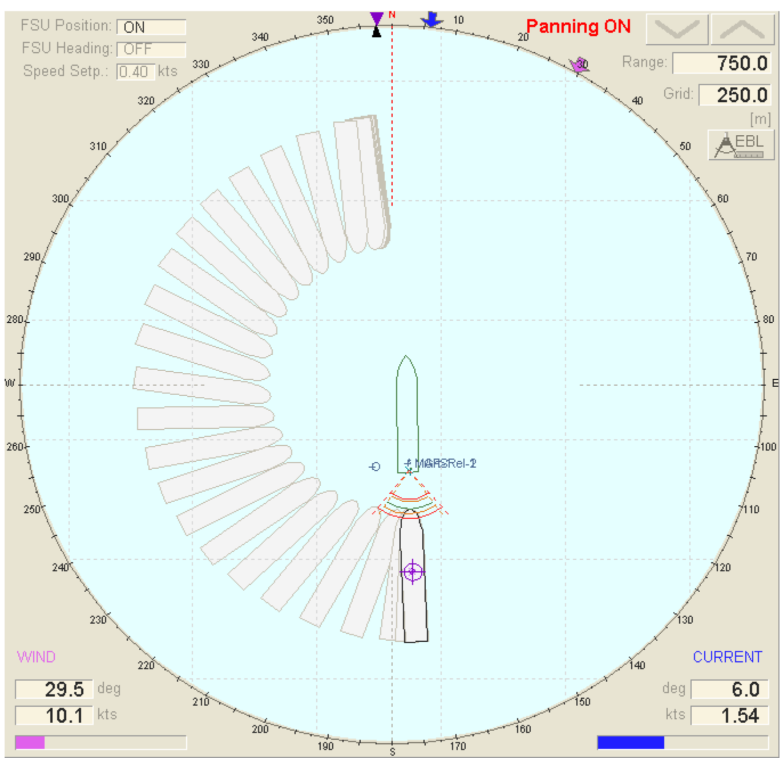

Figure 6: Simulated 180° rotation of tidal current

From the figures above it is quite clear that this type of operation is safer when the FPSO has a heading control system, and thereby is able to some degree adapt its heading to the weather optimum heading for the shuttle tanker. The speed of any wanted heading change can also be considerably reduced when having heading control on the FPSO. Such coordination between the two vessels will normally be covered through the field specific loading procedures, but a more automated coordination of the two vessels have also been evaluated, ref. [2].

Gulf of Mexico; Loop current situation

The strong loop current eddies, that occurs from time to time in the deepwater areas of the Gulf of Mexico, is a known problem for the oil and gas activity. A description of the mechanism behind and the nature of these loop current eddies can be found in ref. [3].

It is still unclear from available information how quickly the current can change. Most references indicate that significant changes are seen after minimum half an hour to several hours; i.e. the situation does not change completely in minutes. For the tandem loading operation it therefore seems fair to indicate that these operations can be performed safely by being prepared for any potential change in current. Forecasting services are available for the surface current as well as for current down to some hundred meters water depth, ref. [3] and [4].

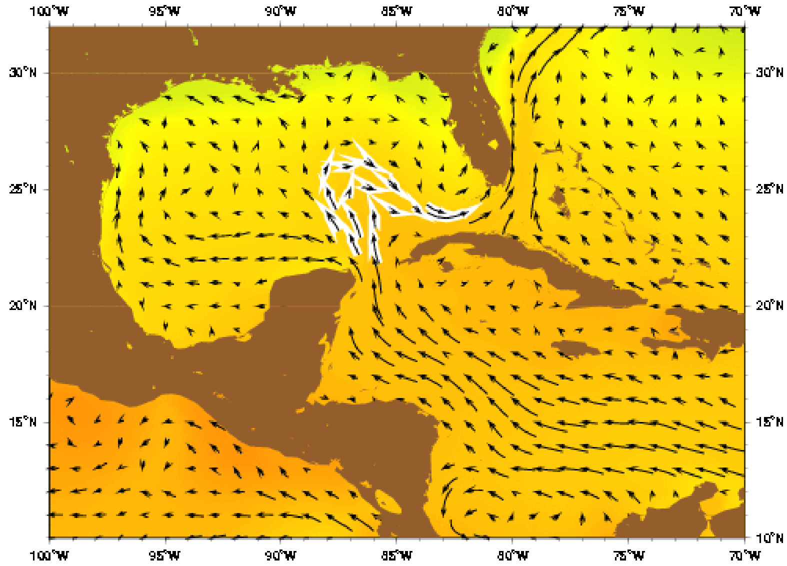

Figure 7: Loop Current, ref.[5]

Utilization of an operator support tool such as an Online Capability, might also have limited value under a high current situation unless accurate current data is available. The sensitivity to errors in the current data becomes high under these conditions. An example is included to illustrate this. Correct current is 3.3 knots from 0°, wind speed 11 knots from 30°.

Figure 8 shows the result from an analysis where wind speed is the varying parameter. The plot to the left shows that the vessel will increase the margin towards increased wind strength by changing heading towards 10° to 15°, and that the operational sector is rather narrow. As the sea current is the completely dominating environmental force, it is a much more valid approach to look at the DP Capability in terms of limiting current as in the right plot. This plot indicates that the safety margins are optimum at the current heading.

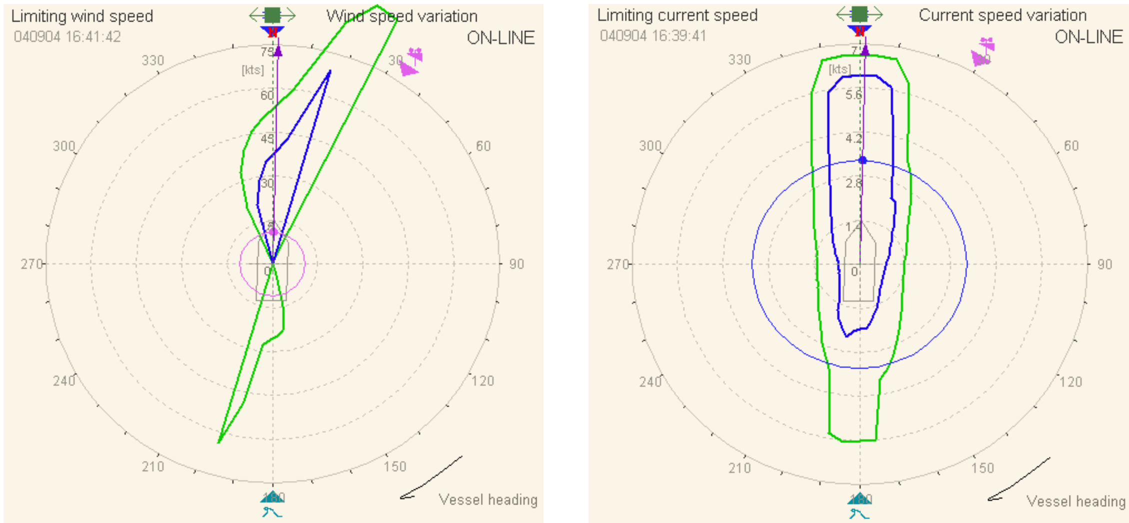

Figure 8: Online Capability plot with correct current input: wind (left) and current (right) variation

If the sea current not is correctly inserted, the plots may become distorted and might even provide misleading operator guidance. This is illustrated by the following two plots where a sea current of 2.8 knots from 15° has been used instead of the correct value. There is a significant difference from the correct plots.

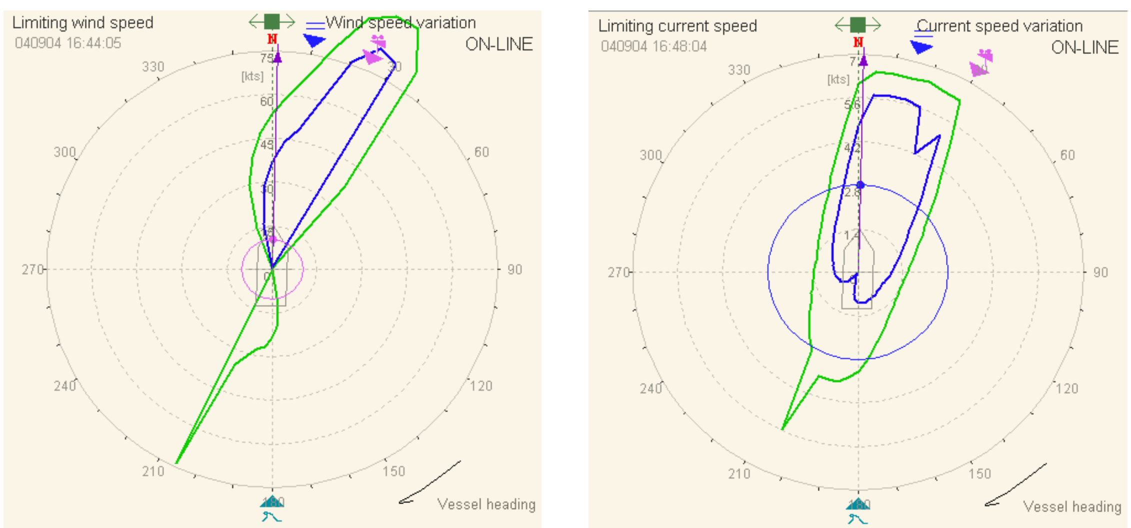

Figure 9: Online Capability plot with wrong current input: wind (left) and current (right) variation

Drilling Operation exposed to current

For many DP operations the situation where wind, current and waves come from different directions might cause operational problems. Especially finding the optimum heading for the operation can be difficult, as the optimum heading for DP in some case not is acceptable for the operation of the vessel due to for instance pitch / roll constraints.

An example with strong current coming from another direction than wind and waves is included in order to illustrate some of these aspects. A drill-ship with the following configuration is used for the example:

- Vessel size: 233 m Lpp, 42 m width.
- Displacement: 102.000 tons.
- Thrusters:
  2 ea. 2000 kW tunnel thrusters bow
  2 ea. 4300 kW azimuth thruster bow
  2 ea. 4300 kW azimuth thruster aft
  1 ea. 12000 kW main propeller aft with rudder

The weather conditions for the simulation are:

- Wind: 23 knots, 80° port relative bow
- Current: 3.3 knots, 10° starboard relative bow
- Waves: 2.0 meter with period 6 seconds, 90° port relative bow

The simulation also includes DP model errors in order to be closer to a a real-life operation. In an operational system there are numerous potential sources for errors in the DP model; wind sensor, wind and drag model, thruster loss etc. All such errors are accumulated in the "DP estimated current" together with real current and wave forces, explaining why the sea current in the figure below does not match the real value.

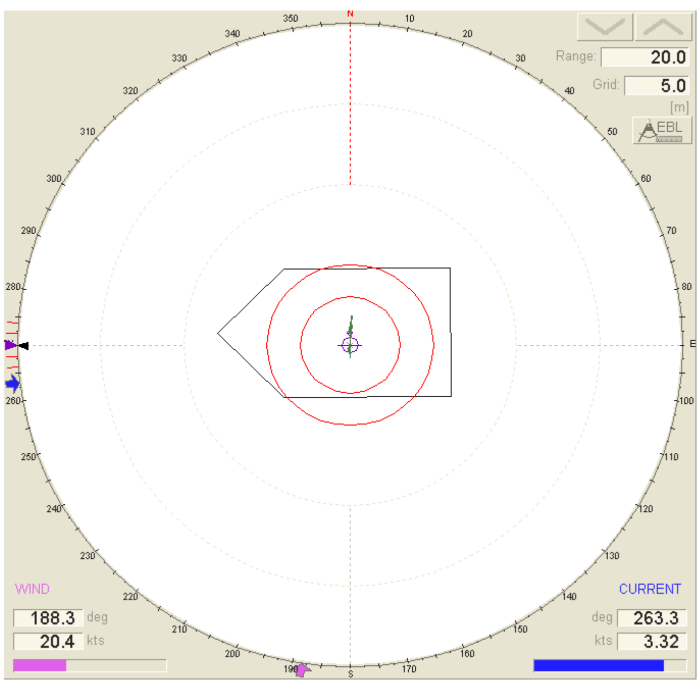

Figure 10: DP Position Plot with vessel heading 270°

In this situation the DP operator finds that the thrust utilisation is high and also expects that the waves will be growing. He therefore considers a change of heading from 270°, and by looking at DP wind and current defines 248° as a good candidate where forces will be in better balance. Having done this heading change he finds a significant increase in applied thruster force and looks at the “DP optimum heading” which now is 260°. Changing heading back to 260° stabilises thrust consumption as illustrated below. It can also be seen that that the DP estimated current direction is changing significantly during the rotation of the vessel.

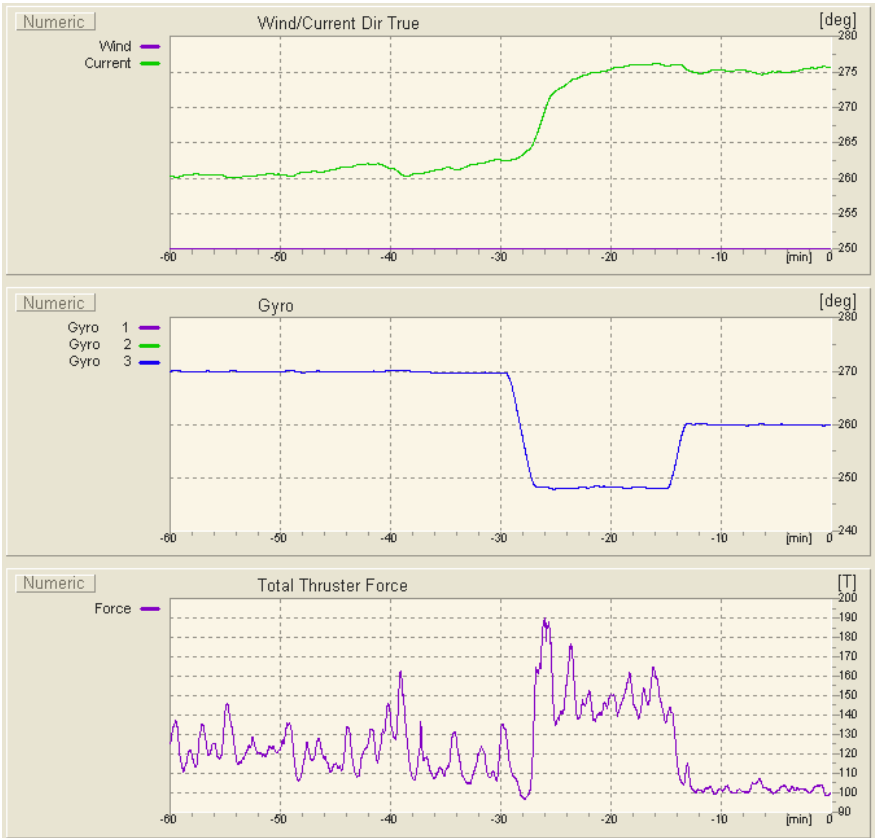

Figure 11: Estimated current direction, heading and thruster force

So, what went wrong in this case? It is obvious that the new heading that was selected by the DP operator was wrong. The reason for this is the un-modeled error forces that give a different impact on the vessel when changing heading. A much better approach in this case would therefore have been to adjust heading in much smaller steps, say 5°, and carefully watched the development of “DP current”, thruster force and “optimum heading” before adjusting more steps.

In this case, an online capability plot with input of **correct** sea current would have helped in performing the correct operator action as well. The plots in Figure 12 clearly show that a heading of 248° is too close to the margins where the vessel might drift off. On the other hand, utilization of “DP estimated current” as input to the online capability plot would in this case have resulted in plots that could have supported the decision to move to 248°.

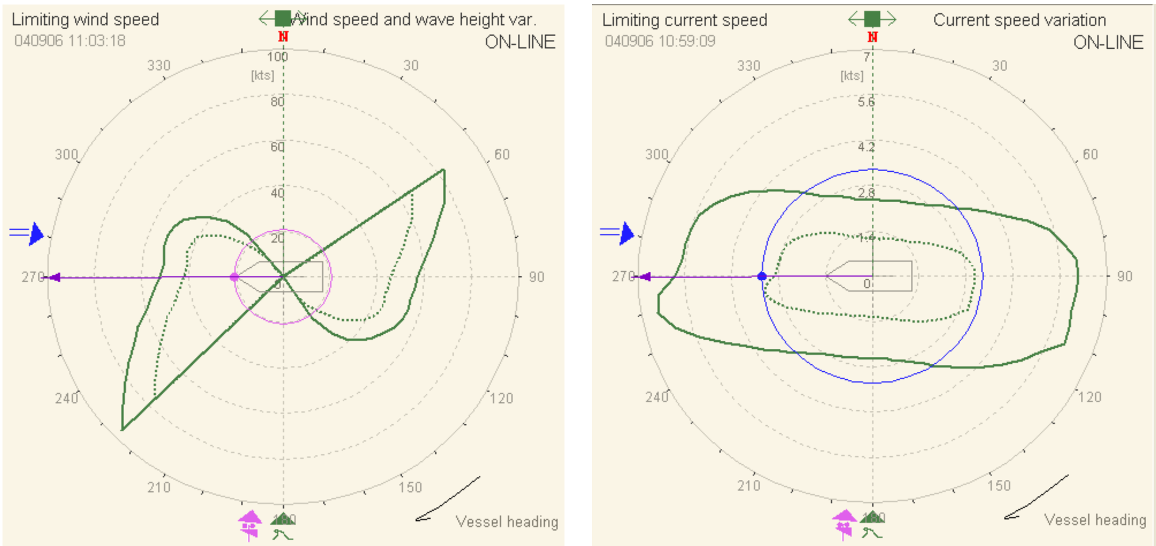

Figure 12: Online Capability plot with correct sea current input

Summary

Operation under changing environmental conditions is a challenge to many DP operations.

In the case of the Tandem Loading Operation, an FPSO with active heading control combined with good procedures and coordination between the two vessels will minimize the chance of incidents due to the change in weather.

Online operator guidance tools will benefit greatly from accurate sea current information as input to the calculations.

Any heading changes under "marginal" situations such as a strong sea current should be performed stepwise and at slow rotational speed.

References

[1] UKOOA FPSO Committee. Tandem Loading Guidelines, Volume 1. http://www.ukooa.co.uk/issues/fpso/docs/tandemvolume1.pdf
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[5] J. Gyory, A. J. Mariano, E. H. Ryan: "The loop current". http://oceancurrents.rsmas.miami.edu/caribbean/loop-current.html