# A NEW ERA IN LOCAL POSITION REFERENCING

**SY Heriot, T Coggins, M Mudrinic & A Stead**, Guidance Marine, UK
**H Busshoff**, Bernhard Schulte Ship Management, Germany
**O M Husøy**, Marine Technologies, Norway

**SUMMARY**

Standard navigation and positioning techniques used in offshore oil and gas are not optimised for navigating inside a wind farm. Unlike an offshore supply vessel servicing an oil platform which may have 1 or 2 approaches per day, wind service vessels may visit as many as 50 wind turbines in a single day. This requires fast and efficient turnaround times without compromising safety.

This paper discusses the challenges of existing position reference systems including laser and DGPS systems and considers the use of a new type of sensor that utilises the physical environment rather than discrete targets to reference position from.

## NOMENCLATURE

| | |
|---|---|
| DGPS | Differential global positioning system |
| DP | Dynamic positioning |
| DPO | Dynamic Positioning Operator |
| FMCW | Frequency Modulated Continuous Wave |
| GPS | Global positioning system |
| PRS | Position reference sensor(s) |
| PSV | Platform supply vessel |
| SOV | Service Operations Vessel |

## 1. INTRODUCTION

Typically a vessel approaches a wind turbine on DP at a distance of 100 meters and then station keeps at a distance of around 10 meters whilst walk to work bridges are deployed and crew is transferred. Whilst the use of laser and radar based position reference systems is common in the oil and gas industry, they are not optimised for use in the off shore wind industry. The number of targets required to cover a typical wind farm, along with the close proximity of workers to targets due to the restricted space on a typical wind turbine present particular challenges to the successful operation of these sensors.

A new type of radar sensor is presented which does not use an active target – rather it uses the local environment as its target; in this case the leg or tower of a wind turbine. This removes the need for physical targets to be installed which makes the vessel completely independent and can increase both safety and decrease turnaround times.

## 2. NAVIGATING IN WIND FARMS

Up until recently, wind vessels which serve the farthest offshore wind farms have typically been converted PSV's with the addition of accommodation blocks and motion compensated walkways [1]. DP2 vessels typically have 2 DGPS sensors and a local position reference sensor [2] which is usually based on laser technology to enable the vessel to approach and station keep at the wind turbine. With the recent appearance of SOV's purpose-built for windfarm applications the development of a purpose-built PRS is just a logical continuation.

### 2.1 DGPS REFERENCE SENSORS

Most readers are familiar with GPS systems for navigation in our cars and many will have receivers on our mobile devices. DGPS sensors provide higher accuracy (<1m) compared to GPS (20m) and are relied on for both navigation and timing in a wide range of commercial, industrial and military applications, including road transport, aviation and marine. DGPS however suffers from vulnerabilities. The paper produced by The Royal Academy of Engineering, 2011 [3] lists no less than 24 failure modes which in the most dramatic cases can result in 1000's of meters in error or total loss of signal. Some examples that cause these issues include damage to satellites, changes in the satellite trajectory or altitude, solar interference, jamming and interference, atmospheric variations and low availability of satellites (including shadowing). Using DGPS for navigating at sea is not immune to any of these vulnerabilities [4]. The problem is well recognised and incidents resulting from DGPS failure have been recorded during station keeping in recent years [5]. If a vessel has 2 DGPS sensors, and a single local sensor fails, then there is a back-up. If the satellite network fails, then there is no redundancy. In close proximity to an asset this presents a recognised hazard.

### 2.2 LASER POSITION REFERENCE SENSORS

Unlike DGPS which provides a global position, laser systems provide a local position relative to a fixed target. The fixed targets for a laser PRS are reflective tape or prisms. The distance is calculated by measuring the time of flight of the reflected light. For a laser PRS to be effective:

- Direct line of sight must be maintained between the laser sensor and reflector
- The reflector must ideally be at a similar height to the sensor (within its specified tilt range)
- No other reflectors should be in the vicinity of the target reflector
- The reflector should be well maintained and clean

Laser PRS were developed for the oil and gas industry and typically one or two reflectors are attached around the exterior of the oil platform. They are generally placed in locations where people will not be walking in high visibility clothing with a good line of sight to an approaching vessel. Prisms reflectors offer high brightness of the return signal compared to a reflective tape, however tape targets are much more common due to their lower cost (~£500) compared to a prism targets (~£1,500) [6]. A well-known issue with tape targets is that they can be difficult for the sensor to differentiate when other reflective surfaces are in the vicinity. Although this is not generally an issue in the oil industry, since users are much more aware of the potential for false reflections and use measures to eliminate this, it is difficult to avoid in the offshore wind industry due to the proximity of the operations to the targets.

The other major difference between oil and gas industry compared to the offshore wind industry are the number of reflectors required. Target installation could cost in excess of £200,000 on a typical 100 turbine offshore wind farm.

Owners and operators of offshore wind farms are imposing cost constrains on reflector targets and proposals for cost effective solutions have been put forward [7]. One proposal suggests placing strips of retroreflective tape around the tower of the turbine, whereas a second proposal suggests hanging a single retroreflective tape target from the transition piece landing platform on a rope. Whilst significantly reducing the cost of reflectors, these concepts are inadequate due to the risk of obscuration and weak return signal which increases the risk of a drop out – this may result in a loss of position incident. Weak reflector targets in the vicinity of access platform also poses a high risk of walk-off incidents – a situation where the sensor locks onto high visibility clothing of work personnel rather than the actual target. This is a real scenario when workers are transferring to and from the vessel and turbine. This could result in vessel movement on DP and the consequences of such an incident when a motion compensated bridge is deployed could be serious. Not only damage to both the vessel and wind tower but the potential for serious injury or loss of life. Installation of prisms on all wind turbines would solve all these issues and some windfarms are installing prisms [8], however few are implementing this solution due to the high cost.

## 3. 'TARGETLESS' PRS SYSTEM

Guidance Marine are the first company to offer a local DP PRS solution that removes the requirement for targets altogether. The system consists of 2 RangeGuard sensors connected to a control unit which in turn is connected to the bridge and the DP system of the vessel. The small light weight radar sensors are mounted onto the side of the vessel pointing in the direction of the transition piece and simple geometry determines the range and relative position of the vessel [9], shown in figure 1.

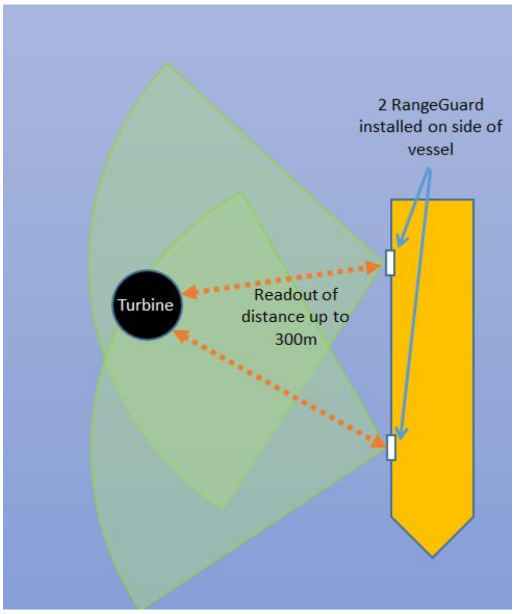


Figure 1: RangeGuard geometry

The RangeGuard sensors are 24GHz licence free FMCW radar transceivers. Their maximum range is 300m and have an accuracy of ±2cm + 0.1% of range [10]. They are configured such that they have an azimuth beam angle of 110º and a vertical beam angle of 11º. Individually each sensor reports the range to the nearest object, in this case the transition piece, which can be displayed on the user interface. Working in tandem they provide the relative position of the vessel which can then be used in the DP system of the vessel.

## 4. DATA COLLECTION

First sea trials were undertaken in August 2015 on the Bernhard Schulte managed vessel the Ocean Zephyr shown in Figure 2.


Figure 2. The Ocean Zephyr [11]

The Ocean Zephyr was fitted with two prototype Wide Beam RangeGuard sensors as shown in Figure 3. The sensors were hardwired to a processing module which was located in the deck IT room. To support the trial two IP video cameras were also installed (separate from the RangeGuard system). The video recorder was also installed in the deck IT room. A bridge monitor was installed running on a Guidance Type 3 Marine Processor (T3MP).

Figure 3. Locations of RangeGuard Sensors and video cameras mounted on custom brackets.

The sensor beam patterns were arranged such that the minimum operating range (for beam overlap) was approximately eight meters with the maximum being significantly greater than 50 meters (The motion compensated walkway operates between 10-30 meters).

Data was collected from both the RangeGuard sensors and video cameras continuously for a 2 week period from 19th August 2015 to 2nd September 2015.

Range data for the two sensors is shown on a display of the bridge as shown in figure 4.


Figure 4. Display on the bridge. Different views are available on the user interface. Left: Range and speed information from the two sensors, Right: Birds eye view showing the vessel and sensor beam patterns.

## 5. RESULTS

Raw radar data is processed in the control box connected to the RangeGuard sensors using a target tracking algorithm. The raw data shows all the radar return signals. An example of the raw data is shown in figure 5.

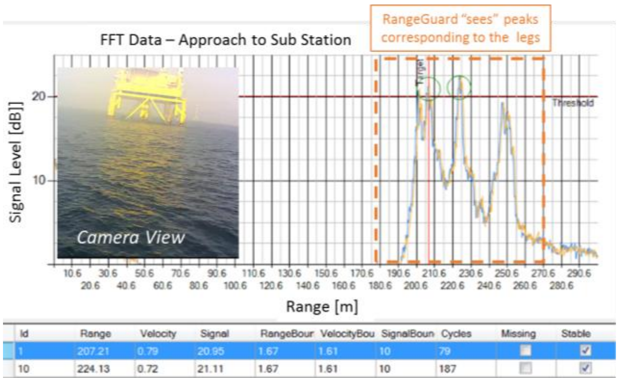


Figure 5. Raw data from a RangeGuard Sensor. The legs of the substation correspond to the peaks observed at different ranges in the signal level. The peaks which are being tracked (identified by circles) are shown in the table below the chart.

The algorithm, can identify and track peaks in signal level. Currently 10 targets are tracked simultaneously, although more targets could be tracked if required. For these trials, the nearest peak is selected, however depending on the application, the largest peak may be more relevant.

By locking on the "nearest peak", plots can be created that show distance from the wind turbine vs time. Figure 6 shows the distance-time chart for approach to a wind turbine from one of the sensors.

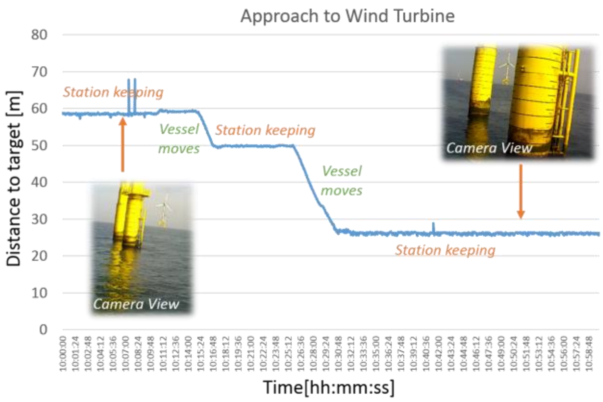


Figure 6. The vessel approaches the wind turbine. It can be clearly seen when the vessel is moving and station

keeping on DP. The Ocean Zephyr has both DGPS and CyScan laser PRS.

The 10m spikes in distance at around 10:07 are attributed to the algorithm jumping between the legs of the turbine and the spike of around 1m at 10:40 is attributed to the algorithm jumping between the main leg of the turbine and the boat landing attached to it. Understanding these phenomena has enabled the algorithm to be improved.

A second approach and departure is shown in figure 7.

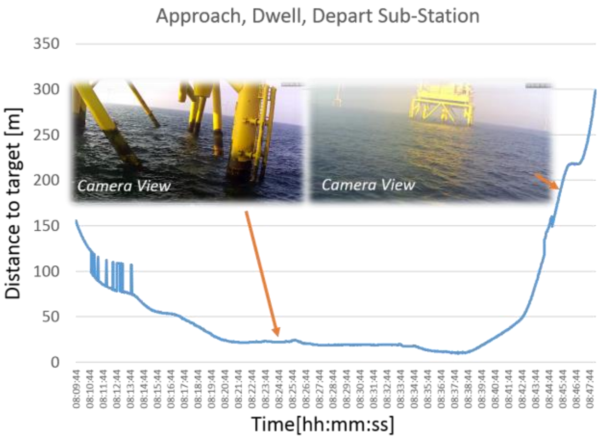


Figure 7. Approach from 150m to a substation followed by a dwell time for 20 minutes at around 25m range then a rapid departure.

During the approach between 8:10 and 8:13, the range data jumps. At this distance (120m to 70m) the angle of approach means that 2 legs of the substation switch between the nearest peaks. As it moves closer a single peak is identified and this is tracked for the duration of the operation.

The vessel moves very close to the substation at 08:38 to 10m which is then followed by a rapid departure. The RangeGuard loses signal at 300m Range.

Note that similar data was obtained from both sensors. Data collection against different targets has allowed the algorithm to be modified specifically for this application so that the jumps in range have been eliminated. This, however, highlights the challenges that must be overcome with an environmentally referenced sensor and the importance of live sea trials.

## 6. DP INTEGRATION

Guidance Marine are working with Marine Technologies (MT) who are integrating the RangeGuard sensor raw data into the DP system. A position telegram, also known as a DP string, has been provided to MT. This is a string of ASCII characters supplied by the RangeGuard control unit to communicate information to the DP system. The DP string can output a maximum of 10 features (or peaks) from each sensor into the DP system, from which the nearest peaks will be identified and simple mathematics calculate the range and bearing of the vessel to the wind turbine or leg.

The distance r from the midpoint of the sensors to the target is given by Equation 1:

$$r = \sqrt{\frac{1}{2} r_R^2 + \frac{1}{2} r_L^2 - h^2} \qquad \text{Equation 1}$$

Where 2h is the distance between the 2 ranging sensors, $r_L$ is the distance from the left-hand sensor to the target and $r_R$ is the distance from the right-hand sensor to the target.

The bearing θ to the target from the midpoint of the sensors is given by Equation 2:

$$\sin\theta = \frac{r_R + r_L}{2r} \frac{r_R - r_L}{2h} \qquad \text{Equation 2}$$

Where r is defined in Equation 1.

The sensor data is sampled three times per second. With 10 features/peaks identified every second and up to four sensors connected it means that there could be over 100 messages per second to the DP system if required. Full DP integration will be available in Q2 2016.

## 7. DISCUSSION

This work has demonstrated the concept that an environmentally referenced sensor system can be used for local position DP referencing. Being completely independent of mounted targets, and based on radar technology, it provides an additional form of redundancy to the DP system. RangeGuard also introduces a new method of data acquisition, thus is not having many common failure modes with DGPS or laser system. The common problems that occur with mounted targets are negated and maintenance of targets is no longer required. This results in an overall more robust redundancy concept on sensor level.

The RangeGuard system uses simple geometry and the wind turbine legs or towers provide excellent referencing targets for the sensors. When approaching a wind turbine there is generally only one “nearest” target and the RangeGuard can easily lock onto this. More complex structures are possible, and have been demonstrated with the substation approach in Figure 7. Work is underway on developing the algorithm to eliminate the significant jumps in range seen in Figure 7 when it is selecting different legs of the substation. It should be noted however, that when the vessel is in close proximity to the substation, the sensors do lock onto a single target and continue to lock onto this target during departure. Data collection in more complex environments is currently underway.

## 8. CONCLUSIONS

A new type of PRS for offshore wind DP operations has been described. Based on radar technology it is unique in the fact that it does not require any physical targets located on the wind turbine. Instead it uses radar reflections from the environment to measure range to the nearest objects. This has potential to significantly reduce cost and improve safety during offshore wind operations.

Trials on the Ocean Zephyr have demonstrated that stable range data can be gathered from the RangeGuard microwave sensor which has enabled development of the target tracking algorithm. The algorithm now performs at an acceptable level to enable DP integration.

At the request of the crew, the system on the Ocean Zephyr has remained on the vessel. Even without a DP feed, the range information displayed on the bridge has proved to be extremely useful to the crew on approach and station keeping at a wind turbine.

After the promising results obtained during the trials on the Ocean Zephyr Bernhard Schulte decided to make full use of the potential of RangeGuard and install a fully DP integrated system on their SOV new build Windea La Cour. The technologically highly advanced vessel is scheduled to set sail in Q2 2016 and RangeGuard will ideally complement and expand the capabilities of the ship.

## 9. ACKNOWLEDGEMENTS

Thanks go to the crew of the Ocean Zephyr who have cooperated throughout the trial. Wilfried Janssen (BussData) and John Farmer (Guidance Marine) who installed the sensor system, Sveinung Tollefsen and his team (Marine Technologies) who are currently working on DP integration. Finally thanks go to the rest of the team at Guidance Marine who have been involved in this project to make the first targetless sensor!

## 10. REFERENCES

1. Ocean Zephyr, Marine Traffic, *http://www.marinetraffic.com/ais/details/ships/shipid:716157/mmsi:538090463/imo:9000625/vessel:OCEAN_ZEPHYR*

2. American Bureau of Shipping, Guide for Dynamic Positioning Systems, *https://www.eagle.org/eagleExternalPortalWEB/ShowProperty/BEA%20Repository/Rules&Guides/Current/191_DPSguide/Guide*, 2014

3. The Royal Academy of Engineering, Global Navigation Space Systems: reliance and vulnerabilities, *http://www.raeng.org.uk/publications/reports/global-navigation-space-systems*, 2011

4. Alan Grant, Paul Williams, George Shaw, Michelle De Voy, and Nick Ward, Many maritime users today believe that GPS will always be available. This is simply not the case, *http://gpsworld.com/transportationmarineavailability-and-safety-12038/*, GLA, 2011

5. IMCA, Dynamic Positioning Station Keeping Incidents, Incidents reported for 2012 (DPSI 23), *IMCA M 228*, September 2015

6. http://marine-direct.co.uk/

7. Guidance Marine, PRS Reflector Target Recommendation for the Off-Shore Wind Industry, *http://www.guidance.eu.com/ui/content/whitepapers.aspx*, 2016

8. Guidance Marine, 201 Rugged Prisms to be installed on the Dudgeon Offshore Wind Farm project, *http://www.guidance.eu.com/UI/Content/Content.aspx?ID=551*, 2014

9. Russ Miles, Geometry for two ranges to a single target, *Guidance Marine Document*, 2015

10. Guidance Marine, RangeGuard Proximity Sensor, *http://www.guidance.eu.com/assets/_managed/cms/files/New%20Brochures/94-0430-4-A%20RangeGuard%20Brochure..pdf*

11. W-H Mastenbroek, Marine Traffic, *http://www.marinetraffic.com/*

## 11. AUTHORS BIOGRAPHY

**Sasha Heriot** is Business Development Manager at Guidance Marine Ltd. After completing her PhD in Physics at the University of Sheffield in 2003, Sasha worked in the field of polymer physics as a research associate for 4 years. She left the world of academia to work in a spin out company from the University of Leeds specializing in novel surface treatments. She then worked for 3 years in a multinational chemical company as Market Development Manager for a specialist chemical business unit. Sasha started her appointment at Guidance Marine in April 2015 where she is currently introducing innovative technology into new markets and new applications.

**Tom Coggins** holds the current position of Microwave Technologies Group Manager at Guidance Marine Ltd. He is responsible for development of Microwave Technologies and Sensor systems. His previous experience includes work in GPS based offender monitoring and Safety related Electronics for both the Railway and Oil industries.

**Milijan Mudrinic** holds the current position of Software Technologies Group Manager at Guidance Marine Ltd. He is responsible for software development. His previous experience includes RadaScan PRS software and Algorithm design and implementation for the Telecoms industry.

**Andrew Stead** is Head of Business Development, responsible for RangeGuard® at Guidance Marine Ltd. He began his career at Campbell Scientific in the in the sensors industry as Head of Sales supplying data acquisition systems. In 2008 he was appointed Managing Director of Muir Matheson supplying MetOcean and Helideck monitoring systems to the oil and gas industry. In 2012 he joined Guidance Marine as Head of Sales.

**Hendrik Busshoff** holds the current position of Offshore Marine Superintendent at Bernhard Schulte Ship Management. As a trained Master mariner he is responsible for offshore marine operations and DP. His previous experience includes SDPO on hyperbaric dive support vessel in the North Sea with Technip and sea time as officer and Marine Superintendent with the merchant navy.

**Ole M Husøy** is responsible for sales & design at Marine Technologies, which includes obtaining feedback from customers/users and conveying this to the R&D team, suggesting improvements to existing equipment and applications, as well as promoting MT's range of products. He is a Master Mariner of education and sailed for 15 years as a navigator on various types of vessels, before going ashore in 1998 and has since been involved in integrated ship control systems.