Return to Session Directory

DYNAMIC POSITIONING CONFERENCE

October 17-18, 2006

Sensors

Increased DP Sensor Demands

Michael C. Ford
L-3 Communications Dynamic Positioning and Control Systems

Abstract

With the increasing number of DP vessels of all types being built and upgraded, and the ever-increasing requirements to increase efficiencies, there is more focus on the DP system and its overall reliability. DP hardware and interfacing is being standardized by most manufacturers, which provides more intuitive operator interfaces and increased functionality. The DP system is however only as good as the sensor information it is presented with. This paper provides a brief review of developments in the actual DP systems to meet these growing industry demands including expanded interfacing, more robust hardware as well as how DP systems operate with these expanded capabilities. In particular, the increasing requirements of the DP on its sensor suite are broken down. This includes the redundancy requirements for sensor operating principles as well as redundancy within individual principles. The data frequency and stability required for the range of sensors is reviewed with analysis for appropriate sensor suites for various applications. Finally some conclusions will be shown regarding how these requirements can best be met as the industry works in continually deeper water depths where overall DP system reliability is critical.

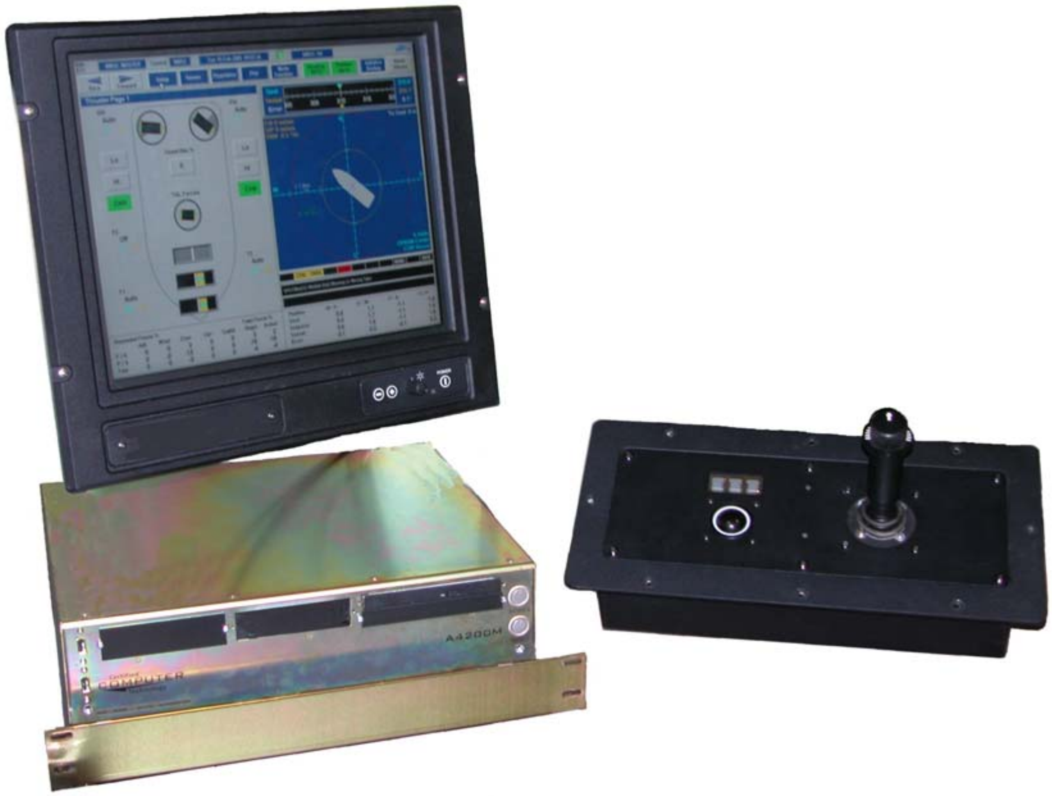
Introduction

The popularity of dynamic positioning (DP) systems in the offshore community has expanded dramatically. Virtually every new-build vessel comes equipped with a DP system or has the wiring in place for a quick installation when a contract calls for it. This popularity has been driven not only by safety but efficiency in the offshore workplace. Mainly driven by the OSV market, the make-up of DP systems has adapted to the new found popularity and created new issues. Not only are the DP system components themselves changing but so are the operator's demands of the systems. They are no longer a simple luxury to reduce fatigue while the vessel is standing by, but a mandatory tool for quick and efficient trips. A DP system being 'down' is vital to the vessel's operation and prosperity. To meet the new uptime requirements, manufacturers have turned to more robust hardware that is easily available and fully supportable. In the worst case scenarios, operators expect their issues to be resolved quickly and long lead parts are not an acceptable excuse for delays.

Operators are increasingly turning to higher specification vessels to improve the operation percentage for vessels. By requiring Class 2 vessels, which are "capable of automatically maintaining the position and heading of the vessel within a specified operating envelope under specified maximum environmental conditions during and following any single fault, excluding a loss of compartment or compartments," the operational time is maximized. As part of the requirement for a Class 2 system redundant sensors are necessary to meet the failure criteria. As operators have gained experience with redundant sensors, a number of limitations have been experienced due to specific operational requirements. This has led to detailed operator requests for internal redundancy of the sensors, not simply increased quantity. Regulatory bodies have always required different operating principles for position reference sensors, but are now fine tuning these requirements based on the experiences gained in the industry along with the demands customers are putting in place to supplement their regulations for their particular sites. Fully understanding the changes in the demands on sensors requires beginning with a brief review of the evolution of DP systems and their current state.

DP System Improvements

DP systems began as room-filling machines with crude displays and tube element electronics that were often hand-built. This lead to customized components manufactured for the single purpose of being used in a DP system which have suffered with the quickening pace of computer development. While ship systems have classically been purchased with the expectation of lasting the life of the vessel, computer driven systems have forced "technology refreshment"



onto operators. Just as they replace their home and office computers on a regular basis, now they are being pushed to do the same with the control systems. The rapid advancements in computer technology and display technology have further bolstered this dramatic change. The latest method to combat this progressive technology drive is a shift to standard commercial components or "Commercial-Off-The-Shelf" (COTS) equipment. The shift to COTS equipment includes not only the hardware (computer, display and joystick/trackball controller as pictured above) but also the software. Utilizing current standards allows a quick upgrade when necessary and insures compatibility and supportability over time. Commercial products are already designed for consumer supportability that brings a wider reaching support system as well as higher availability.

Using standard industrial automation products from manufacturers like Allen Bradley and Siemens allows DP manufacturers to take advantage of their massive production and support capabilities and focus on the DP system itself. They no longer need to custom design and build input/output (I/O) modules or the controllers for them. In addition, DP system manufacturers can avoid the requirement to hold significant stock for spares as the commercial manufacturers maintain a much larger stock in many locations. Additionally, the tools to program commercial hardware are readily available and provide the end user with improved capability to support the systems on-board requiring fewer costly visits from dedicated DP technicians. Similar ideas apply to the software, ultimately leading to most current systems operating under the Microsoft Windows XP platform.

Technological improvements have also allowed more advanced system features to be introduced ranging from high-resolution graphics to added modes and functions. While some systems continue to develop custom display screens some manufacturers have begun using standard commercial tools for screen development as well, further improving the product's supportability. Advanced screen displays also offer improved performance with smoother and safer operation. The ergonomics of the system design has lead to changes in how user interfaces make use of the higher resolution displays as well as to touch-screen interfaces that provide very intuitive operation. The operator directly touches what he wants to interact with, instead of looking at the screen and then searching for the appropriate button on a console below. Some systems are already looking at the potential for "heads-up" displays allowing the operators to use the DP system without taking their eyes off critical operations on deck. Many current generation systems incorporate "triple-voting," which provides comparison of three sensors to vote out spurious data making system operation smoother and more reliable. This technique was originally applied just to position reference sensors and has been expanded to all of the system sensors. The new technology has also enabled integrated systems that are becoming more and more popular combining dynamic positioning with alarm and monitoring as well as thruster control and power management to be scaled down for use on virtually any size vessel. Each technological advancement has lead to more robust and more reliable DP systems, leaving the sensors as the next critical element to improve for added overall system reliability and operability. More advanced software has also enabled DP systems to have more system interfaces for sensors as well as other vessel systems. Early DP systems typically offered only the number of sensor interfaces dictated by regulatory bodies, while current systems often allow virtually unlimited interfaces many of which are operator selectable. Sensor redundancy in quantity is now easily achievable well beyond the regulatory requirements.

Technology has allowed the sensors themselves to improve using the same processing and software advances. Many sensors now incorporate advanced diagnostic features and displays to keep the user informed of exactly how well the sensor is operating. This information can often be passed on the DP systems themselves for added operator awareness. In addition, they have allowed "integrated" sensors leading to internally redundant sensors such as GPS/GLONASS and USBL/LBL hydro-acoustic systems. Additional solutions have evolved for the other required sensors. Transmitting Heading devices (GPS compasses) have improved in capability to the point they can provide not only a secondary heading input but also a secondary attitude input for DP systems.

Sensor Redundancy – Regulatory View

The vast majority of regulatory bodies are in agreement about requiring different operating principles for position reference sensors when multiple sensors are specified. Actual wording for several of the regulatory bodies is shown below to show the close agreement. While the details vary slightly, the general intent is the same; if redundant position reference sensors are supplied, they should operate on different principles such that if one fails, the other will not be affected. With the advances in technology, new situations have developed which test this simple approach.

Operational requirements for sites can limit the sensors that are useable on location, which has forced operators to use systems employing compromises to meet the regulatory requirements. As an example, in many cases two DGPS systems can be used as long as the corrections are provided by different methods, i.e. one INMARSAT connection and one "Spotbeam" (L-band) antenna. This takes the first step towards sensor redundancy, but many officials are now going further and requiring two different GPS engines as well. This helps remove the common mode failures noted by several authorities. Another solution to this concern has been increased use of dual mode GPS/GLONASS units to exploit the two different satellite constellations. This has been successful but often raises questions on the viability of the GLONASS satellites. DGPS manufacturers have also used technology to develop verification software to make the user more aware of the systems operating condition and allow more flexibility for the cross-connection of the correction signals. With post processing systems checking multiple correction inputs, these systems provide a robust and reliable solution. Along with the increase in higher specification DGPS units have also come increased requests for systems that can operate on only GPS signals. Since the US Government turned off "Selective Availability", many deepwater sites can operate successfully with simple GPS signals when there are issues with the differential correction services.

American Bureau of Shipping (ABS)	"Two of the position reference systems may operate on the same principle. A single failure is not to affect simultaneously more than one position reference system, i.e., no common mode failures." ABS (4-3-5) Section 15.7.2
Det Norske Veritas (DNV)	"When more than one position reference system is required, at least two shall be based on different principles." DNV (6-7-3) Section C101
Lloyd's Register of Shipping (LRS)	"At least three position reference systems incorporating at least two different measurement techniques as defined in 4.3.2 are to be provided and are to be arranged so that a failure in one system will not render the other system inoperative." LRS (7-4) Section 5.3.4
Bureau Veritas (BV)	"When two or more position reference systems are required, they are not all to be of the same type, but based on different principles and suitable for the operating conditions." BV Section 4.43.14
China Classification Society (CCS)	"When two or more position reference systems are required, they are not both (all) to be of the same type, but based on different principles and suitable for the operating conditions." CCS Section 6.8.1

Relative position sensors have also advanced with systems that are more tolerant of adverse weather to become more likely candidates in varying operational conditions. While laser range and bearing systems are typically susceptible to smoke, haze and fog, the new generation of radar range and bearing sensors, are much more robust in these conditions. In addition, the hydro-acoustic systems are now incorporating multiple operating principles for internal redundancy as well. There are a number of units that offer either SBL/LBL operation or USBL/LBL operation. Some manufacturers offer upgrades to older systems to provide the new dual mode operation.

Along with all of the advancements in the technology of the sensors, the data transmission rates have increased as well. While the regulatory bodies do not specifically call out a required rate, most systems accept signal rates around 1Hz. In general, this is more than acceptable for DP operations, as the actual response of the mechanical systems (engines and propulsors) cannot act fast enough to make use of higher data rates. In some cases the data rates have had to be slowed to avoid overloading the networks with additional data. This problem has been all addressed by introducing faster network protocols and improved network architectures but remains a concern as operators try to combine more workstations and operations onto the main network.

Sensor Redundancy – In Operation

As the use of DP has expanded to virtually all facets of offshore operation, the limitations of the sensors have forced operators to use various methods to meet the regulatory criteria as well as the operation needs to their situation. A supply vessel cannot realistically use hydro-acoustics for typical out and back supply runs as the time to deploy and recover the beacons would be prohibitive. In addition the cost of sensors is also a consideration for operators even in the midst of heightened day rates. Armed with improved technology, operators turn to different compromises to satisfy the regulatory surveyors by demonstrating that their solutions meet the regulatory guidelines in the context of their operation. Many of these still have drawbacks, but are accepted by surveyors on the basis of the specific operational situation presented. The first step was simply cross-linking two identical GPS receivers with different correction signals. While this avoids the potential failure for the corrections signals, it does not address the chance for a common failure of the GPS units themselves. Though this is an unlikely failure, the potential can easily be remove by utilizing different GPS engines. This represents the next step in the solution for operators; multiple DGPS systems employing different receiver brands and correction inputs. Combining Satellite Based Augmentations Systems (SBAS) such as WAAS and EGNOS with subscription correction services on different brand GPS engines provides redundancy and avoids the unlikely chance of a single point failure from identical GPS engines. This method works well in most areas except those susceptible to atmospheric influence that affects the actual satellite signal reception. In these areas, operators must take the next full step to employing additional sensor varieties.

The drilling community specifically has driven hydro-acoustic products to evolve for their needs in a similar way. Most current acoustic systems offer the capability to use two of the available acoustic positioning methods including ultra-short baseline (USBL), short baseline (SBL) and Long Baseline (LBL). Combining these positioning technologies has provided very good solutions for operators but also introduced unrecognized limitations. While many systems touted for deepwater operations use combined USBL/LBL operation as a method of redundancy, the accuracy limitation of USBL in higher depths reduces the actual redundancy provided. Combined SBL/LBL systems offer more inherent redundancy in accuracy at higher depths, but also require additional hull penetrations that can be an issue for owners with space limitations.

The critical concern for any DP system is maintaining a consistent and reliable position reference input. Ultimately, this drives the requirement for redundant sensors with suitable accuracy and update rates. The update rates for satellite-based sensors can be driven much higher than those for acoustic systems due to the physics involved; a given hydro-acoustic signal simply cannot travel as fast as a radio-frequency (RF) signal. A wider variety of position reference signals provides for a smoother complement interfacing to the DP by avoiding specific issues associated with each and its inherent update rate. Obviously, this arrangement also meets regulatory requirements for different measurement technologies.

While many successful sensor suites have been employed two ideal arrangements will be reviewed along with why they work so well. Offshore Support Vessels (OSV's) ranging from standard supply vessels to advanced anchor handlers and dive support vessels, need reliable data which allows them to move on and off locations quickly while having rapid access to accurate positioning fixes. They encounter a variety of conditions and experience higher pitch and roll movement than larger vessels making accurate pitch and roll correction mandatory. A suitable complement of sensors (depending on specific Regulatory requirements for the class notation desired) might include two different brand DGPS receivers, one with SBAS corrections and one with subscription service for times when high accuracy is needed, one range and bearing system (laser or radar based depending on operating region), one gyrocompass and one THD which also provides an additional attitude interface to the DP system, one motion reference sensor (either a solid state unit or if the vessel is equipped with acoustics for other operations and motion reference unit) and two wind sensors. This sensor arrangement provides consistent data input to the DP system combined with redundancy both in operating principles as well as hardware basis.

Drilling assets require a similar selection of sensors with two notable differences. Drilling assets target a much higher operability percentage, as they do not have the mobility of OSV's allowing them to easily return to shore for support and repair services. With this in mind they tend to have more physical redundancy, i.e. more sensors. In addition, drilling assets have the benefit of maintaining a single location for an extended period of time which makes hydro-acoustics a much more beneficial positioning method in place of range and bearing type systems. A suitable sensor complement for these vessels (depending on specific Regulatory requirements for the class notation desired), might consist of the following three DGPS receivers, one using SBAS corrections, one with an INMARSAT based correction and one using an RF based correction signal, two hydro-acoustic systems with redundant operating methods i.e. SBL and LBL, two gyrocompasses, one THD (with both position and attitude outputs), two motion reference units, one vertical reference unit and three wind sensors. Generally on these vessels different manufacturers for the DGPS receivers are not necessarily required for each of the units as a post processing system is used that detects equipment problems and prevents common mode failures. The table below shows the layers of redundancy each complement of sensors provides both functionally and physically.

Sensors	Redundancies	Methods
OSV		
Position	4	2x DGPS, 1x Range/Bearing, 1x THD
Heading	3	2x gyrocompass, 1x THD
Attitude	3	2x MRU, 1x VRU, 1x THD
Wind	2	3x solid state sensor
Drilling		
Position	8	3x DGPS, 4x hydro-acoustics (2x per system), 1x THD
Heading	3	2x gyrocompass, 1x THD
Attitude	4	2x MRU, 1x VRU, 1x THD
Wind	3	3x solid state sensor

In each system, the layers of redundancy provide similar performance for the vessel to maintain a consistent data rate and stability as well as avoid single point failures for operational requirements. The sensor suites described above are not all encompassing, as many operations require specific measuring systems for acceptable performance such as riser angle measurements for drilling assets. In addition, these guidelines are intended to present solid bases to work from when developing the required complement of sensors. In many cases this may be considered excessive, but the relevant surveyor when reviewing the specific operational details of the vessel and its intended location should make this decision.

Conclusions

With DP systems advancing, many new demands on the sensors are emerging, which further supports the regulatory redundancy guidelines but also will likely be extended to other sensors used. Further as the popularity of DP continues to grow, new situations will appear which require careful evaluation and may require compromises for effective operation. While a fully redundant sensor suite incorporating multiple principles for each of its sensors including heading (gyrocompass and Transmitting Heading Devices), attitude (analog vertical reference units and advanced motion reference units), wind velocity/direction (typical analog and ultrasonic) and position reference can easily be devised, it may not be required as different evaluations prove the viability of integrated sensors such as THD's. The benefits offered by a THD provide a solid redundancy for a relatively low cost, though it should be recognized that this is a satellite-based sensor and therefore susceptible to all of the same atmospheric influences as other satellite based units. In addition, in the future Inertial Navigation Systems (INS) may become inexpensive enough to offer another level of redundancy to DP system operations. The benefits offered by a THD provide a solid redundancy for a relatively low cost, though it should be recognized that this is a satellite-based sensor and therefore susceptible to all of the same atmospheric influences as other satellite based units.

While the advances in DP systems have made input of multiple sensors very simple, the popularity of using DP has lead to new situations that require added review. Complete redundancy is not a realistic expectation as it could easily be extended to the DP systems themselves as well as the other equipment on the vessel. Realistically, items with limited likely hood for failure as derived from both operational experience and proper application of FMEA analysis, can simply be provided in multiples. This is supported by the "voting capability of current generation systems which further reduces the risks a of a failure affecting operations. However, to insure the proper performance of these systems will continue to require operators trained to properly operate the systems and understand the impact of these sensors on that effort.

References

L-3 DPCS (Nautronix) Technical Descriptions, 6/06.

American Bureau of Shipping (ABS), Rules for Building and Classing Steel Vessels, 2006

Det Norske Veritas (DNV), Rules for Classification of Ships, 2006.

Lloyd's Register of Shipping (LRS), Rules and Regulations for Classification of Ships, 2006.

Bureau Vertitas (BV), Classification of Dynamic Positioning Installations, 2006.

China Classification Society (CCS), Guidelines on Surveys for Dynamic Positioning System, 2002.

Bray, David, "Dynamic Positioning", Oilfield Publications Limited, 1998, 269pgs.

Morgan, Max J., "Dynamic Positioning of Offshore Vessels", Petroleum Publishing Company, 1978, 513pgs.

Faÿ , Hubert , "Dynamic Positioning Systems", Editions Technip, 1990, 189pgs.

Michael Ford – Mr. Ford graduated from the University of New Orleans with a Bachelor of Science Degree in Naval Architecture and Marine Engineering. After consulting on deepwater mooring projects with David Tein Consulting, Mr. Ford joined Nautronix in 1996. After holding many positions ranging from staff naval architect to product manager with Nautronix (now L-3 DP and Control Systems), Mr. Ford is now the Vice President of Sales for North America.