Archives of
Transport System
Telematics

Volume 9

Issue 4

November 2016

Position reference systems for offshore vessels

J. PAWELSKI
GDANSK UNIVERSITY OF TECHNOLOGY, Faculty of Electronics, Telecommunications and Informatics, Narutowicza 11/12, 80-233 Gdansk, Poland
EMAIL: slagaj@eti.pg.gda.pl

ABSTRACT

Dynamic positioning (DP) system is an automatic system allowing vessel to keep position or move along pre-determined track using solely own propellers and thrusters. Position reference systems provide very accurate position of vessel in relation to chosen points which is the key element of DP operations. Systems made by different manufactures they have to use standardized data exchange protocols for proper communication.

KEYWORDS: dynamic positioning, offshore, reference positioning system, data transfer

1. Introduction

Dynamic Positioning (DP) today is defined as computer controlled system allowing vessel to maintain position or to move along pre-determined track. This relatively new technology arose in early 1960's to answer demands from offshore oil and gas industry exploring new hydrocarbon reservoirs located in deep waters where jack-up platforms couldn't be operated . Mooring systems with multiple anchors were used for floating drilling units but at depths greater than 500 m costs of such moorings were very high and operations were difficult. Mobility of such drilling rigs was severely limited. In 1961 small monohull drilling vessel "Cuss 1" was launched and successfully carried out several coring drillings in Gulf of Mexico at depth from 100 to 3,500 m. She was fitted with four manually-controlled steerable propellers. Vessel's position was checked by ranging by radar four anchored buoys and by sonar measuring distance to underwater hydro acoustic beacons. After such humble beginnings next drilling vessel "Eureka" was fitted with automatic system for maintaining her position. Steerable propellers were operated by analogue controller interfaced with taut wire reference system. For next few years analogue PID controllers were used for DP purposes, with single reference systems, providing no redundancy at all. Development of digital technologies in late 1970's replaced analogue DP systems with computer controlled sophisticated equipment. Improvement in DP technology led to its wider application, not limited to drilling operations only. It is being used today for pipe and cable laying, rock dumping and dredging. Large passenger vessels and ferries use it for manoeuvring in confined waters of harbours. Increased interest in DP resulted in development of new types of position reference systems. DP systems in use today offer very high degree of reliability and redundancy to meet safety requirements of complex offshore operations. Main elements of DP system with direction of data flow are shown below:

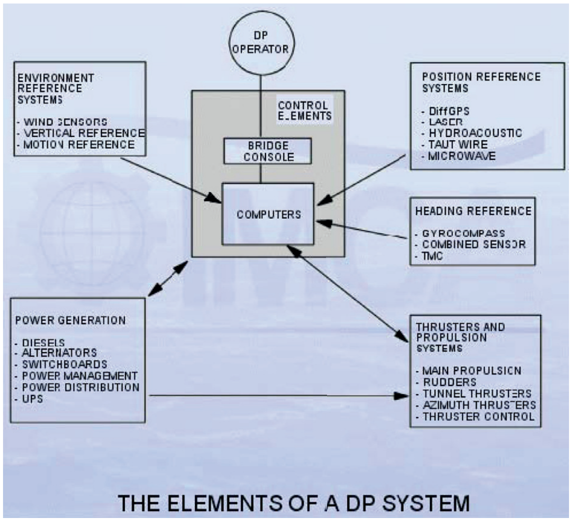

Fig. 1. Schematic diagram of Dynamic Positioning System [5]

Very important part of DP system is group of Position Reference Systems providing information regarding vessel's current position necessary to process commands for thrusters to counter external forces and to bring vessel to set position. Position accuracy depends on character of task to be carried out. Offshore projects with high level of risk always require simultaneous operation of three independent reference systems. DP system can work either in automatic or manual mode but always requires close supervision from highly qualified DP operator.

2. Reference systems

DP operations are not using standard system of geographical coordinates characteristic for marine navigation. Offshore industry uses Universal Transverse Mercator Projection (UTM) where position is given in UTM zone number and easting and northing pair in that zone, expressed in meters. Offshore projects usually call for position accuracy better than 1 meter.

Many tasks performed by offshore vessels within oil and gas fields instead of 2-dimensional Cartesian coordinates require polar coordinates i.e. range and azimuth to given point. Offshore reference systems are required to work with accuracy of fraction of meter. There are several types of such systems in use today. Some of them like Differential Global Navigation Satellite Systems (GNSS) can provide position accuracy 0.1 m almost worldwide.

2.1. Taut wire reference

It is one of the oldest reference systems for DP applications, but still in use for operations in water depth up to 500 m due to low costs involved. Taut wire reference measures movement of surface vessel relative to fixed point at the bottom where sinker weight called depressor is placed. Vessel winch maintains constant tension on wire connected to depressor. Any movement of vessel will cause the tensioned wire to deviate from its initial inclination. This movement is transferred to two potentiometers connected to gimbal supported sensor. Resulting analogue electric signal is proportional to inclination change in two perpendicular axes. Drawing below explains principle of work:

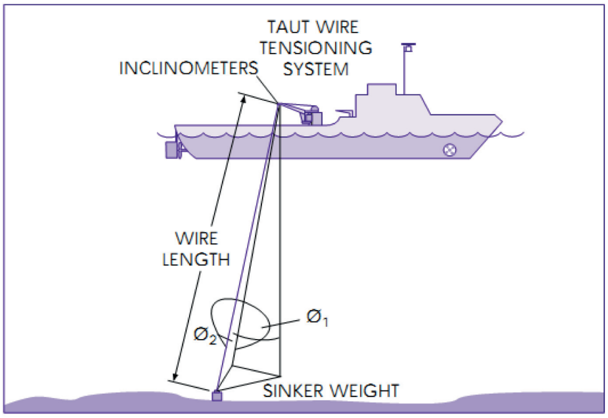

Fig. 2. Basic idea of Taut Wire Reference system [1]

Konsberg Maritime Bandak Lightweight Taut Wire Mk 15B is still commonly used where three independent reference systems must be used. Its analogue electric signal with range from 0 to 10 V is processed in programmable logic controller (PLC) with digital output suitable for installed type of DP system. Typical accuracy of Taut Wire Reference is app. 2% of water depth.

2.2. Hydroacoutstic reference

Hydro acoustic reference systems have been used by offshore industry since the beginning of dynamic positioning. Despite many years in service this technology is still under constant development. System is based on propagation of pressure wave through the water with speed approximately 1500 m/s. Signal reflected back by bottom or other object is detected by the system. Propagation time corresponds to the distance between transducer and object. Transducer's direction beam pattern allows for determination of bearing. Typical range of acoustic frequencies is from 21 to 31 kHz. In practice, instead passive objects, hydro acoustic transponders are used with individual carrier frequencies for identification purposes. High Precision Acoustic Positioning system (HiPAP) by Norwegian manufacturer Konsberg can work in several configurations, depending on particular needs:

- Super Short Base Line (SSBL0
- Short Base Line (SBL)
- Long Base Line
- Multi-User Long Base Line (MULBL)

Graphic presentation below shows MUBL with array of hydro acoustic beacons at sea bottom:

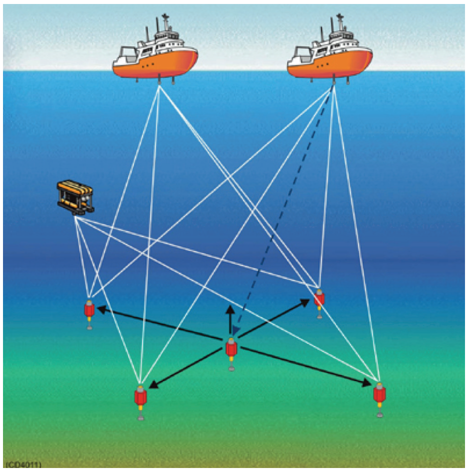

Fig. 3. Multi –User Long Base Line (MULBL) system configuration [3]

Signal is being transmitted with Frequency Shift Keying (FSK) modulation. Typical accuracy of range measurement is about 0.2 m. Direct-Sequence Spread Spectrum (DSSS) modulation has been introduced in recent time, which increased range accuracy to 0.1 m. Equipment of new generation is directly connected to Acoustic Position Operator Station (APOS) console by Ethernet cable but internal communication between transceiver unit and Ethernet switch/converter is made by fibre optic cable to eliminate influence of external electromagnetic fields. Konsberg recently enhanced accuracy and reliability of acoustic reference systems by introduction of inertial navigation in Hydroacoustic Aided Inertial Navigation system (HAIN). Inertial Measurement Unit (IMU) contains three accelerometers and three fibre-optic gyroscopes (FOG) measuring linear accelerations and angular velocity in three axes. Data are processed by reference processor using Kalman Filtering method to limit position drift inherent in inertial navigation systems. System provides good position data smoothing and support precise positioning during occasional acoustic measurements dropouts.

2.3. Microwave reference

After World War II development of marine radars working in X-ban led to construction of microwave reference position systems for offshore industry. First system called Artemis by CHL Netherlands B.V., used frequency 9.2 – 9.3 GHz and pulse method of distance measurement. Azimuth was determined by unique antenna build as slotted waveguide and divided into two independent halves. Each part had two ports where signal was provided with phase and opposite in phase to other halve of antenna. Signals from ports opposite in phase formed antenna characteristic with zero signal at line perpendicular to antenna. This setup allowed angular measurement accuracy 0.02°. For many years system used data transmission standards RS232C and RS432A. For peripherals input additionally was provided 20 mA loop. Despite of slowly being phased out by newer microwave reference systems, last generation Artemis MkV is still in use and received Ethernet data transmission which becomes standard for currently manufactured DP systems. Main disadvantages of Artemis are susceptibility to interferences from marine radars working in X-band, ability to track only one station and high running costs.

New microwave reference system RadaScan made by Marine Technologies offer several advantages improved position reliability due to multiple targets tracking, compact design and low equipment cost. RadaScan sensor is Frequency Modulation Continuous Wave (FMCW) mono-pulse radar. Internal filtering circuits provide immunity to nearby transmitters. To overcome target detection problems in cluttered offshore environment sensor works with multiple transponders. Rotating parabolic scanner and radar digital signal processing hardware are placed inside protective dome. Transponders are retro-reflecting reflectors and they don't amplify any signal. Received signal is reflected back and the same time transponder flips polarisation of reflection 90° while imparting target identification code. This coding method eliminates most of the background clutter typical for marine radar. Battery power is needed only for electronics imparting target code which allows battery replacement once in two years only. This specific mode of operation is often termed as passive transponders. RadaScan outputs work in both RS422 and Ethernet standards to match communication systems of older and new DP systems. Sensor and operator interface are pictured below:

Fig. 4. RadaScan sensor and operator interface [4]

2.4. Laser reference

For time being they are two laser reference systems used in DP operations. Older of them is called Fanbeam and its fifth is still manufactured by Renishaw. Newer laser system with better performance named CyScan is made by Marine Technologies and shares with RadaScan the same intuitive user interface. View of CyScan laser sensor is presented below:

Fig. 5. Cyscan laser sensor with revolving head [4]

Sensor is based on pulsated (30 kHz) laser diode operating at 904 nm and classified eye safe to Class 1 IEC 60825. With angular resolution 0.012°and range resolution 8.5 mm system overall position accuracy is better than 0.5% of range. Self-levelling platform enable targets tracking at -20° to +20° vessel's roll and pitch. Optical filters are protecting detector from low sun rays and offshore installations flood lights. Targets are made up as flat surface covered with light reflective tape for short range operations or glass prism clusters for long range. Signal processing algorithm rejects false targets e.g. crew wearing reflective bands on their coveralls. System resolved many problems troubling its predecessor. Ability to track of multiple targets, maximum five, allows for uninterrupted operation when target is out of line of sight. Laser systems are suffering from poor performance during heavy precipitations and fog. Sensor is fitted with 2 x RS422 communication ports and 2 x Fast Ethernet 100 base-T connections. Transmission protocols are supporting data transfer used by majority of DP systems in use today.

2.5. DGNSS reference

Differential Global Navigation Satellite Systems (DGNSS) have special place among offshore reference systems. Today most of offshore DP vessels carry 2 DGNSS receivers to provide fallback in case of equipment failure. Satellite navigation became primary source of position reference for DO and offshore survey operations. Position accuracy required for offshore operations is 0.1m. Two competing manufactures Fugro and Veripos are providing advanced GNSS receivers capable to fulfil such requirement. Position high accuracy is secured by use of services available from above mentioned organizations and available by subscription. Corrections are broadcasted from geostationary satellites in L-Band. Several types of services are offered with different levels of accuracy and costs of subscription. For local applications UHF telemetry can be used with reference station placed at offshore installation. External antenna and receiver are needed for reception corrections broadcasted by International Associations of Lighthouse Authorities (IALA) in MF-Band. Another option used in some offshore is broadcasting of Pseudo-Range Corrections (PRC) in HF-Band. New generation of offshore DGNSS receivers work with all systems available for non-military users. They are built with 220 parallel channels and work in dual frequency mode if available for particular satellite system. Time delay and carrier phase measurements are used for pseudo-range determination. Receiver's hardware is capable to work with all existing satellite navigation systems but equipment generally leaves factory with software for processing GPS and Glonass signals. Other systems can be added by simple software upgrade in the field when such need arises.. Corrections from subscribed services are also provided through Internet and use low orbit Iridium OpenPort communication system allows for full polar coverage. High accuracy subscription services are used only when vessel performs her duties in worksite. Subscription is terminated upon work completion and system switches to corrections available Satellite Based Augmentation Systems (SBAS) which is less accurate but free of charge. Data from SBAS are also used as backup. Data inputs/outputs of Fugro 9205 GNSS receiver are shown below:

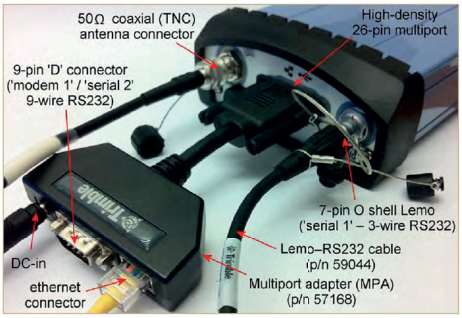

Fig. 6. Fugro 9205 GNSS receiver data inputs/outputs [2]

Receiver use only RS232 outputs for export of position data. Ethernet connector is for connection to local network or directly to external computer for configuration purposes and corrections received from Internet. Receiver has also Bluetooth wireless connection but is used solely for service purposes, not for communication with other equipment.

3. Data transfer standards for reference systems

First reference systems were working with analogue PID regulators and their outputs were designed to drive current loop 20mA or provided voltage proportional to measured value. With digital technology first serial transmission technical standard was RS232 was introduced. Unbalanced signal transmission allowed for slow data transfer at limited cable length. Most popular was 3-wire configuration for simplex or semi-duplex transmission for its simplicity and being less susceptible for interferences than full-duplex 9-wire system. Faster and longer range communication called for standard RS422 with balanced signal transmission. National Marine Electronic Association (NMEA) came with data format based on American Standard Code for Information Interchange (ASCII). Format for serial data transfer was termed NMEA 0183. NMEA published set standard sequences, called also strings, for navigational equipment but manufactures were allowed to use also their proprietary sentences. International Electro technical Commission adopted this standard and published its own as IEC 61162-1. High speed NMEA 0183 standard was adopted as IEC 61162-2. In year 2001 NMEA published new standard NMEA 2000 based on Controller Area Network (CAN), technology developed by Bosch for automotive industry. It was internationally standardized as IEC 61162-3. Years of work on shipboard networks resulted in 2011 in new standard IEC 61-162-450 Lightweight Ethernet (LWE) primarily intended for navigation and radio communication equipment. LWE uses standard strings first published in NMEA 0183 standard. Ethernet standard 10base-T is used mainly for external equipment configuration and corrections transfer to DGNSS receivers. Data transfer from reference systems to DP processor needs faster medium like 100base-TX Fast Ethernet. Some equipment has Bluetooth wireless communication and USB ports. These standards are used solely for service purposes, not for communication with other equipment.

4. Conclusion

Systems and protocols of data transfer in offshore reference systems evolved parallel to changing international standards and recent development is use of Ethernet to build ship internal networks for integration of equipment used for navigation and DP operations. Some manufactures have begun to use fibre optic technology for instruments internal communication to improve large data flow required for operation of new generations of highly sophisticated equipment.

Bibliography

[1] ALSTOM Power Conversion Ltd., DP Guide, Paris 2000.
[2] Fugro, 9205 GNSS User Guide, Skoyen 2013.
[3] http://www.km.kongsberg.com [date of access: 14.10.2015].
[4] http://www.marine-technologies.com [date of access: 14.10.2015].
[5] http://www.shipseducation.com [date of access: 14.10.2015].