Web-Based Integrated Precise Positioning System Design and Testing for Moving Platforms in Offshore Surveying

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SUMMARY

Positions of points which are decided to drill exploration and development wells are defined after some feasibility studies in petroleum exploration activities carried out in offshore sea areas. For the wells that are planned to drill or to develop in the offshore sea areas, petroleum platforms (in shallow sea: jack-up platforms, in deep/ultra deep sea: semi-submersible, and in deep sea/ultra deep: drillship) must be transported from another well location that was drilled before or from a port to new well location whose coordinates are predefined. Carrying this platform (called Rig Moving) to this location by its own engine or by trailer vehicles (or tug boats or submersible barges) and locating the axis direction of the drilling rig of the platform to predefined well place inside of limits precisely are very important parts of whole study. Moreover, this platform must be oriented according to a predefined bearing. Equipments used in exploration activities which are carried out in offshore sea areas are very expensive. While cost of a well drilled in shallow offshore is a few ten million dollars, of which drilled in deep/ultra deep offshore is generally a number of hundred million dollars. Thus, even a small deviation from the planned route of the platform may delay whole study and cause extra costs. Also, because of the movements of semi-submersible or drillship platform that is conveyed to planned well location, if the axis of the drilling rig pass over the security circle limits (caused by environmental conditions, such as, waves, winds, currents, weather or other conditions, such as, excessive thrusters force of the power engine, erroneous real time positioning data etc.) the equipments may be injured and this situation may prevent whole study proceed. Correct real-time/DGNSS positioning (dynamic positioning) data is necessary in order to limit these movements in defined limits.

In the scope of this study, it is targeted to develop a tool, equipment and a web-based software system that provides integration of positioning systems and prevents production of erroneous or inadequate real-time/DGNSS positioning data in order to navigate a petroleum platform while it transports between two locations and to track it dynamically where they are precisely positioned. Moreover with the support of web-based implementation of the system designed will provide online remotely monitoring availability for the moving platform activities in offshore.

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Before drilling wells in offshore areas, there are some activities which have to be carried out. The final positions of wells are determined according to these studies. First of all, obtaining exploration rights of a block in mentioned offshore area is necessary. Some of these activities which are intended to understand the geology and hydrocarbon systems in the offshore areas are basin analysis, gravity-magnetic data acquisition, 2D-3D seismic surveys, preparing bathymetry maps, exploring activities in sea bottom's structure etc. After such preliminary studies, all of the data are analysed and interpreted. Finally, it is decided where the well will be drilled. In addition, in some cases, re-positioning is necessary to develop a well which was positioned and drilled before. It may be required to carry out directional drilling from the previously drilled well head as well. According to the drilling aim, the heading angle is determined. Intended final well coordinates may be in local datum or they may be based on global datum. Whatever the aim is, there is a requirement: positioning of the offshore platform.

1. TYPES of OFFSHORE PLATFORMS

Since the first *jackup* was built in 1954, jackups have become the most popular type of Mobile Offshore Drilling Unit (MODU) for offshore exploration and development purposes (Fig.1). One of two types of bottom-supported MODUs (the other being the much less popular submersible rig), jackup rigs rest on the sea floor rather than float. The premise of a jackup rig is that it is self-elevating; here, the legs are stationed on ocean floor and the drilling equipment is jacked up above the water's surface. Providing a very stable drilling environment, in comparison to other types of offshore drilling rigs, jackups can drill in waters up to 350 feet deep. Once drilling is required in waters that are deeper than the capabilities of a jackup, semisubmersibles and drillships become a more logical choice for exploration and development operations. When their legs are not deployed, jackups float, which makes these types of MODUs quite easily transported from one drilling location to another. While some are capable of self-propulsion and do not need an outside source for movement, most jackups are transported via tug boats or submersible barges. While towing is easily performed, barges are the transportation of choice when the jackup needs to be moved quickly or over a longer distance. Once the jackup is on location, the legs are lowered to the ocean's floor and the rig hull and drilling equipment is elevated well above the water's surface and away from any potential waves (URL3, 2010). After finishing its work, a jackup sits on the sea surface and takes its legs up and gets off to the next location.

Fig 1: Jack-up platform

Originally conceived as a bottom-supported drilling unit, *semisubmersibles (semisubs)* eventually found their true calling (Fig 2). Now, semisubs are the most stable of any floating rig, many times chosen for harsh conditions because of their ability to withstand rough waters. A semisubmersible is a MODU designed with a platform-type deck that contains drilling equipment and other machinery supported by pontoon-type columns that are submerged into the water.

Fig 2: Semisub (Leiv Eiriksson), (URL2, 2010)

Another type of drilling rig that can drill in ultra-deepwaters, *drillships* are capable of holding more equipment; but semisubmersibles are chosen for their stability. The design concept of partially submerging the rig lessens both rolling and pitching on semisubs. While in transit, semisubs are not lowered into the water. Only during drilling operations are semisubs partially submerged. Because semisubs can float on the top of the water, transporting these rigs from location to location is made easier. Some semisubs are transported via outside vessels, such as tugs or barges, and some have their own propulsion method for transport. Based on the way the rig is submerged in the water, there are two main types of semisubmersibles: bottle-type semisubs and column-stabilized semisubs. Mooring lines are then used to keep the semisub in place, and these anchors are the only connection the rig has with the sea floor. As a semisub, the rig offered exceptional stability for drilling operations, and rolling and pitching from waves and wind was great diminished. In addition to occasional weather threats, such as storms, cyclones or hurricanes, some drilling locations are always harsh with constant rough waters. Being able to drill in deeper and rougher waters, semisubs opened up a new avenue for exploration and development operations (URL3, 2010).

Fig 3: Drillship (Deepwater Millenium), (URL1, 2010)

Truly what it sounds like, a *drillship* is a marine vessel that's been modified to drill oil and gas wells (Fig 3). While drill ships look similar to a tanker or cargo vessel, there are a couple of major differences. Drill ships are equipped with a drilling derrick and moon pool. Additionally, drill ships have extensive mooring or positioning equipment, as well as a helipad to receive supplies and transport staff. Typically employed in deep and ultra-deep waters, drill ships work in water depths ranging from 2000 to more than 10000 feet (610 to 3048 meters). Drilling equipment is passed through the vessel's moon pool and connected to the well equipment below via riser pipe, a somewhat flexible pipe that extends from the top of the subsea well to the bottom of the drillship. Drill ships are differentiated from other offshore drilling units by their easy mobility. While semisubmersible rigs can also drill in deep waters, drillships are able to propel themselves from well to well and location to location, unlike semisubs, which must rely on an outside transport vessel to transfer them from place to place. While capable of drilling in deep and ultra-deep waters, a disadvantage to using a drill ship is its susceptibility to being agitated by waves, wind and currents. This is especially troublesome when the vessel is actually drilling, because the drillship is connected to equipment thousands of feet under the sea. A proper mooring system on a drill ship is integral to drilling successful wells. In shallower waters, drillships are moored to the seafloor with anywhere from 6 to twelve anchors. Once the water depth becomes too deep, drillships depend on Dynamic Positioning Systems (DPS) to keep the vessel in place while drilling. DPS relies on several thrusters located on the fore, aft and mid sections of the ship, which are activated by an onboard computer that constantly monitors winds and waves to adjust the thrusters to compensate for these changes. Sometimes, both positioning systems are used (URL3, 2010).

There are some other types of platforms, such as, Drill Barge, Inland Barge, Platform Rig, Submersible and Tender, and these kinds of platforms are used in some different operations and environments.

2. STATISTICAL INFORMATION

By the time 2010, there are 1246 offshore platforms in the world and 825 of these platforms consist of most used 3 types addressed above (Table 1). 506 of the total number of these three types have been carrying out the exploration and development projects offshore in the any area of all over the world.

Table 1: Statistical Information about offshore platforms (URL3, 2010)

RIGTYPE	RIGS CONTRACTED (Number of rigs)	RIG FLEET (Number of rigs)	UTILIZATION (%)
Jackup	310	514	60.3
Semisub	153	226	67.7
Drillship	43	85	50.6
Sum of Major Three Types	**506**	**825**	**61.3**
Others	227	421	53.9
General	**733**	**1246**	**58.8**

3. POSITIONING of DRILL RIGS

Offshore platforms which are employed to drill petroleum/natural gas exploration or development wells in offshore areas necessitate to be positioned onto the predefined well locations. There are different situations for the different kinds of platforms. For example, Jackup platforms are positioned by navigation software that uses GNSS and other sensor's data. After positioning, a jackup sits bottom of ocean and then the positioning process is finished. If we come to the semisubmersible platforms, they are positioned by similar navigation software and anchoring or dynamic positioning may be chosen to rest of the process according to the environment in which drilling operation will be carried out. Similarly, drillship offshore platforms may be positioned by navigation software and then they may be anchored or dynamically positioned with regard to the water depths, currents, winds, etc.

3.1 Positioning with Navigation Software

When we talk about positioning of the offshore drilling platforms, there are primary and secondary or more GNSS receiver antennas which are set up some suitable positions on the platforms and one gyro equipment which is established fore-aft line to measure heading angles. These antennas are connected to receivers and real time data which come from global positioning satellites are transferred into the navigation software. Navigation software uses real time GNSS positioning and heading information to calculate the coordinates of rotary (drilling equipment's axis) and headings near real time. This process lasts until the platform reaches the targeted position which is inside of the positioning tolerance circle. When the axis of the drilling equipment gets into the targeted circle, legs of jackup rigs are lowered to the bottom of the ocean till leg penetration is completed. After completion, a final check is carried out and if the rotary point is still inside of the positioning tolerance circle, positioning process is finished and demobilisation of the equipment takes place. When positioning of other kinds of offshore platforms is carried out similar processes are valid. Hereafter difference arises for the submersibles and drillships and other kinds of platforms. Anchoring with 6-12 anchors the platform may be applied or dynamic positioning may be put into use in order to keep the rotary point inside of the positioning tolerance circle.

3.2 Dynamic positioning

The winds and waves of the ocean can wreck havoc on offshore oil and gas operations. Whether a drillship is conducting drilling operations or an FPSO (Floating Production Storage and Offloading vessels) is serving as the development's production facility, offshore vessels must stay on position despite changes in the wind, waves and currents (Fig 4).

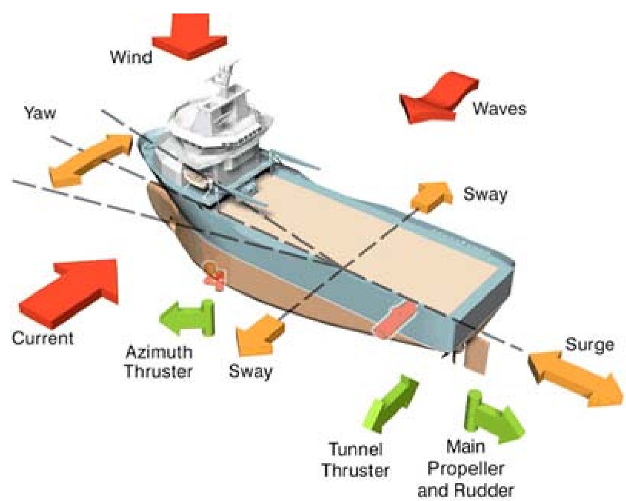

Fig 4: Forces Working on the Vessel, (URL3, 2010)

While offshore drilling in shallower waters allows a jackup to position itself on the sea floor above the location, drilling in deepwaters requires the rig, whether a semisub or a drillship, to float above the location. Taking into account that drilling equipment must sometimes span thousands of feet of water before even reaching the ocean floor, slight movements above the water's surface can have drastic effects on the drilling operations. Additionally, some offshore developments require floating facilities. FPSOs and semisubmersible production facilities are positioned above the subsea development, housing production equipment and other machinery. Multiple risers connect the development below the water to the facilities above it. If the wind and waves knock the facilities off-track, the development would have to stop production and undergo extensive repairs. Keeping floating equipment in position, whether performing drilling or production operations, is an important logistical aspect of the overall procedures. While drilling and production risers are somewhat flexible to provide for limited movements caused by the ocean currents, too much movement can break them and cause drilling or production to cease, as well as costly require repairs. Like boats, floating facilities can be anchored to the ocean floor. According to the environment and the shape of the vessel, there are myriad ways to moor a vessel, which involves strategically anchoring the vessel by a number of lines to the ocean floor. Most recently, dynamic positioning has offered a more stable way to ensure that the vessel stays in position.

Dynamic positioning requires the vessel to have a number of thrusters, or powered propellers, throughout the vessel. These thrusters are located on the front and back, as well as both sides of the vessel, in order to maintain position from every direction. A computerized system automatically employs the thrusters when it is necessary. Information about the position of the vessel is communicated from special sensors on the ocean floor. Additionally, satellite communications and weather and wind information is transmitted to the computer system, further helping it control the movements of the vessel. Using the information provided to it, the computer automatically engages the thrusters to overcome any changes in the location of the vessel. Sometimes mooring and dynamic positioning are used together to keep the vessel on position. Additionally, with a dynamic positioning system, these vessels many times can stop operations and move out of the way of threatening storms, such as hurricanes and cyclones, further strengthening the safety of the offshore development (URL3, 2010).

There are several rules to flow up for dynamic positioning in offshore surveying. However these rules is not given in this paper for page limitation. Readers who are interested in about these rules and regulations can look over (IMO, 1994), (IMCA, 1997) and (IMCA, 2007).

4. WEB-BASED INTEGRATED POSITIONING SYSTEM DESIGN and TESTING

Today, generally petrol platforms are moving from one location to another location by the aid of both temporally mounted DGPS/DGNSS receivers and gyro technologies on platforms. Measurements received from these technologies are separately used. Commonly they are used as primary and secondary systems rather than combining these measurements in a processing system. (Celik, 1996) Since positioning accuracy provided by DGPS/DGNSS technologies are generally sufficient for such applications in practical case. There are mainly two DGPS/DGNSS receivers are used for modelling both positioning and the heading of the platforms.

The independence between the two DGPS receivers is the fundamental condition for using two DGPS inputs in general positioning applications in offshore. One differential link should not be used by more than one DGPS at one time. There may be other latent causes that could impair the independence between two DGPS receivers in the future. For example, software failure and/or human failure, possible external causes, such as available satellites, atmospheric disturbances, shadow zone near platforms, may also affect two DGPS receivers antenna simultaneously. After all, two DGPS receivers may not be kept as independent as two position reference systems based on different principles. If the two DGPS systems are both based on global positioning system (GPS), both DGPS receivers correct functioning will depend on the external GPS satellite conditions. Use of GPS and other satellite system such as GLONASS, GALILEO, etc. this combined DGNSS system could increase the available positioning satellites, and hence reduces the system's dependence on the GPS satellite conditions. This may also bring the advantage of different hardware and software in the two DGPS receivers in order to maintain the independence. (Chen et al., 2007)

Thanks to informatics technologies, web application based on spatial information are getting very popular and beneficial for many different kind of dynamic applications such as navigation, monitoring, fleet management and etc. Web based applications in marine circle are also very hot and popular and hence very beneficial since it allows people/users reaching and monitoring even dynamic information online. This provides very efficient and helpful advantages in any offshore applications.

Turkey is the country whose geography located as a bridge in between Europe and Asia. It is a very large semi island country. There is also a large inner sea, so-called Marmara Sea, in the country that is connected with Aegean Sea and Black Sea with both İstanbul and Çanakkale Bosporus. Even though, marine activities are not very efficient and well developed in the country. This might be, due to political concentration of the governments so far. However it slowly changes and national politics are now focusing marine activities much wishful then the past. The topic of the design project that is explained here for positioning moving petrol platforms is a PhD study. It is supported by both Turkish Republic Ministry of Industry and Trade and Leica - System Computer and Technical Services Inc. By this project a web based platform positioning system is designed and testing. Currently there is no such service in the country for positioning petrol platforms or checking position of a platform already positioned. When this project is completed it is going to be the national alternatives for solving such positioning, monitoring, inspection and etc. problems.

Figure 5 shows the general design view of the system. As is seen from the figure there are three GPS/GNSS receivers that are cable of running as differential, real-time or in both mode.

Additionally there is one gyro. All of these are used for navigation and precise positioning purposes at the platform. There is also one processing and display unit that receives and then displays the results of all positioning and heading information received from these sensors in real-time. Positioning and heading information received from these sensors are integrated within an algorithm based on least square theory. Integrated results achieved are displayed as the positioning out put of the rotary and the heading of the platform rather than positions provided by one system that is dedicated as primary one. Therefore if any of the sensors fails, its measurements is going to be taken in to account as outliers and positions are computed with remaining measurements rather than replacing the secondary system with the primary one. The advantage of designing this system, in this way is that benefiting all sensors measurements to increase the redundancy and reliability of the positioning system and hence having more accurate, reliable and better quality statistical positioning results of the rotary of the platform.

In affect two DGPS/DGNSS receivers are sufficient for positioning and rotating the platform. Third receiver, as is mentioned, is used for redundancy and reliability. Additionally heading measurements received from gyro and derived from DGPS/DGNSS positioning are also taken into account to increase the redundancy. More on to that third receiver are also considered for attitude determination of the platform. However attitude determination is not the focusing topic of this paper. When GPS/GNSS system running in differential mode, differential corrections received from either differential data provider or a GPS/GNSS reference station or national Continuously Operating Reference Station (CORS) network. When real-time mode is considered GPS/GNSS reference station data is provided by either especially dedicated reference station at shore or CORS network. In any case GPS/GNSS positioning data and gyro data of individual sensors are transferred in NMEA format to processing unit for further process and analysis.

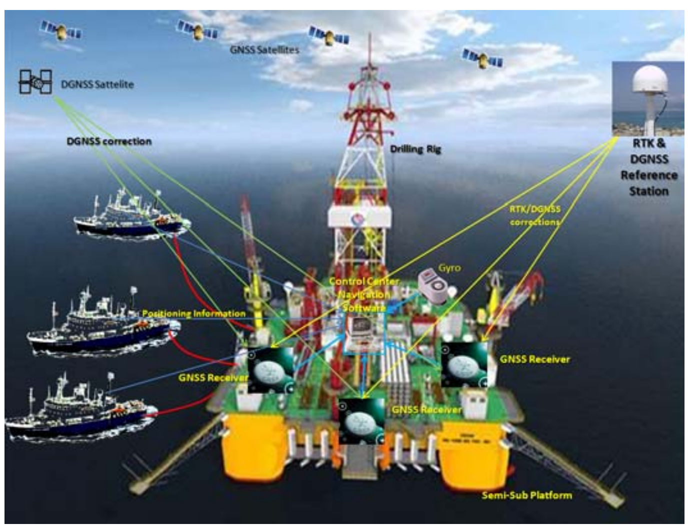

Fig 5: Integrated system design

When semi-sub platform is concerned platform need at least three outside transport vessel for moving towards and anchoring at drilling location. This is also another navigation problem to be solved for since these vessels must be well conduct during moving and anchoring. Therefore their spatial information must be known in real-time. In order to solve for this problem SISNav is considered. SISNav is a software developed in J2ME platform for mobile devices by a team supported by System Computer and Technical Services Inc. SISNav can be run more than 200 different mobile deceives that have mainly java and Bluetooth specifications. SISNav is developed for personal and vehicle navigation at first step. However its developing platform and infrastructure is suitable for any kind of navigation application. It has been developed for such purposes. SISNav is able to use either internal or external DGPS/DGNSS receiver via cable or Bluetooth technology. Based on device specifications, SISNav is capable of transferring navigation data via Wi-Fi, GPRS, Bluetooth, SMS etc. in NMEA or special format (Çelik et al, 2006). Therefore having outside transport vessels positions are determined by SISNav, it is then transferred to platform processing unit for the information of the tow master for easy conducting of platform navigation and anchoring.

All navigation data, platforms outside transport vessel and etc., are displayed in the processing unit at the platform for precise navigation, positioning and efficient conducting. However thanks to internet technology a new demand is come out to remotely monitor the platform and vessel positions during navigation and anchoring by the contractor or business owner. In that case new positioning system should also provide online access via internet to platform operation. This is also a good advantage for taking care of emergency cases and security. The system designed and developed is also providing this facility for the users, since it has been developed server based technology.

Test of the system is considered as in both laboratory and real petrol platform. Developed components of the system have been successfully tested in the laboratory environment. For instance positioning data are successfully received from the receiver and post it to the internet environment. Thereafter posted positioning data listened and captured via internet and remotely displayed in several different computer connected to internet. However, real case testing stage has not been achieved yet. Real case testing is in the stage of agreement with one of the platform user. When agreement is done, it is expected to be realized next October. Experience gained from the real case testing will be shared on the following paper about the project.

5. CONCLUSIONS

Turkey is encircled from three sides by three seas and it also has an inner sea. Recently, there has been increasing activities in petroleum and natural gas exploration. Especially in last ten years, in Black Sea, there have been intensive studies carried out in order to explore hydrocarbon which is estimated to be under the sea bottom. In the next future, it is easily predicted that these studies will continue incrementally. Accordingly, platforms will be used to drill shallow or deep/ultra deep sea wells and these platforms will be positioned via positioning systems. As is mentioned there is currently no such national service in the country for positioning petrol platforms or even checking position of a platform already positioned. Therefore, when this project is completed by all means, it is going to be the national alternatives for solving such positioning, monitoring, inspection and etc. problems in offshore applications. Further developments and results of the project will be shared following publications.

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He is an active member of Turkish Chamber of Surveying and Cadastre Engineers. Three times he was taken the position in the executive board of the Chamber in Istanbul. In between 2000 and 2002 he was in the position of president of the executive board of the Chamber. He actively remains supporting chambers activities and taken position as a string head or a member in the technical commissions, like Earthquakes and Natural Hazards Commission, Geographic Information System Commission, Education Commission and, National Regulation Preparation Commission for Large Scale Map and Map Information Production, etc. He used to be the representative of the Chamber in European Group of Surveyors (EGoS). He is currently the Vice President of EGoS. He is the founder member of Spatial Information Initiative Association of Turkey. He used to be the president of the Association and he is currently the board member of the Association. Moreover He is the founder member and also the board member of Association for Geospatial Information in South-East Europe.

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