OFFSHORE POSITIONING METHODS IN ENGINEERING APPLICATIONS
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ABSTRACT

Marine civil engineering projects in India are in a stage of a major upsurge due to the large oil finds on the continental shelf, improvements and developments of coastal loading/unloading and port facilities. These projects vary in distance from the nearest land from near-coastal to far-offshore, viz., 150-250 km. Accurate position fixing for these jobs requires optical (visual), radio-nav and underwater acoustic systems. Selection of an optimum method is made considering the specific job requirements and for the economics. The important criteria for the adoption of a particular system normally are the range and accuracy required, repeatability, duration and frequency of operations, number of users, climatic conditions and the coastal terrain, etc. The deciding economic factors are the costs towards mobilisation/demobilisation, geodetic surveys, equipment costs or rentals, operating and maintenance costs, etc.

A study of these factors and an approach to selection of the most advantageous systems in varying Indian conditions, has been dealt in light of EIL's experience through several projects.

INTRODUCTION

It may sound a little too presumptuous, but the present surge in marine activity both in terms of our attempts to explore and exploit offshore oil resources and the national defence build-up remains unprecedented in the history of our nation. Within the last three years or so, the country has added a self-propelled jack-up drilling unit, a geophysical vessel, an oceanographic research vessel and two offshore supply vessels to its permanent assets. Five other drilling rigs and about a dozen supply vessels are working off our coasts on different charter terms. In addition, considerable oceanographic instruments including a few shallow seismic profilers, in situ current meters, wave riders and underwater acoustic releases have been procured all in the last 3 years only. The effort is in a continuous process of augmentation by more crafts for drilling, supplies, and installation of pipeline terminals and fixed platforms. To perform a job on the sea, next to the requirements of a suitable platform is the need to know one's position and the ability to return to the same position for future works.

SCOPE AND REQUIREMENTS

A look at the projects at hand and the potential works to come in near future indicates that from the viewpoint of position fixing, these works would fall in five probable different categories:

Coastal or port and harbour development works — within couple of kilometres of the shore or the indentations in the coastline, requiring development of harbours, backwaters, harbour crossings, bridges etc.

Nearshore — up to 15-20 km, terminals either in the shape of offshore islands, SBMs or jetties, connecting pipelines or other conveyor systems, directly linked up with VLCCs.

Intermediate offshore — 25 to 80 km; the works in this category seem to be small except for the Gulf of Kutch navigation channel or when the oil exploration in Gulf of Cambay is revived.

Main continental shelf — between 80 km and 200 km on the northwest shelf and somewhat similar on the northern Bay of Bengal shelf, Palk Strait etc., to include programmes of Reading & Bates, ONGC, Natomas, Asamera groups of oil explorers.

Outer continental shelf and slope — The OCS project is just taking off, the seismic surveys have almost been completed.
Apparently all these kind of jobs would require different kinds of positioning systems, with the desired operational criteria and optimum investments (Thomson, I. and J. B. Brewner, 1968).

Where the operations justify larger investments, the choice of an operator to select the requisite positioning method becomes a somewhat less difficult exercise. However, during the initial surveys, especially if they happen to be of a smaller magnitude, e.g., environmental oceanographic or certain seabed surveys, the decision to employ the requisite system becomes very difficult especially if it happens to be expensive and involves foreign currencies.

For example, it may be an easier task to convince an operator to spend $1000 per day on positioning if a ship hired at $5,000 a day is conducting continuous operations. However, deploying the same positioning system to conduct a few preliminary surveys may cost more for the chain than for the operations and be a difficult sellable idea.

In our conditions, therefore, many a situation puts an Indian engineer in a tight corner to stretch the available means, sometimes beyond their limit with a fair amount of success.

The kind of jobs in which an engineering company is normally involved and their position requirements are presented here (Gaskell, T. F. and K. V. Blaiklock, 1974).

(i) Location survey — These surveys are essential for almost all offshore projects to obtain such data as (a) Depth of water; (b) Side-scan sonar search for microtopographic variations and obstructions such as pipelines, ship-wrecks, etc; (c) Shallow-penetration high-resolution seismic profiling for initial stratigraphy and information on leg penetration and anchor holding; (d) Diving search for specific information on seabed morphology and presence of obstructions, required for insurance coverage also; (e) Core samples, especially for platform construction; and (f) Magnetometer searches for cables, pipelines, etc.

(ii) Rig Positioning and final fix — Presently, all three types of drilling rigs, i.e., jack-ups, semisubmersibles and drillships are being employed in the Bombay High area. To commence drilling on the site selected from geophysical survey results, the rigs are being positioned using the Shoran chain.

A buoy pattern is laid to make the anchor positions or the location of the rig. The final location is determined indirectly by making a few passes alongside the rig and determining the derrick’s position with respect to the antenna on positioning ship.

(iii) Pipeline route surveys and pipelaying—These operations require several surveys to be carried out in great detail along a narrow corridor which may be many kilometres long. The surveys may even take months to complete, e.g., when the oil is to be brought from Bombay High to shore in large quantities, it would be necessary to investigate a few alternative routes running over 100’s of kilometres in order to avoid rock outcrops and delineate the most feasible route.

A problem encountered during the pipelaying operations is the re-radiation effect from the various heavy lift cranes towering over everything when in use.

(iv) Platform positioning — With the production phases now on in the Bombay High area, and likely to come up in other areas in near future, fixed platforms, floating terminals, etc. will have to be positioned relative to each other with far greater precision than that is available with the long-range positioning method in use. These could be carried out by using visual or VHF positioning systems.

(v) Port and harbour surveys — Accurate positioning is required for the alignment and construction of breakwaters, and pre-dredging and postdredging surveys. Although the usage of optical aids has been customary, nevertheless, radiopositioning chains, e.g., Toran, HiFix and SeaFix have been successfully employed in India for dredging operation.

(vi) Oceanographic investigations — Surveys conducted for collecting wave and current information and on physical and
chemical characteristics of seawater do not require very high accuracy of position fixing except when sensors are left underwater for in-situ recordings. Such surveys, if conducted in isolation, do present problem of position fixing on account of economics of operation.

SYSTEM OF SELECTION

At various places, tables showing the different systems available, the usable range, the accuracies attainable, etc. are given (Hastings, C.E. and A.L. Comstock, 1969; Ingham, A.E. 1975; Powell, C. 1973; William Marchal, A. and R.L. Longton, 1972). However for us that is the starting point.

In order to make a wise selection, an explorer must know something about:

(a) How the position fixing information is obtained?
(b) How accuracies are predicted?
(c) Where to start his selection for a system?
(d) How much will it cost him for the direct system operation, or, the indirect mob/demob etc.

(i) Position fixing—In the broadest terms, all position fixing systems have one thing in common, i.e., they must provide two or more position lines which intersect at an angle of sufficient magnitude, such that a possible displacement of one or both lines does not result in an intolerable error. These systems are azimuthal, or ranges, or a combination of the two.

These lines can be obtained by visual (optical) methods over short ranges and by radio-electric methods over long ranges.

Whereas we do not intend to describe the methods to produce position lines, we may say that all hyperbolic and two-range systems use one of the two approaches:
(a) pulse-time measuring technique; (b) continuous-wave phase comparison technique. (Only few systems use both, e.g., LORAN-C.)

(ii) Accuracy — One prime factor with which the explorer is concerned with is accuracy of the errors. These can be broken down into two:

(a) Systematic errors remain constant in value and sign. These may be due to incorrect alignment of equipment, incorrect assumption of propagation velocities, or in the case of short-range systems, the use of an incorrect index of refraction.

(b) Random errors arise due to such causes, as short-term changes in the equipment being used, changes in ionospheric conditions, reading errors, etc.

Normally, these random errors are quoted as reference is made to the accuracy. And these are the errors that affect the repeatability accuracy, i.e., the accuracy with which the operator can return to a previously occupied position.

Random errors are usually expressed as root mean square value representing approximately the 65% probability value, i.e., 65% of observations taken would fall within a circle of radius equal to that value and centered at the point of observation. A circle of twice that radius would contain about 95% of all fixes taken.

In hyperbolic systems, this accuracy is given in terms of hundredths of a lane. In which case we must determine the width of a lane and the direction of the hyperbolae at the point of question.

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\text{lane width (in m)} = \frac{\text{speed of propagation in km/sec}}{2 \times \text{comparison frequency in kHz}} \times \frac{\text{Angle subtended by base systems}}{2}
\]

Hyperbolic vs. Range-range systems

(i) The latter offers a much larger area of high accuracy coverage, disadvantages: saturalty of users.

(ii) Hyperbolic systems offer unlimited number of users, with sacrifice of accuracy. Preparation of lattice is little more complicated, and maintenance of atleast 3 shore stations is required as compared to 2 in former case.

RANGE

Apart from knowing the ranges required during the operation; it is important to know how the range is quoted by the supplier? Is it from the farthest station or
from the baseline, in hyperbolic configuration or in range-range etc.? The range of any radio positioning system as supplied by the manufacturer is also influenced by (a) the media over which the signals travel, (b) the siting of the stations, and (c) ambient atmospheric and man-made noises.

As such, fresh water presents poor signal path. Similarly land-water interfaces and travel over land also need to be kept at the minimum while considering siting of station.

At the present day it is not uncommon to obtain excess ranges over seawater surface than those specified by the suppliers. However, in case of VHF systems, or other line of sight systems, nothing but an increase in effective height of antenna will help increase the range.

SCHEDULE

Both in visual and radio aids, we find that scheduling of work in day or night, can usually result in effectively using the system to its maximum possible range.

It is known that a medium frequency system operating in the upper limits is more susceptible to night-time sky wave interference than a system in the lower limits.

Thus, if the work is to be carried out during night time also, as usually is, an expensive, longer range system may be more economical. On the contrary, one may work during prime daylight period with minimum ionospheric disturbances, using the shorter range system.

Similarly in case of using shore-based theodolites due to visibility or direction of sun problems, we may concentrate certain works at night time when the visibility improves and sighting of a lighted target becomes possible for longer distances.

COSTS

Any comparative selection of a particular system will necessitate a thorough analysis of costs; and a complete cost estimate by the company should be broken down in the following manner:

- **Equipment rental** — with purchase options, if any.
- **Mobilisation costs** — which includes not only lump sum fees but also taxes or duties, shipping, installation of equipment on site including local transport and costs for special construction.

In certain remote areas, the cases are known where these costs may add up to $50,000.

- **Site survey, site selection and charting** — Sites would have to be chosen (a) to obtain the best coverage for the area and (b) for accommodation of equipment and antenna systems required by the shore stations. These sites have to be surveyed by a land survey team giving coordinates in one accepted spheroid system.

- **Preparation of lattice charts and post-plots** — The latter can be easily obtained by adding a track plotter to the system, if available, avoiding tedious continuous plotting.

- **Operating costs** — These include cost of living, accommodation for operating personnel, local travel, fuel costs etc. which when totalled can be considerable.

- **Demobilisation** — We may normally be expected to pay the rental for the personnel and equipment until they arrive to their head office, place of origin.

- **Miscellaneous costs** — Especially during customs clearances delays in local transport etc.

Having examined all the above aspects in their ideal conditions, it is possible to understand that how some of the field problems have been solved or remain to be solved.

EIL’s approach to this may be summarised as follows:

First, the range requirements of the survey area are determined, including the height of adjacent land, size of craft or shore targets, speed of the craft and conditions like fog, haze, direction of sun, etc. Then the availability of personnel, magnification factor of operational instruments are considered.
If the above factors are found to be favourable, a visual method is decided upon to be used. Examples are outcrop delineation in the Port of New Mangalore using sextants, pipeline route and terminal location surveys offshore Mangalore and off Narara Bet in Gulf of Kutch using shore-based theodolites, and lighthouse location surveys on Bobby, Gurur and Ranwara shoals in the Gulf of Kutch, etc. Ranges up to 18 km from the shore were covered by scheduling the work in the night time.

Assuming that the visual methods are to be ruled out, an electronic system will become necessary. Taking into account the accuracy requirements and the operational methods, here a consideration is made for the utilization of the “Public Service” systems, i.e., the Decca main chain. For example, to locate a soil boring craft on the Lushington shoal, whose subsoil profiles were previously shot in great details, the Decca main chain position was obtained and a location given with reference to bottom topographic features of the shoal.

If both the above are ruled out, then the obvious choice is an electronic radio-location system. A selection is made from a number of specialised systems now commercially available taking into consideration the following points:

(a) Number of users — single or multiple — If only one craft has to use the chain a range-range chain is preferred, because of greater area covered at high accuracy and comparative ease of preparation of lattice sheets.

If more than one user have to operate simultaneously a multi-user system is sought which is mostly hyperbolic. However, some range-range chains provide multi-user facility up to a limited number of users operating on slave sharing basis.

While working with ONGC, in the Bombay High a Shoran chain is used. This chain provides a great accuracy of positioning without any ambiguity of lane identification. The chain was shared by two users with partial success. However, the operation of chains remain suspended during monsoons, heavy rain and cloudy conditions.

In the Gulf of Kutch, a HiFix chain was shared with Navy for sparker surveys of Lushington shoal. But, lane identification was always a problem throughout the surveys which was solved by a few marker buoys dropped at the commencement of surveys and by comparison of seabed topography of previous surveys.

(b) Range: If the distance from farthest station is limited to radio line of sight, VHF systems are preferred as they are comparatively inexpensive and provide greater accuracy. Since the line of sight is dependant on height of antenna, an elevated location, on coast such as the top of a hill, a lighthouse, can be utilised obtaining a corresponding increase in range.

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REFERENCES


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