LOCATION AWARE MANAGEMENT AND CONTROL FOR POLLUTION PREVENTION

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ABSTRACT

This paper discusses improvement in the control systems, for overboard discharge of pollutants and other harmful substances like, oily mixtures/effluent from cargo area or slop tank of an oil tanker, processed machinery space bilge water from oil filtering system onboard all the merchant and naval ships etc. The paper presents a control scheme so as to enable the control systems, for the overboard discharge of pollutants and other harmful effluents from the ships, take location based control actions automatically. The proposed scheme applies to all kinds of pollutants and other harmful substances discharged into the sea from the merchant and naval ships. Two specific examples of oil pollution are described for brevity. In first case, the discharge of oily effluent from the cargo space and/or the slop tank of an oil tanker is considered. In second case, the discharge of processed effluent from oil filtering system onboard all kinds of ships is considered.

KEY WORDS: Location Based Control; ODMCS; Oily Water Discharge; Marine Pollution Control.
INTRODUCTION

The discharge of effluent from cargo area or the slop tank of an oil tanker into the sea is governed by international convention for marine pollution, known as MARPOL 73/78. The control system for discharge of effluent from cargo area or slop tank of oil tankers into the sea is known as Oil Discharge Monitoring and Control System (ODMCS) (McGeorge, 2007). ODMCS is an important system for discharge of oily mixtures/effluents on oil tankers. The norms for discharge of effluent from cargo area or slop tank of oil tankers are specified by MARPOL 73/78, annexure I, regulations 1, 29, 31 and 34 (IMO, 2006).

There is also a need to control the overboard discharge of machinery space bilge water from all kinds of ships. The bilge water is first processed into oil filtering system (for example, oil/water separator) before discharging into the sea. A separate control system is used for controlling the discharge of processed effluent from oil filtering system into the sea, on all ships (McGeorge, 2007). The norms for discharge of processed effluents from oil filtering system are governed by MARPOL 73/78, annexure I, regulation 15 (IMO, 2006).

The MARPOL regulations prohibit the overboard discharge of oily effluents from the shipboard in certain areas, called “special areas”. These areas are described in details in MARPOL convention adopted by International Maritime Organisation (IMO) of which a majority of countries all over the world are signatories. Also, the MARPOL regulations prohibit the discharge of oily effluents in-port i.e. within fifty nautical miles from the nearest shore (IMO, 2006). These regulations require that the control systems for the discharge of effluents from the shipboard must be location aware in order to be completely automatic (Dave 2006; Dave 2007; Dave, 2009). On detection of any or both of these conditions, the respective control system may send appropriate control command. For example, ODMCS may send a control command to close the overboard discharge valve (ODV) and a control command to open the slop tank valve (STV) when slop tank is not full.

If these regulations are violated by human error, machine error, machine fault, negligence etc., it could be considered a serious criminal offence and may lead from huge monetary penalty to imprisonment, depending on the law of the land and extent of violation (US Dept of Justice, Environmental Crime Center, 2005). This leads to serious repercussions for the authorities and the ship owner company. This also warrants complete automation and reliable warning mechanism to be built-in into the respective control systems so that any unintentional hazards may be effectively avoided.

It has been found that the human errors are normally caused because of various reasons like lack of operator understanding/training, work pressures, negligence etc. (Achuthan, 1996). A completely automatic system obviates manual operation, thereby leading to reduction of work (and related work pressure), and improvement in pollution prevention. Because existing control systems (e.g. ODMCS) are costly, it is not feasible for many educational and training institutes to use those systems for education & training purpose. Hence a low cost system is needed to provide an effective alternative to cater to the needs of education & training on these control systems.

There are many companies manufacturing ODMCS as well as control system for discharge of processed effluent from oil filtering system. At present, the control systems from these or any other manufacturers are not location aware. The discharge of oily mixtures/effluents from cargo area or slop tank of an oil tanker, as well as the processed effluent from oil filtering system, is required to be stopped/started manually, whenever the ship enters/leaves a special area, or when the ship enters/leaves an area, which is in-port.
Also, all these existing control systems do not produce any alarms when the ship enters/leaves a special area and when the ship enters/leaves an area which is in-port.

Therefore, there is a need in art for a new technology and a system which provides for; (a) detection of presence of ship in environmentally sensitive areas (as specified by MARPOL regulations), (b) to find, on a continuous basis and in real-time, if the ship is in-port, and (c) a system which is low-cost so that it is feasible for use in educational/training institutes and universities.

This paper presents a novel and low cost approach for the completely automatic alarm and control command generation for the two conditions mentioned above, that is, when the ship enters/leaves an environmentally sensitive area and when the ship enters/leaves in-port area. The system detects the occurrence of any one or both of these conditions simultaneously. The invented system uses input from Global Positioning System (GPS) (Ackroyd, 1994; NMEA, 2002) in conjunction with modified World Vector Shorelines (WVS) database (Soluri, 1990) to detect these alarm conditions, on a continuous basis and in real-time. The prototype model developed being a low cost system, proves to be a more feasible alternative for education and training of ODMCS, for example, in educational and training institutes and universities. Also, because it is software based, any location based management and control features may be added. For example, identification of Sulphur Emission Control Area (SECA) and related alarms and management, waste management etc. may be easily incorporated making the system more versatile and cost effective.

The invented system may cooperate with the installed semi-automatic control system, to make the overall system completely automatic. The invented system may also be used as the decision support system on board the ship, when the installed control system fails or is out of operation for any reasons. The availability of a powerful context sensitive help system enables, even a person with relatively lesser experience, understand the operation and application of the invented system easily.

Abbreviations Used and Definitions
This research work integrates some well-known technologies and terminologies. The following technologies and terminologies are used within this paper.

Marine Pollution (“MARPOL”) Convention — is the International Convention for the Prevention of Pollution From Ships, 1973 as modified by the Protocol of 1978. MARPOL 73/78 was designed to minimize pollution of the seas, including dumping, oil and exhaust pollution. Its stated object is: to preserve the marine environment through the complete elimination of pollution by oil and other harmful substances and the minimization of accidental discharge of such substances.

Digital Input Output Electronics (“DIOE”) — an electronic hardware system used for reading external analogue/digital signals into the computer and also for sending data from within the computer to an external hardware in analogue/digital form. This is also described as Data Acquisition Card (“DAC”) by many vendors.

Global Positioning System (“GPS”) — any one of several available technologies for determining geographic position electronically, including most prevalently use of a network of satellites in geosynchronous orbit and a receiver to pinpoint the receiver's location.
Input Output Management Module (IOMM) — the hardware which manages and controls, the input of data from sensors to the computer, and output of data/status information from computer to the external hardware devices for display on front panel.

Location Based Services ("LBS") — set of services, which are associated with and driven by the location of a device such as a wireless telephone, personal digital assistant, or other computer. LBS may use one of several available technologies to determine the geographic location of a device, including but not limited to GPS or micro-networks such as open-standard Bluetooth.

Recommended Standard-232C ("RS-232C") — a standard interface approved by the Electronic Industries Alliance (EIA) for communication of serial data between two devices.

Special Areas — In MARPOL 73/78 Annexes I, Prevention of pollution by oil, II Control of pollution by noxious liquid substances and V Prevention of pollution by garbage from ships, MARPOL defines certain sea areas as "special areas" in which, for technical reasons relating to their oceanographical and ecological condition and to their sea traffic, the adoption of special mandatory methods for the prevention of sea pollution is required. Under the Convention, these special areas are provided with a higher level of protection than other areas of the sea.

Sulphur Emission Control Areas (SECAs) — MARPOL Annex VI entered into force on 19 May 2005 and Regulations 14 and 18 define the method of controlling Sulphur Oxide (SOx) emissions on a global basis and in defined protected areas called Sulphur Emission Control Areas (SECAs).

Particularly Sensitive Sea Areas (PSSAs) — A Particularly Sensitive Sea Area (PSSA) is an area that needs special protection through action by IMO because of its significance for recognized ecological or socio-economic or scientific reasons and which may be vulnerable to damage by international maritime activities. The criteria for the identification of particularly sensitive sea areas and the criteria for the designation of special areas are not mutually exclusive. In many cases a Particularly Sensitive Sea Area may be identified within a Special Area and vice versa.

DESCRIPTION OF PROPOSED SYSTEM

Figure 1 shows the high level organisation of the system. The heart of the system is a computer, which hosts the software governing the system. The field inputs, for example the inputs from ship’s speed sensor, oil content (PPM) sensor, overboard discharge rate sensor etc are received by front panel. The selection and routing of these signals is done by software. The field input signals are selected using the IOMM. The signals undergo analogue to digital conversion and necessary signal conditioning in DIOE module from where, they are fed as input signals to computer. The position information is received by the computer from GPS/LBS receiver device. The location information from GPS/LBS receiver is sent to computer using RS-232C serial communication interface.
The mains supply feeds 220 volts AC power, to the power supply module, which produces DC power for IOMM and Front Panel. The power supply module steps down the supply voltage, converts AC to direct current (DC), performs voltage and line regulation and filters out the ripples in the output. The User Interface Devices (PC-mouse, Keyboard, VDU, Printer etc) are used to exchange information between the operator and the system.

Figure 2 shows the layout of the Front Panel, for example, for implementation of location aware ODMCS. It consists mainly of the display devices, indicating devices, field input points, selector switches, input emulator devices, and power switches.

The display devices are 16x2 liquid crystal displays (LCDs). These devices are used to display the following system parameters:
- Current position of the ship (Longitude, Latitude)
- Total Oil on Last Cargo and Total Oil Discharged Overboard
- Instantaneous Discharge Rate
- Oil Density and PPM of oil
- Ship Speed and Flow Rate

Indicating devices indicate the alarm conditions. These are light emitting diodes (LEDs). When turned ON, these LEDs indicate the following alarms and other conditions:
- Power On (+5 V)
- Instantaneous Discharge Rate exceeded 30 litres per nautical miles
- Total Overboard Discharge of Oil exceeded \((1/30000)^{th}\) of total cargo on last voyage
- Ship is stationary (not En-route)
- Ship in Special Area
- Ship less than 50 nautical miles from nearest shore
- Overboard Discharge Valve open
The system user has an option to select the inputs (for example ship speed, flow rate and PPM) either directly from the field sensors or emulated inputs from the front panel. The system has three selector switches for selecting between field inputs or emulated inputs. Field input terminals receive the inputs from the field sensors. The devices for emulating the field inputs i.e. field input emulators may be used for testing the working of the system as well as for training purpose, where it is not possible to generate the field signals.

Figure 3 shows the details of hardware layout for implementation of IOMM. IOMM is responsible for managing the process of input of field parameters for example, ship speed, flow rate and PPM, and display of parameter values on front panel along with the alarm and status indication. IOMM works at the backend of front panel.

The user may enter the values of various system parameters (as mentioned above) using the user interface devices connected to the computer. Once the system parameters are entered, the user starts the operation of the system using the graphical user interface and user interface devices. Now, the system calculates the values of instantaneous flow rate and total overboard discharge of oil using input parameters, for this example, ship speed, flow rate, PPM etc and checks for any violation of MARPOL regulations, continuously in real-time. The sampling interval of the input parameters may be set using the software. If a MARPOL
violation is detected, for example, in case of oily water discharge from cargo area or slop tank of an oil tanker, if the instantaneous flow rate exceed 30 litres per nautical miles and/or if the total overboard discharge of oil exceeds \((1/30000)\) of the total oil on last cargo, Overboard Discharge Valve (ODV) is closed and if slop tank is not full, Slop Tank Valve (STV) is opened. This control action is done automatically by all the available ODMC systems. However, as mentioned earlier, the two specific conditions, for which there is no provision for automatic event detection, alarm and control in the presently available ODMC systems, are automatically detected, appropriate alarm is raised and the necessary control action is initiated. The following examples further illustrate the operation of the system under these two special conditions.

Example 1:
Control System – ODMCS
Location Based Event - Ship entering special area

There may exist a combination of alarm conditions causing the system to respond in various different manners. For keeping the explanation simple, it is assumed that no alarm conditions existed just before entering the special area. The system responds to this condition as shown in Table 1. The internal database contains the data corresponding to each of the special areas and the control algorithm scans through all the special areas to see if the current position of the ship falls within any of the special areas. If yes, then the system sends a control command to close the ODV. Also, it sends a control command to open STV if slop tank is not full.

**Fig. 3: Input Output Management Module (IOMM)**
Table 1. Ship Entering in Special Area

startAction
When (CUR_POS in SPL_AREA) then
(SHP_IN_SPL_AREA_INDICATOR = ON) AND
(ODV = CLOSE)
When (SLOP_TANK_NOT_FULL)
(STV = OPEN)
Otherwise
(STV = CLOSE)
endWhen;
endWhen;
endAction

Example 2:
Control System – ODMCS
Location Based Event - Ship entering in-port (within 50 nautical miles from the nearest shore).

Again, for brevity, it is assumed that no alarm conditions exist just before entering this area. The system responds to this condition as shown in Table 2. The internal database contains the data corresponding to the shorelines of the entire world and the control algorithm checks if the current position of the ship falls within 50 nautical miles from any shoreline. If yes, then the system sends a control command to close the ODV. Also, it sends a control command to open STV if slop tank is not full.

Table 2. Ship entering in-port

startAction
When (SHORE_DISTANCE <= 50 ) then
(SHP_NEAR_SHORE_INDICATOR = ON)
AND (ODV = CLOSE)
When (SLOP_TANK_NOT_FULLSCREEN)
(STV = OPEN)
Otherwise
(STV = CLOSE)
endWhen;
endWhen;
endAction

RESULTS

A prototype model for completely automatic ODMCS was developed (Dave, 2010) using GPS (GARMIN, GPS-72) and WVS datasets. The photograph of developed system is shown in Figure 4. The ODMCS model was first simulated using the developed simulator (Dave, 2006; Dave, 2007) for MARPOL compliance and then verified against the manually calculated results. After verification of the simulation model, the prototype model was developed as a particular case of the proposed location based control system. The results of the developed control system are published in a separate publication (Dave, 2010).
CONCLUSIONS

The various test results are found to be complying with the MARPOL 73/78 regulations. The system offers a very low cost, user friendly and reliable alternative for providing computer-based training on working and operation of ODMCS, which may be used on-board as well as in training schools. The ODMCS simulator may also be used to test whether the installed ODMCS on-board the ship is functioning properly or not. If the proposed system is present on the shipboard, it may be configured to receive inputs in parallel with installed ODMCS. The outputs of the proposed system and the installed OCMCS may be compared periodically, for verifying the proper functioning of the installed ODMCS. The proposed system may also act as a reliable decision support tool, in case of failure of installed ODMCS. The system may be proposed as a replacement for installed ODMCS after the sea-trials of the same are completed.

Some other location-based management and control features like, waste management, automatic detection of sulphur emission control area (SECA) etc. may be easily incorporated in the system at later stages.

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