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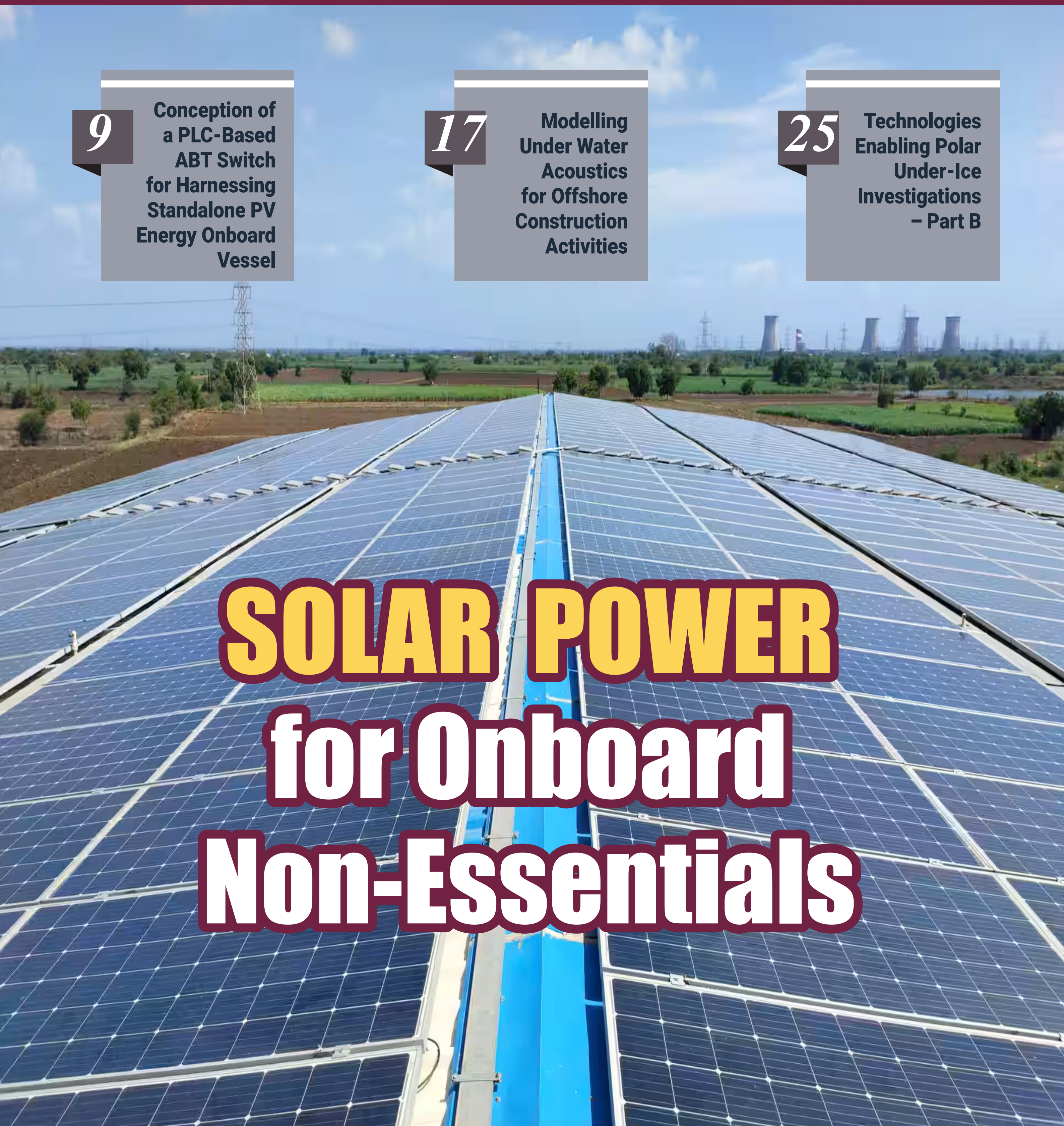

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EDITORIAL

Those who cannot remember the past are condemned to repeat it.
- George Santayana

With the vessel disasters on the western Indian shores, I was tempted to repeat that the sea finds out everything you did wrong (from the last issue of MER) and now it is being proven that air also finds out everything you did wrong.

Foundering, fire, fall from flight... we have been witnessing a passing show of disasters.

As technology progresses the scope for failures increase. It will be naïve to believe that better the technology, better is our control of the same. And as memory fades on one disaster, there is another. There is a consecutiveness. To illustrate, the foundered vessel Elsa 3 still has boxes which can open and spill the contents and fuel tanks which can leak the oils (last update: tapping plans to remove the oils have been abandoned). Calcium Carbide is another pollutant that the vessel had carried (India already has the carbide curse; remember Union Carbide and the Bhopal gas tragedy?). Disasters wait at the starting grid.

So what entails the remembering?

It is the preparedness to meet similar disasters, thereby limiting the damage. In every episode, it is this lesson... this knowledge which goes missing. Strangely so, even the conversations on these tend to stay on responsibilities, legalities etc., rather than pondering on what we must have (must have had) to mitigate.

Are we equipped to prevent life loss, pronto? Are we equipped to contain an oil/chemical spill?

And the Agencies to the rescue.. the capacity and competence of stakeholders in and out of the National Oil Spill Disaster Contingency Plan (NOS-DCP) etc., are all fields to be covered.

We must learn to build on the knowledge that the disaster has brought in and the mirror it shows us exposing the lapses.

The raging fire sighted in the waters (!) of Cuyahoga river* resulted in the Clean Water Act and formation of the Environmental Protection Agency in the USA. Though we have all the ingredients for such a phenomenal disaster (Arabian Sea burning?), it would certainly be wiser to learn, lest we are condemned to witness the repetitions.

* **Cuyahoga river** (Ohio, USA) started to burn (circa 1969) causing great economic losses due to industrial effluents being let in over prolonged period. Can there be a remembrance and course correction from this negligence?.

In this issue

We start with a technical discussion on how solar power can be used on board. Midhu Paulson and Mariamma Chacko propose a design and development of a programmable logic controller (PLC) for a solar power support. The arrangement works towards shifting the non-essential loads from the ship's main bus to solar bus. The takeaways are the description of ship's electrical architecture and the Photovoltaic (PV) power alignment and the functions of Automatic Bus Transfer (ABT) switches. Sailing marine engineers will find this interesting.

We follow with a serious discussion on underwater acoustics. Prabu Duplex takes through options for modelling UW noise in shallow waters arising from offshore construction activities. After a brief discussion on basics and approaches, various models are deliberated upon. The takeaway is on the MATLAB ActUP description. Research students will find this informative.

Dr. Vedachalam continues with the under-ice discussions. Part B talks on the importance of polar research and evolution of the under-ice observing systems of the robotic types. The discussion then turns to modern robotics under development and the ice drilling efforts. The takeaway is the discussion on the thermal part which aids drilling into the thick, cold ice. This educational piece is an easy read.

Under Technical Notes, the Jains continue with Part 3 on the merits of occupational therapists.

We also feature pointed notes on development of a floating DD. Chief Engineer Debashis Chatterjee goes into CBA and a few more details. This will be of interest to marine engineers.

MER Archives from July 1985 has an interesting read on sail assisted robotic ship trials, which has contemporary relevance today as autonomous ships are being thought of.

While enduring the pains of the fatal flight and wishing that peace returns elsewhere on earth, here is the MER July 2025 issue.

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Conception of a PLC-Based ABT Switch for Harnessing Standalone PV Energy Onboard Vessel

Midhu Paulson
Mariamma Chacko

***Abstract*:** Shipping is a major contributor to greenhouse gas emissions and air pollution. Growing awareness of the shipping industry's environmental impact, regulatory pressure from the International Maritime Organization (IMO), market demands, cost reduction needs, and advances in renewable energy technologies drive the adoption of green shipping initiatives. Achieving greener shipping may be accomplished through the use of renewable energy resources (RES), of which solar energy, a source of zero emission is a crucial component. A ship electrical power system architecture that incorporates PV energy for supplying the non-essential loads at the instant of preferential tripping has been previously proposed by the authors and has been designed and simulated using Electrical Transient Analysis Program (ETAP). This paper describes the design and development of a programmable logic controller (PLC) for the operation of ABT switches to transfer these non-essential loads from the ship's main bus to solar bus. The status of three circuit breakers connected to the non-essential loads at the main bus side are given as digital input signals and the state of charge (SOC) of the battery is given as an analog input signal to the PLC. The operating coils of the circuit breakers on PV bus side are energised through the as outputs of the PLC. Ladder logic diagram is used for PLC programming and has been simulated and verified via an online PLC simulator for various ship operating scenarios and a sample case is presented. PLCs offer internal password features for added security which prevents unauthorised operation and also require only less time to start up.

Keywords: Carbon emission, Green shipping, Ship's standalone photovoltaic power system, Programmable logic controller (PLC), Ladder diagram.

I. INTRODUCTION

Various renewable energy resources are adopted in marine vessels due to the strict regulations made by the International Maritime Organization (IMO) to reduce greenhouse gas emissions [1]. Solar energy has been used in marine vessels to meet the different energy needs of the ship, like air conditioning, living lighting system and refrigeration system [2]. Even though solar Photovoltaic (PV) energy alone cannot be used as a primary marine power source for commercial ships, vessels with enough battery capacity along with PV can significantly reduce fuel consumption and emissions [3]. Solar PV energy has been harnessed in naval engineering [4], such as; passenger ships [5, 6], cruise ships [7], survey vessels and tankers [8]. A low-voltage marine solar power system using thin panel PV technology and energy storage could provide a continuous stable power supply to a direct (DC) load on Blue Star Delos [9].

Control and automation forms an integral part in the design of solar power conversion systems. In [10], a programmable logic controller (PLC) software design for a standalone photovoltaic system, enabling the assessment of various maximum power point (MPPT) algorithms has been presented. When a Single Axis Solar Tracking System (SASTS) hardware integrated with a PLC is used [11], the PV panel harvest the greatest amount of solar energy by moving in accordance with the programmed ladder diagram. Using PLC and human machine interface (HMI) a control logic has been developed for a gravity based energy storage system of a solar distributed power generation system [12]. Automatic Bus Transfer (ABT) switches are essential components of any emergency or standby system which can automatically transfer power to critical loads from a normal power source to an alternate power source in the event of interruption or abnormal conditions [13]. There are various technologies used to regulate ABT switches in solar PV systems. Automatic transfer switch (ATS) is a type of ABT switch which use microcontrollers or microprocessors for control. These intelligent devices can monitor various parameters like voltage, frequency, and load, and make rapid transfer decisions based on predefined settings. Microcontroller-based ATS are highly customisable and can incorporate advanced features like data logging and remote monitoring [14]. Better system control and optimisation of ATS are made possible by the use of communication protocols like Modbus or IEC 61850, which enable data interchange and coordination amongst various components [15], [16]. This increases the flexibility and efficiency of the system by giving operators access to real-time data and empowering them to modify or transfer choices from any location. In order to guarantee a seamless and secure transfer, solar PV systems frequently use phase detection and synchronisation mechanisms to synchronise the incoming power source with the grid. In the event of a constrained power supply, certain ATS systems use load shedding capabilities to provide priority to essential loads. Some control designs employ digital implementation platforms such as robust industrial standard PLCs with remote control/access capabilities [17]. The utilisation of a PLC based ATS in a large on-grid PV system is detailed in [18]. The ATS is designed with PLC system which can receive instructions either from the human machine interface (HMI) or voltage and phase detection sensor for a shipboard application [19]. The complexity and needs of the particular solar PV installation determine the technology to be used to manage Automatic Transfer Switches in solar PV systems.

> *Automatic Bus Transfer (ABT) switches are essential components of any emergency or standby system which can automatically transfer power to critical loads from a normal power source to an alternate power source in the event of interruption or abnormal conditions*

The exploitation of solar energy onboard vessels for supplying the non-essential loads during preferential tripping of these loads during the sea-going condition is well presented by the authors in [20]. It is worth mentioning that this paper is subsequent research of the above reference. The scheme proposal for incorporating PV panels in the ship's electrical power system includes a standalone PV system architecture that helps the marine vessel to comprehend the 'green ship' concept and preserve the non-essential loads without using separate backup generators. Furthermore, the proposed architecture utilised clean solar energy to assist the unnecessary tripping of the main generator circuit breaker during an overload condition of the main generator, thereby maintaining comfort in luxury vessels. This paper describes the conception of a PLC based control of ABT switches for an installed standalone PV system onboard to transfer the non-essential loads from ship's main bus to solar bus. Battery banks can store energy from the PV panels and can provide the power to non-essential loads when these loads are preferentially tripped during the overload condition of the main generator. ABT switches are used to switch power sources automatically between the ship's main generators and battery power sources. This article mainly focuses on developing the control logic using PLC ladder diagram for transferring the non-essential loads to solar bus.

Following the introductory section, the paper is organised as follows. Section 2 briefly covers the description of the installed standalone PV power system onboard and the schematic representation of ship standalone PV system for transferring non-essential loads from main bus to solar bus. Section 4 presents the simulation results of ladder diagram for a typical case and section 5 draws the conclusions.

II. SYSTEM DESCRIPTION

III. Installed Standalone PV power system

A schematic diagram of the standalone PV system installed in a typical target ship is explained and simulated using Electrical Transient Analysis Program (ETAP) software [10] and is depicted in **Figure.1.** The ship's main generator is connected to the main bus of the main switchboard (MSB). The target ship chosen has an overall length of 141 m, breadth of 41 m, gross tonnage (GRT) of 8129 tons and deadweight of 2651ton. The proposed standalone PV system comprises all the components of the conventional standalone PV system. A total of 260 PV panels, each rated at 540 watts, 24 volts (Monoperc, Waree) are estimated to be installed onboard, to meet non-essential load requirement of 1312kW (rounded to1400 kW for design) for one hour per day. Thirty eight such panels are connected in series to attain PV array voltage of 900V. Seven such strings are connected in parallel. The PV energy produced by the PV panels with appropriate MPPT controller is used to charge the battery bank.

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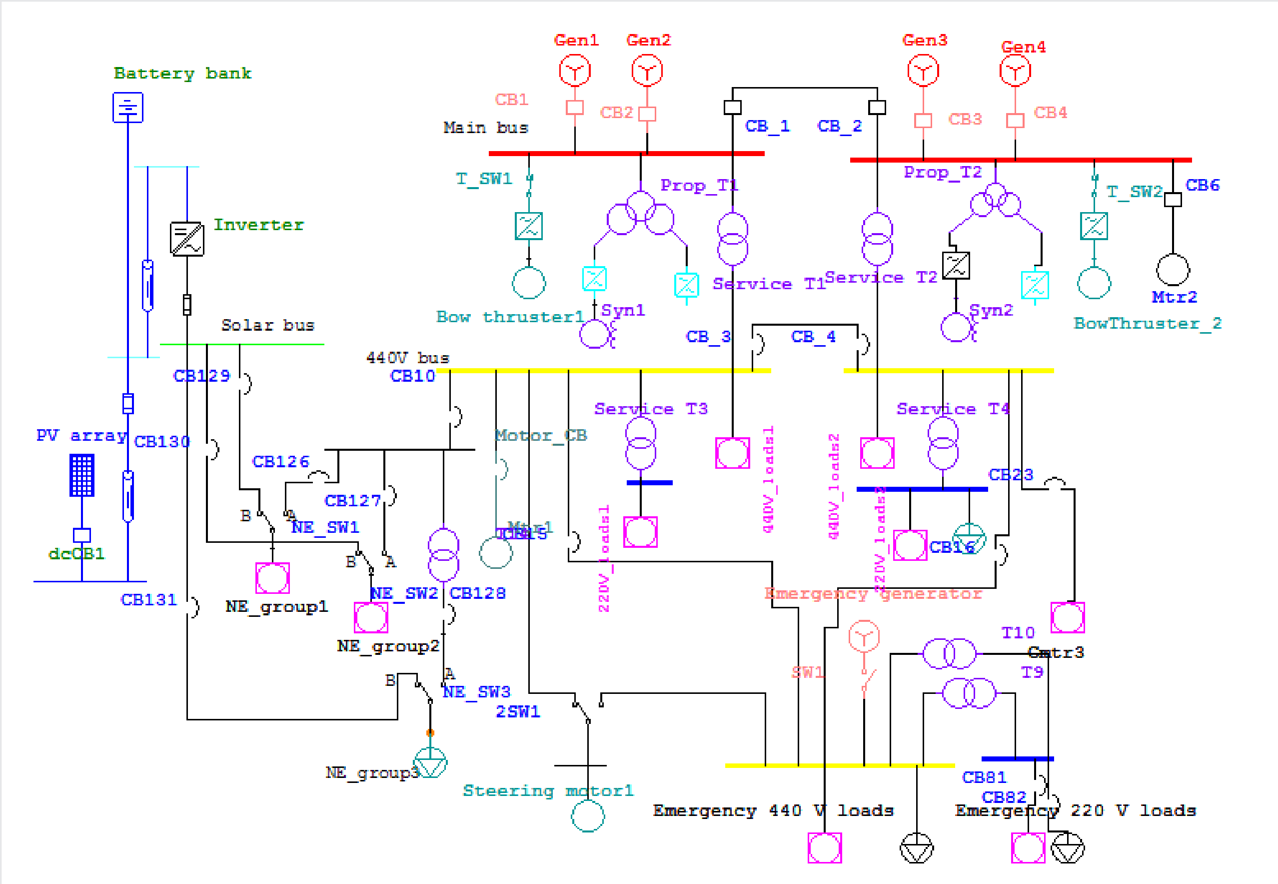

Figure.1. Simulation of PV incorporated ship power system in ETAP.

The nonessential 440V AC loads can be supplied from three numbers of standard three phase inverters each rated 600kW, 440V AC, 98.5% efficiency are connected in parallel. Since most of the non-essential loads consists of pumps, compressors and motors, which requires high starting current a 30% excess power is considered for selecting the inverter capacity. Considering the DC input requirement of inverter, battery bank is designed with the following specification. Sixteen batteries, each rated 48 V, 230 Ah are connected in series to form a string and ten such strings are connected in parallel creating a battery bank with a voltage of 768 volts and a total capacity of 2300 Ah. 48V battery is assembled from a standard cell of $LiFePO_4$ with 3.2V nominal voltage and 230Ah (1C). The battery bank system is managed by an appropriate Battery Management System (BMS).

The ship's primary AC grid supplies electrical energy to the essential and non-essential loads under normal working conditions and the switch position of all the three ABT switches (NE_SW1, NE_SW2, and NE_SW3) will be at the normal position 'A'. In **Figure.1,** each of the three non-essential load categories entitled NE_group1, NE_group2 and NE_group3, are fed from the ship's MSB through the non-essential bus through the corresponding circuit breakers, CB126, CB127, and CB128. When an overload condition arises, the overload relay sends a signal to the microcontroller to activate the preferential trip relays to protect the main generator from the overload condition. The preferential trip relay disconnects the non-essential loads by opening the associated circuit breakers (CB126, CB127 and CB128) of each non-essential load category in different predefined time sets and thereby attempts to reduce the connected loads on the main generator. Preferential tripping can be done for individual loads or groups of loads by a microprocessor-controlled system with several inputs and outputs. Preferential tripping reduces the generator load so that the main generator may continue to supply the essential loads of the ship. When any one of the non-essential load category is disconnected, the PLC is programmed to transfer the associated ABT switch positions to the solar bus (labelled as 'B'), only if the state of charge (SOC) of

> ***The scheme proposal for incorporating PV panels in the ship's electrical power system includes a standalone PV system architecture that helps the marine vessel to comprehend the 'green ship' concept and preserve the non-essential loads without using separate backup generators***

the battery is also sufficient for feeding the disconnected group. Thus, these non-essential loads are fed from the stored PV energy through ABT switches in the case of preferential tripping events. If the SOC is not sufficient, the disconnected non-essential load group remains cut off for the preferential trip period. The preference trip relay resets after the overload condition is resolved. If the overload condition persists, the overcurrent relay begins to time out, which activates the master trip relay of the generator, and the main generator generally trips. Only four possible configurations of three circuit breakers are associated with the operation of preferential tripping of non-essential loads. Under normal working condition, all circuit breakers (CB126, CB127 and CB128) are closed. When NE_group1 is preferentially tripped, CB126 is open, CB127 and CB128 are closed. When NE_group2 is preferentially tripped, CB126 and CB127 are open, CB128 is closed. When NE_group3 is preferentially tripped, all the three circuit breakers are open.

IV. Schematic Representation of Ship Standalone PV System for supplying Non Essential Loads

A schematic diagram illustrating ship standalone PV system incorporating a PLC is provided in **Figure.2.** Under preferential tripping, each of the ABT switches 'NE_SW1', 'NE_SW2' and 'NE_SW3' transfers the contact position from 'A' to 'B', only when SOC of the battery is sufficient for feeding the disconnected groups. PLC is also programmed to generate three output signals 'L1', 'L2' and 'L3' if the battery has the sufficient SOC to supply for NE_group1, NE_group2 and NE_group3 respectively. Therefore PLC is programmed to generate three output signals 'X', 'Y' and 'Z' for the operation of ABT switches 'NE_SW1' 'NE_SW2', and 'NE_SW3' respectively, only when some conditions are met. The status of the circuit breakers CB129, CB130 and CB131 can be sensed by BSS, entitled Bss1, Bss2 and Bss3 respectively and are given as digital input signals. The SOC of the battery can be given as an analog input signal to the PLC.

Next, the control rules for the PLC controller is formulated according to the requirement. Ladder diagram logic is used for PLC programming [21]. Under normal working conditions, all three circuit breakers ('CB126, CB127, and CB128) are in a closed position. The status of these breakers are given as rung inputs and are represented by 'C1', 'C2' and 'C3' respectively. These are represented by 'NC' (normally closed) contact switches and therefore the rung connected outputs cb1, cb2 and cb3 are not actuated under normal conditions. When these circuit breakers are open due to preferential tripping, the rung inputs C1', 'C2' and 'C3' are energised and the corresponding rung outputs cb1, cb2 and cb3 shall be actuated. Depending upon the input value of SOC, three different rung outputs 'L1', 'L2' and 'L3' also becomes actuated. A cell's SOC denotes the remaining charge available as a function of the rated capacity. The value of the SOC varies between 0% and 100%. If the SOC is 100%, the cell is said to be fully charged, whereas a SOC of 0% indicates that the cell is completely discharged. The lower threshold of the battery (SOC_{low}) is taken as

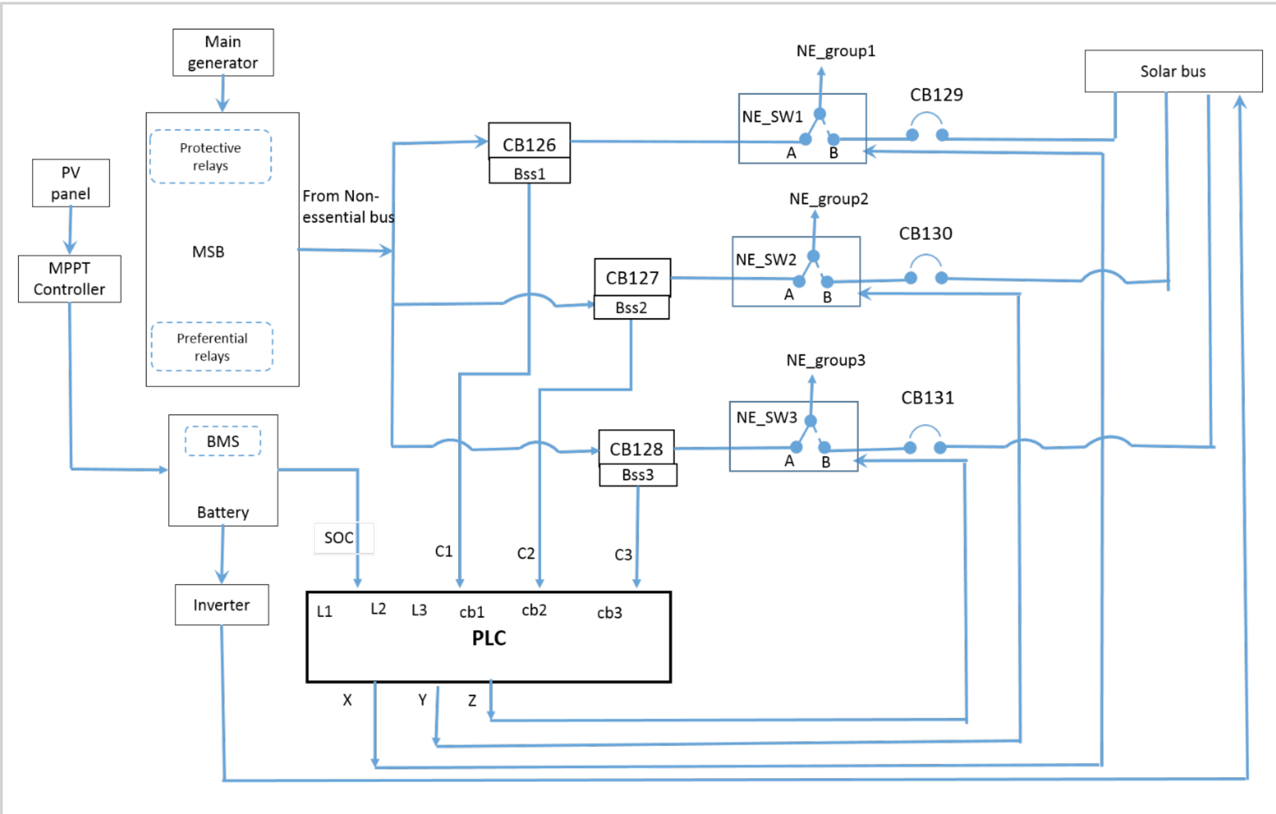

Figure.2. Schematic representation of ship standalone PV system for transferring the non-essential loads from main bus to solar bus during preferential tripping

15% which is about 345 Ah. Non-essential loads are expected to operate from solar bus for about 15 minutes per day during preferential tripping. The minimum battery capacity needed in ampere hour for each non-essential load category to receive power from the PV bus for about 15 minutes is calculated using equation (1)

$$A = (W \times T) / V) \qquad (1)$$

where 'A' is the minimum battery bank capacity in ampere hours, T is the battery run time in hours, W is the connected load in watts and V is the battery bank voltage in volts. The minimum battery Ah required ($A1$) to provide power to 83 kW (NE_group1) is 27.018 Ah, which is nearly 1.17% of installed 2300 Ah. The minimum Ah needed to power 572 kW ('NE_group1' and 'NE_group2') is computed as 186.19Ah which is nearly 8.09% of installed capacity. Since the SOC_{low} is taken as 15%, the PLC is programmed to activate 'L1' and 'L2' only when SOC is greater than or equal to SOC_{low}.

Similarly, the minimum Ah needed to power 1312 kW ('NE_group1' and 'NE_group2') is computed as 186.19Ah which is nearly 8.09% of installed capacity. Equation (1) is employed to compute the minimum Ah required ($A3$) for supplying 'NE_group1', 'NE_group2', and 'NE_group3' over a period of at least 15 minutes, considering a combined electrical load of 1312kW, yielding a value of 427.083 Ah. The obtained result is nearly 18.56% of installed 2300 Ah. Therefore PLC is programmed to activate 'L3' only when SOC is greater than or equal to 20% for supplying 'NE_group1', 'NE_group2' and 'NE_group3'. L1, L2 and L3 status are determined and the corresponding PLC output X, Y and Z are given in **Table 1.** For simplifying the logic control design, the actuation / energisation is represented as logic state '1' and normal/ non actuated is represented as logic state '0'. Based on the logic states of PLC output X, Y and Z the corresponding ABT switches are operated.

V. SIMULATION RESULTS OF PLC LADDER DIAGRAM

The designed ladder diagram is simulated in an online PLC simulator for various ship operating scenarios and verified. Considering a typical case in which, all the three non-essential groups, 'NE_group1', 'NE_group2', and 'NE_group3', are disconnected due to preferential tripping and a 30% SOC. When 'NE_group1', 'NE_group2', and 'NE_group3', are disconnected due to preferential tripping, the circuit breakers CB126, CB127, and CB128 are open. Thus the rung inputs C1, C2, and C3 becomes false, then the corresponding outputs cb1, cb2 and cb3 becomes actuated. Since the SOC is greater than 20% which is needed for supplying the whole non-essential loads during the time of preferential tripping, the rung outputs L1, L2, and L3 are true. In this case, PLC generates the output signals 'X', 'Y' and 'Z' that energises the operating coil of circuit breakers CB129, CB130 and CB131 respectively which transfers the switch position to 'B' incorporating necessary delay. Thus NE_group1, NE_group2 and NE_group3 can be supplied from the stored PV energy.

Table 1 : Relevant Combinations for generating PLC output signals

Circuit breaker status			Signals representing SOC status			PLC output		
C1	C2	C3	L1	L2	L3	X	Y	Z
1	0	0	1	0	0	1	0	0
1	0	0	1	1	0	1	0	0
1	0	0	1	1	1	1	0	0
1	1	0	1	0	0	1	0	0
1	1	0	1	1	0	1	1	0
1	1	0	1	1	1	1	1	0
1	1	1	1	0	0	1	0	0
1	1	1	1	1	0	1	1	0
1	1	1	1	1	1	1	1	1

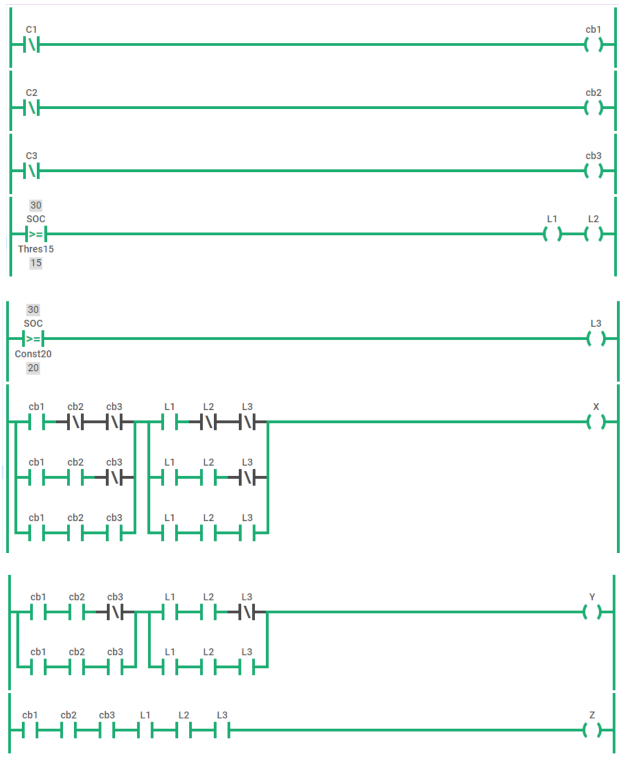

Figure.3 Ladder logic simulation diagram

VI. CONCLUSION

This paper details the design and development of a programmable logic controller (PLC) based automatic bus transfer (ABT) switch for the standalone PV system to transfer these non-essential loads from the ship's main bus to solar bus during the time of preferential tripping. The

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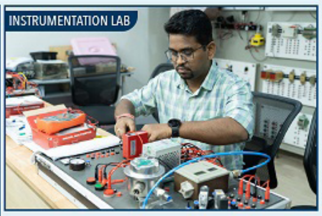

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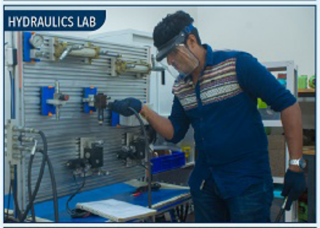

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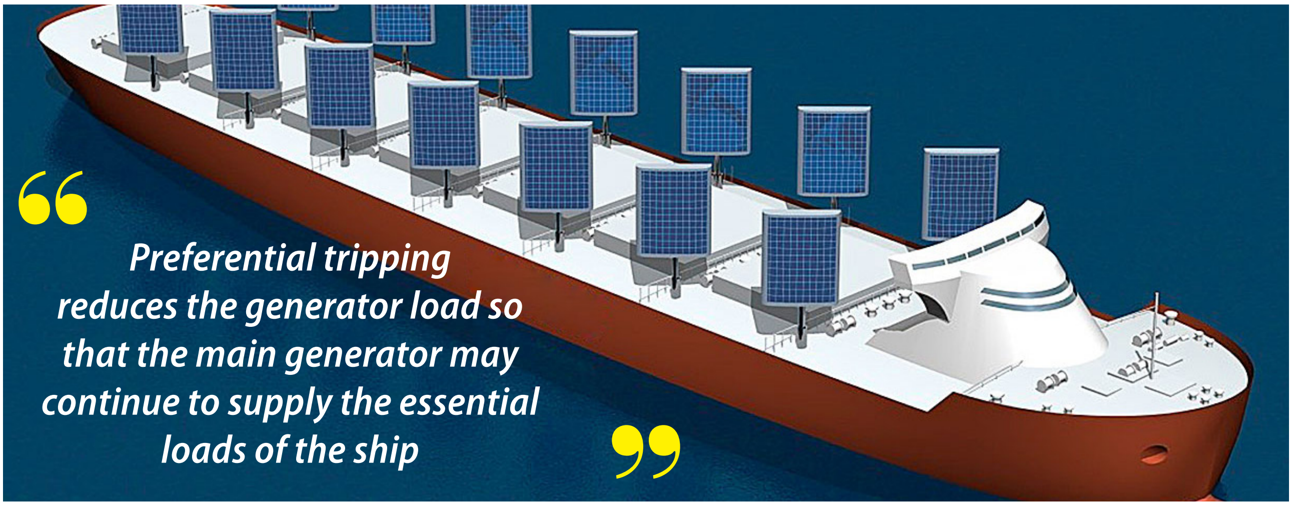
required control protocols for the PLC controller has been formulated. The designed ladder diagram is simulated via an online PLC simulator, validating the proper functionality of the PLC controller under a specific ship operational condition. The compact PLC SIMATIC S7-1200, developed by Siemens, is a suitable choice for configuring the hardware setup necessary for the specified control of ABT switches. Interlocking facilities of circuit breakers can be provided to ensure that both power sources are not supplying the non-essential loads simultaneously. The non-essential loads remain on the solar bus until sufficient SOC is available. By incorporating necessary information to the PLC, the non-essential loads can be reconnected to the main bus when the main generator is ready after the fault correction, irrespective of the SOC levels.

[This paper was presented at the CC Marpol Conference, February 2024]



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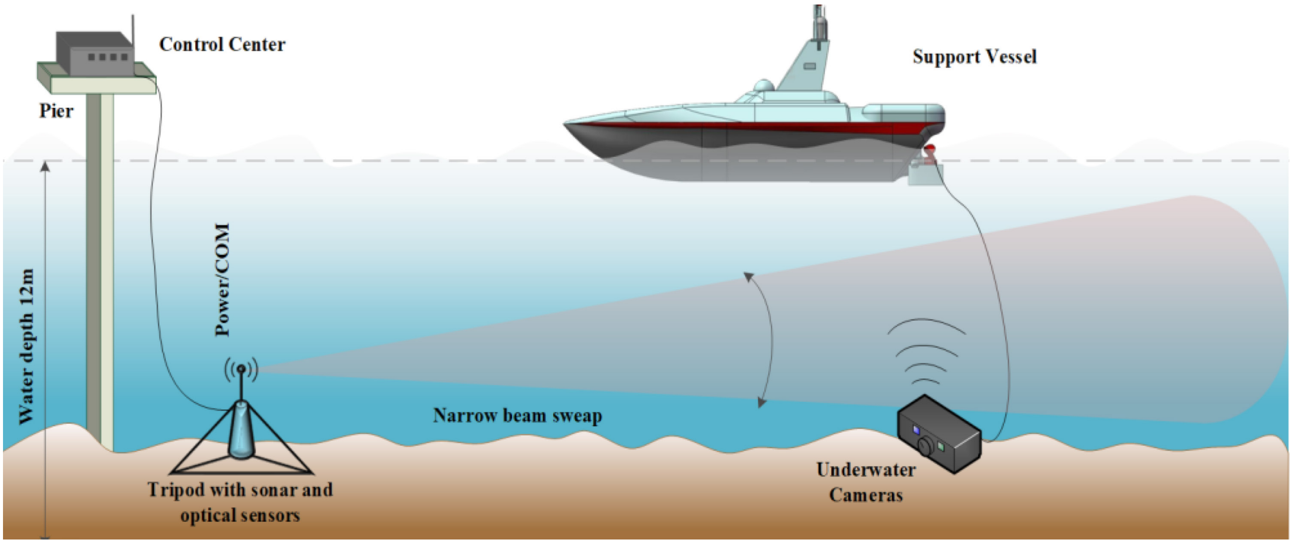
Modelling Under Water Acoustics for Offshore Construction Activities



Prabu Duplex

Introduction

The number of marine constructions is on the rise. An increase in underwater noise has been reported in several regions around the globe especially in the form of offshore wind farm constructions, operations and maintenance. Given the important role sound plays in the life functions of marine mammals a way to analyse these effects is vital. This work aims at briefing fundamental concepts involved in the generation and propagation of **underwater noise and modelling methods of sound propagation in shallow waters**.

This work excludes exhaustive discussions of all existing underwater acoustic models. It focuses on operationally oriented applications such as field activities, including fleet operations at sea during offshore construction activities. Operational applications generally require rapid execution, under demanding conditions; moreover, modelling accuracy may be subordinate to processing speed. This underlines the methodology followed in this work. In line with these discussions a solution has been demonstrated as a proof of concept.

> *Underwater acoustics deals with the acoustical methods to image underwater features, communicate information through oceanic waveguide, or to measure oceanic properties*

1.1 Acoustical Oceanography

Underwater acoustics deals with the acoustical methods to image underwater features, communicate information through oceanic waveguide, or to measure oceanic properties [2]. Historically, sonar technologists initiated the development of underwater acoustic modelling to improve sonar system design in the support of naval operations. This forms the discipline of computational ocean acoustics.

Sound propagation is greatly affected by the conditions of the surface and bottom boundaries of the ocean also, as by the variation of sound speed within the ocean volume. The important aspects that influence sound propagation are addressed in this section.

1.1.1. Sound Speed

The speed of sound in sea water determines the behaviour of sound propagation in the ocean. The nine-term equation [2] is presented here where *c* is the speed of sound in sea water (m s^{-1}), *T* is the water temperature (°C), *S* is the salinity (%) and *D* is the depth (m). The final equation is as follows:

$$
\begin{aligned}
c = {} & 1448.96 + 4.591T - 5.304\times10^{-2}T^2 + 2.374\times10^{-4}T^3 \\
& + 1.340(S-35) + 1.630\times10^{-2}D + 1.675\times10^{-7}D^2 \qquad (1) \\
& - 1.025\times10^{-2}T(S-35) - 7.139\times10^{-13}TD^3
\end{aligned}
$$

1.1.2. Transmission Loss

The standard unit of measure of underwater acoustic propagation is acoustic intensity (*I*), which is sound pressure flow (power) per unit area (reported in units of watts per square meter):

$$I = \frac{p^2}{\rho c} \tag{2}$$

where *p* is the instantaneous pressure amplitude of a plane wave, ρ is the density of sea water and *c* is the speed of sound in sea water. Sound intensity is a vector quantity, but in the far-field approximation it is represented as a scalar quantity based on sound pressure squared. The product of ρ and *c* is commonly referred as characteristic acoustic impedance. Transmission loss (TL) is defined as 10 times the log (base 10) of the ratio of the reference intensity (I_{ref}), measured at a point 1 m from the source to the intensity (*I*), measured at a distant point, and is expressed in decibels (dB):

$$\mathrm{TL} = 10 \log_{10} \frac{I_{\mathrm{ref}}}{I} \tag{3}$$

TL has conventionally been plotted for each frequency, source depth and receiver depth as a function of range, as in **Figure. 1.**

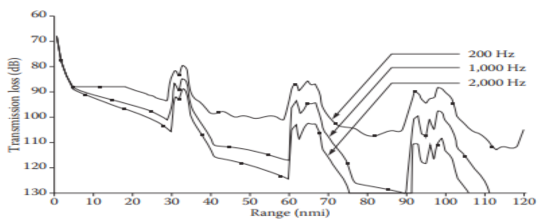


Figure 1: Example of standard transmission loss curves [2]

1.1.3. Attenuation and absorption in sea water

Sound losses in the ocean can be categorised according to spreading loss and attenuation loss. Absorption describes those effects in the ocean in which a portion of the sound intensity is lost through conversion to heat. Field measurements of the absorption coefficient (α), typically expressed in units of dB km^{-1}, span the frequency range 20 Hz–60 kHz. The equation developed by Thorp (1967) is widely used and is valid for frequencies below 50 kHz:

$$\alpha = 1.0936\left[\frac{0.1 f^2}{1+f^2} + \frac{40 f^2}{4100+f^2}\right] \tag{4}$$

where α is the absorption coefficient (dB km^{-1}) and *f* is the frequency (kHz)

1.1.4. Ocean Depth

The prime areas of interest are shallow-water acoustics and deep-water acoustics.

Absorption describes those effects in the ocean in which a portion of the sound intensity is lost through conversion to heat.

- **Shallow-water acoustics** is concerned with the propagation and scattering of low-frequency (10 Hz to ~3 kHz) acoustic energy in shallow-water ocean environments.
- **Deep-water acoustics** is concerned with low-frequency acoustic propagation, scattering and communication over distances in the deep. High-frequency acoustics is also applicable in deep waters and it concerns the interaction of high frequency (~3 kHz - 1000 kHz).

2. Mathematical Models

Ocean acoustic propagation models usually solve the wave equation (or Helmholtz equation) [1]. This is generally done for a given frequency, and broadband signals, for example, a pulse, may have to be modelled using a time-domain model. Alternatively, a solution is calculated for each frequency or frequency band across the required frequency range, with the use of a suitable inverse transform. In general, propagation modelling solutions can be divided into three classes based on: 1. the frequency characteristics of the source; 2. the environmental dependence of the propagation region; and 3. the water depth. Models within class 2 are categorised as range independent (the environmental parameters are kept fixed with range), and range dependent (environmental input parameters, such as water depth and sound speed, are allowed to vary with distance from the source), the latter being the choice when the bathymetry or water column conditions change along the propagation path. Given a particular frequency band and environment, the choice of a suitable propagation model can be made. Out of models available, few are available for free download, but these are complex models which require expertise to use. The factor that influences model choice is computational cost and a decision is required between higher fidelity and the computational time. The available propagation models are commonly categorised based on their underlying method into the following groups:

- Ray tracing
- Normal mode
- Parabolic equation
- Wavenumber integration
- Energy flux
- Finite Difference, Finite Element models

The frequency band of interest is the primary discriminator between propagation models. For low-frequency sound, the parabolic equation solution and the normal mode solution, represent the most appropriate model choice. For high frequency computations ray tracing or energy flux models are generally used.

Shallow water - low frequency	Shallow water - high frequency	Deep water - low frequency	Deep water - high frequency
Ray theory	*Ray theory*	*Ray theory*	*Ray theory*
Normal mode	*Normal mode*	*Normal mode*	*Normal mode*
Wave number integration	*Wave number integration*	*Wave number integration*	*Wave number integration*
Parabolic equation	*Parabolic equation*	*Parabolic equation*	*Parabolic equation*
Energy flux	*Energy flux*	*Energy flux*	*Energy flux*

Green – suitable; Amber – suitable with limitations; Red – not suitable or applicable

Figure 2: Models based on frequency range

From the list of computational models discussed Parabolic model can be chosen considering the range of low frequencies involved during ship transit and ocean hammer piling noise being analysed [4,5]. High frequency also needs to be considered in such cases, which requires additional investigation.

2.1.1. Parabolic equations

Almost all acoustic modelling involves the computation of the field propagation from a source to a distant receiver. In this problem the propagation is one-way. Separating the wave equation into incoming and outgoing solutions leads to the Parabolic Equation. Neglecting incoming (back-scattered energy), the acoustic field can be computed using a marching algorithm referred to as the Parabolic Equation (PE) model. There are two classes of PE models available – the split-step Fast Fourier Transform solution developed by Tappert and the Padé expansion solution developed by Collins [11]. The PE is an efficient marching solution that is suitable for range-dependent environments, discontinuous sound speed profiles and is commonly used in shallow and deep water. The PE computational requirements increase with frequency squared for the Fourier PE) and therefore the PE is generally used at frequencies less than 1 kHz. The split-step Fast Fourier Transform approach does not handle density discontinuities easily and therefore it is not used in shallow waters.

2.1.2. Parabolic equation implementation in Actup

The parabolic equation (PE) method assumes a solution in the form of an outgoing cylindrical wave:

$$p(\mathbf{r}) = \psi(r,z)H_0^{(1)}(k_0 r) \tag{5}$$

where ψ (r, z) is assumed to be a slowly varying function of range, and k_0 is a reference wavenumber. Substituting into the homogeneous (zero r.h.s.) form of (3) and making the further assumption that energy is propagating at small angles to the horizontal (the paraxial approximation) leads to the parabolic equation:

$$2ik_0\frac{\partial\psi}{\partial r} + \frac{\partial^2\psi}{\partial z^2} + k_0^2\left(\left[\frac{c_0}{c}\right]^2 - 1\right)\psi = 0 \tag{6}$$

where c_0 is the reference sound speed corresponding to k_0.

This equation is only first order in range and, given the field at one range, can be readily integrated to obtain the field at a subsequent range. This leads to an efficient "range marching" algorithm. Although (6) is only accurate for propagation at angles close to the horizontal, developments have led to PE algorithms that relax this restriction to the point where it is no longer an impediment.

The Range-dependent Acoustic Model (RAM) developed by Mike Collins (Collins 1993) [11] implements an extremely efficient algorithm that allows a trade-off between the range of propagation angles that can be accurately modelled, and computation speed. This trade-off is implemented through the user specifying the number of terms to use in a Padé expansion that appears in the equations. More terms give accuracy over a wider range of angles but result in longer computation times. RAM comes in several variants as explained in the subsequent section.

2.2. AcTUP v2.2 Acoustic Toolbox

Two modified versions of Mike Collins' Range-dependent Acoustic Model (RAM) have been integrated into the AcTUP framework [11, 15]. RAM is a parabolic equation (PE) code that uses a split-step Padé algorithm to achieve high efficiency and the ability to model propagation at large angles from the horizontal (the usual limitation of PE codes). There is a trade-off between the angular range and the speed of computation that is governed by the number of terms the user specifies for the Padé approximation – the more terms, the wider the angle, but the slower the code runs. RAM is capable of modelling low frequency propagation in fully range dependent environments (i.e. range dependent bathymetry and sound speed), and this capability is fully supported by AcTUP. RAM comes in several variants:

- RAM - fluid seabeds, seabed layering specified relative to the water surface. (Strata are horizontal.)
- RAMGeo - fluid seabeds, seabed layering specified relative to the seabed. (Strata follow bathymetry)
- RAMS - As for RAM but can handle elastic seabeds.
- RAMSurf - as for RAMGeo, but also inputs a file specifying the height of the top boundary of the water column as a function of range.

RAMGeo is more consistent than RAM as it handles range-dependent bathymetry and was therefore selected for use with AcTUP. To allow for modelling situations where shear wave propagation in the seabed is important, CMST developed a modified version of RAMS that uses the same seabed layer specification method as RAMGeo. This is known as RAMSGeo. This program required significant modifications to be made to the original code and, although it has been tested successfully on a number of standard problems, should be used with a certain degree of caution and expert advice.

2.2.1. ACOUSTIC TOOLBOX USER INTERFACE AND POST-PROCESSOR (ACTUP)

A simplified block diagram of the way AcTUP works is shown in **Figure 3.** The environment and code parameter editor allows the user to load, modify, and save the environment specification (sound speed profiles, seabed characteristics etc.) and other parameters relating to the propagation calculation (source and receiver depths, receiver ranges etc.). This block also allows the user to specify the propagation code that will be run, and any parameters that are specific to that propagation code. All of this information is saved in the run definition file. The code engine uses the information in the run definition to write the input file that is required by the propagation code that it has been told to run. In some cases the run definition will require several codes to be run in sequence (eg. BOUNCE then BELLHOP, or KRAKEN followed by FIELD), in which case several input files will be required. The next step is for the code engine to run the propagation codes in the required sequence. The codes are compiled .exe files and are run using Matlab command. The propagation code(s) will produce one or more output files. The post processor includes an extensive set of routines for reading the output files and plotting the results. AcTUP is menu driven, and most parameters are entered via dialog boxes. The exceptions to this are sound speed profiles, which can either be entered into a dialog box or read from a file, and bathymetry, which is always read from a file.

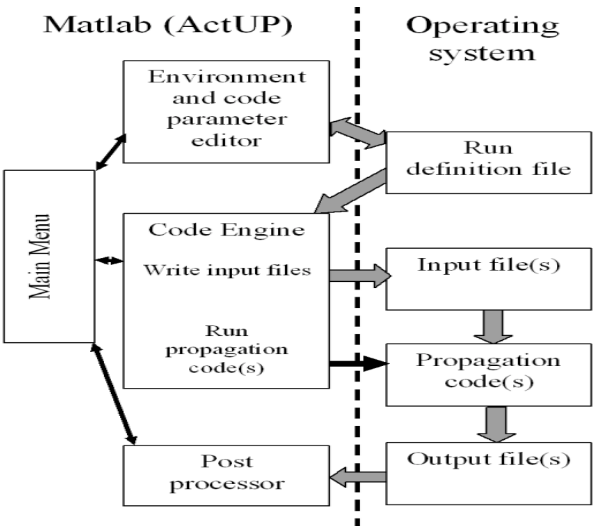


Figure 3: Bellhop structure [11]

3. Simulation Setup

Motivation at this phase is to test the software works. Once it is ensured that the software responds to other settings, the actual simulations can be performed subsequently.

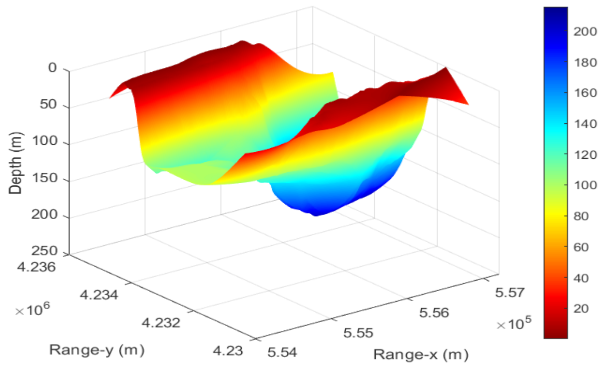


Figure 4: SSP considered (L), Bathymetry coordinates (R)

Sound speed profiles (SSP) are assumed as shown in **Figure 4.** Bathymetry **(Figure 4)** details are modelled in xyz format (in metres) to represent a shallow water zone. Seabed geological properties are chosen from [14]. Gravely Smooth Bottom is chosen for analysis and corresponding values such as sediment density, P-Wave velocity and attenuation coefficient are as follows:

Seabed type: Gravely Smooth Bottom

Density: 2030 kg/m^3

P-Wave velocity: 1836 m/sec

Attenuation coefficient: R- 0.42 (dB/m) kHz.

Seabed is assumed to be Acoustic-Elastic space. Seabed layers, S-Wave velocity, reflection coefficients are not considered, as the motivation of this work is to develop a prototype version. Space above water column is chosen as vacuum above surface and bottom reflection coefficient is not considered.

Source coordinates for simulations are chosen to be the centre of the area under consideration and transmission loss distance considered is at 300 m. One sound source is considered at a depth of 10.537 m. The receivers are placed every 5 m upto a depth of 250 m. The receiver distance is chosen as 300 m from the source because at this phase the motivation is to test the software works. Once it is ensured that the software responds to other settings, the actual distance can be chosen in the subsequent steps. For bathymetry 2D plane has been derived from the 3D bathymetry (an arbitrary plane chosen) as shown in **Figure.5** (to cater the 2D nature of RAMGeo). Seabed attenuation coefficient is converted in dB/wave length [14]. Frequency is chosen to be 50 Hz (low frequency based on [21]). Regarding numerical setup the number of Pade expansion were 6 with one stability constraint. These values are default setups observed from a demonstration simulation available in RAMGeo. The other parameters such as max range of stability constraints, attenuation layer thickness and attenuation layer maximum p-wave attenuation and related simulation setup values are also chosen from the same demonstration simulation of RAMGeo.

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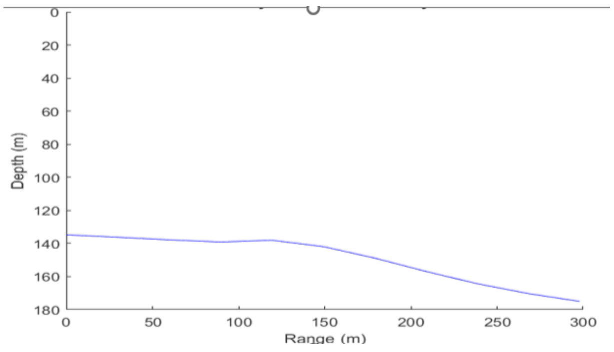

Figure 5: 2D bathymetry considered

Transmission loss plots with respect to depth and range are the ones which are useful in real time, so in the simulations way to validate such plots are focused. TL Plots are shown in **Figures 6** and **7** for various receiver depths and ranges. In these figures subscript s denotes source and subscript r denotes receiver. As shown in these figures transmission loss increases as depth increases. Thus, one can get an initial confidence that the software setup is done correctly. Transmission loss with respect to a chosen depth and corresponding range is shown in **Figure. 7.** Transmission loss with respect to a chosen receiver location and corresponding depth is shown in **Figure. 6.** In the plots representing transmission loss with respect to depth, at deep waters transmission loss is maximum. This characteristic is also observed from the 2D transmission loss plots for the chosen depth plot.

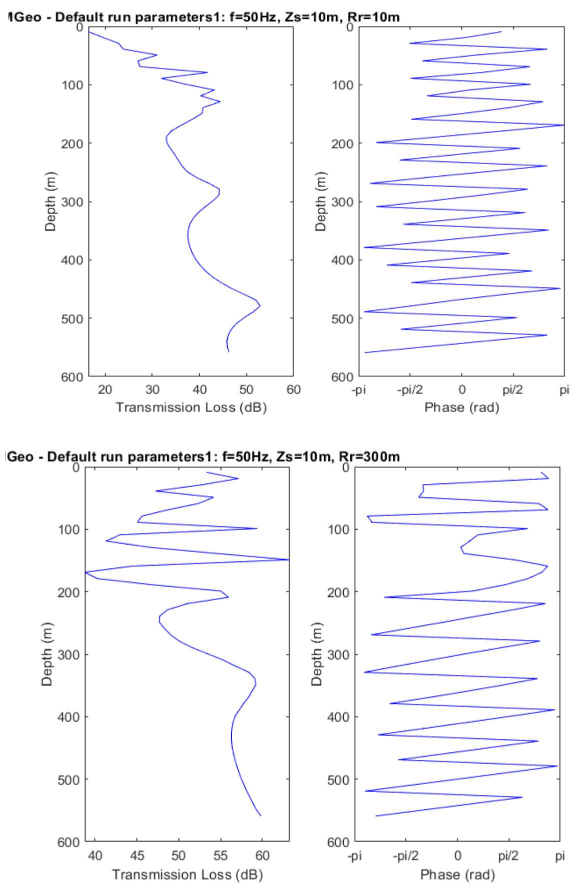

Figure 6: Receiver at 10m, various depths (L), Receiver at 300m, various depths ®

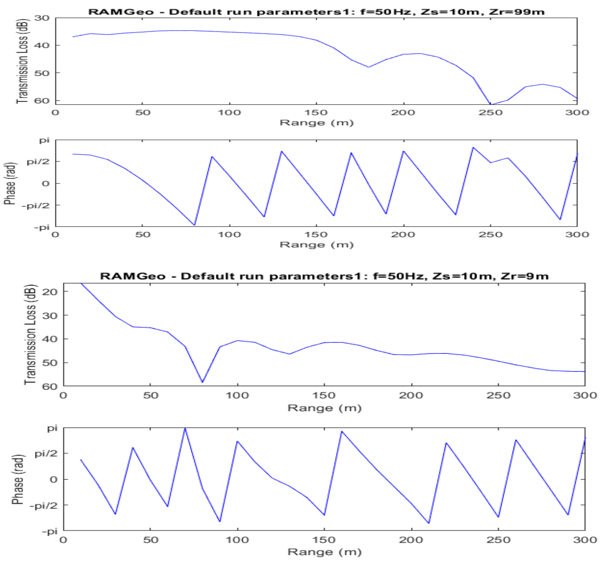

Figure 7: Source: 10.537m, Receiver depth: 100 m, Range: 300m (L), Source: 10.537m, Receiver depth: 11 m, Range: 300m (R)

4. Moving Ship Simulations

Moving ship simulations are discussed in this section. The ships involved in construction activities emit sound in a range of spectrum [4,5]. This spectrum is however converted into an equivalent sound pressure level (SPL) and assessed to verify the allowable limits. Assumption is made such that a ship travels from point 1 to point 5. The discrete steps in between range from 2 to 4. The ship is assumed to emit a source sound power level of 160 dB. The same sound power level reaches a receiver. Source and receiver depths are at 10.537 m (assuming the ship noise because of propeller and engine room originate from this depth) and source frequency is 50 Hz. Source x,y coordinates in metres (m) are (555000, 4232500), (555500,4232500), (556000,4232500), (556500,4232500), (557000,4232500) and receiver coordinates are (556000,4233500) as shown in **Figure 8.** Source coordinates are chosen to be near the coast (assuming construction activities in these area) and approximately from a distance of 1km away (assuming the cetacean movements in this zone), transmission loss is analysed. The rest of the simulation set up (concerning number of receivers, sea bed characteristics and numerical set up of parabolic equation) are the same as mentioned in the section 3. The resultant Total Sound Pressure Level (dB) is calculated according to the following equation, where L_{total} stands for total Sound Pressure Level perceived at the receiver as the result of the ship movement from point 1 to 5. L_t stands for instantaneous sound pressure level received for each source.

$$L_{total} = 10 \log\left(\sum_{i=1}^{n} 10^{L_t/10}\right) dB \qquad (7)$$

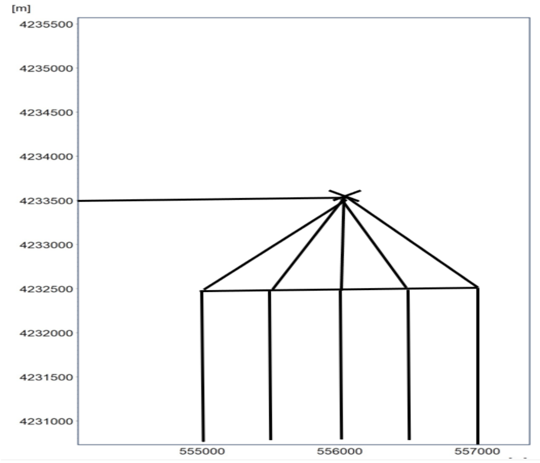

Figure 8: Source coordinates marked (position in x-axis read as 1 to 5 from left)

Since RAMGeo has only 2D capabilities the first step is to extract the 2D bathymetry across the chosen vertical section and the procedure is explained in this paragraph. Case 4 is discussed, and the procedure is same for all cases. To begin with, the bathymetry coordinates in 3D

> *RAMGeo, developers have also provided with an option to perform multiple simulations across the chosen coordinates, which needs to be investigated further*

are marked (for the plane), subsequently bathymetry is loaded (by means of a script). Following this the bathymetry is oriented along the plane and the required bathymetry coordinates are extracted. However, difficulty still exists in reading the values, that needs to be improved in future. **Figure. 12 (R)** gives the bathymetry in metres (m) across sections and **Figures. 9 to 12** (L) represents the way that bathymetry is extracted.

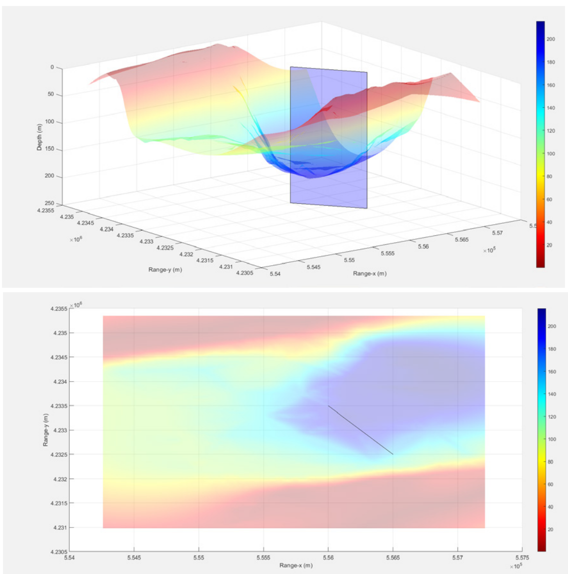

Figure 9: Step 1 (for extracting bathymetry)

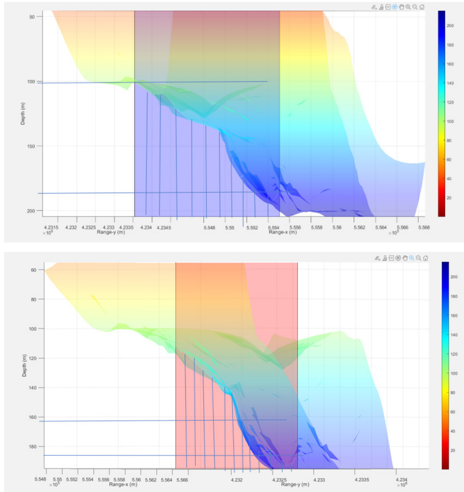

Figure 10: Bathymetry: position 1 (L), position 2 (R)

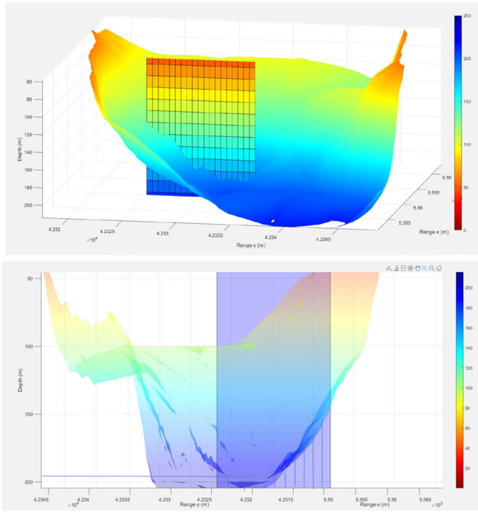

Figure11: Bathymetry: position 3 (L), position 4 (R)

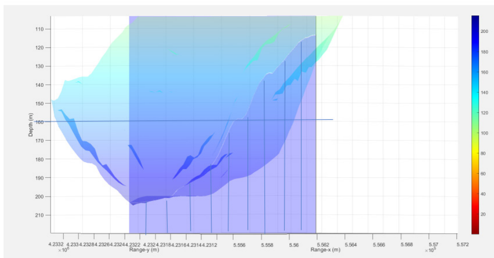

Figure 12: Bathymetry at position 5 (L), Bathymetries for all the positions (R)

The simulation results are shown in the **Table 1** and **Figure. 13.** In **table 1** the resultant Total Sound Pressure Level (dB) is calculated according to the equation 7, where L_{total} stands for total Sound Pressure Level perceived at the receiver as the result of the ship movement from point 1 to 5. L_t stands for instantaneous sound pressure level received for each source. As shown in Figure 13, position 3 which is closer to the source receives less sound when compared to the nearest positions 2 and 4. This may be due to the bathymetry effects. This scenario is counter intuitive because position 3 which is closer to the receiver should receive more noise than the others, but the results

Table 1: Simulation set up and results for source 160 dB

Position	Source Coordinates (m)	Receiver Coordinates (m)	Angle (α)	TL (dB)	Actual level (source 160 dB)
1	555000, 4232500	556000, 4233500	45	66	94
2	555500, 4232500	556000, 4233500	63	59	101
3	556000, 4232500	556000, 4233500	90	68	92
4	556500, 4232500	556000, 4233500	117	49	111
5	557000, 4232500	556000, 4233500	135	58	102
	Total Sound Pressure Level L_{total}(dB)				111.99

are opposite. This may be due to bathymetry slope or 3D effects.

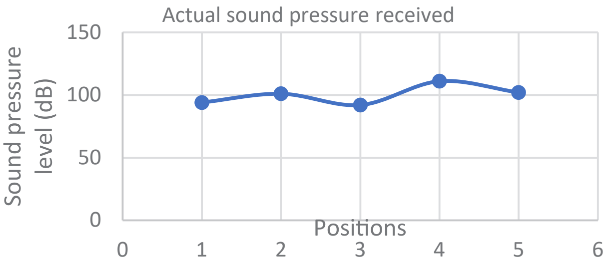

Figure 13: Actual sound pressure received at receiver

4.1. Conclusion and discussion

Extracting 2D bathymetry from 3D is challenging. One solution is using QGIS. QGIS has options to extract 2D bathymetry across the chosen direction. A code needs to be written to automate the solutions for the ship trajectory. This is basically looping the functions in order to perform simulations for the given coordinates and output the cumulative sound power levels perceived. RAMGeo, developers have also provided with an option to perform multiple simulations across the chosen coordinates, which needs to be investigated further. Moreover most propagation models are two-dimensional solutions, calculating the propagation loss along a transect, which does not include horizontal refraction, reflection or diffraction (i.e. each transect modelled is independent of the neighbouring transect). It may be necessary to use a three-dimensional model, which accounts for horizontal diffraction to accurately represent the sound field.

Acknowledgement

This work was performed at the University of Pisa under the project "Study of Road Noise with Innovative Methods" in close collaboration with Agenzia regionale per la protezione ambientale della Toscana – Direzione (ARPAT). I thank Prof. Gaetano Licitra and Prof. Francesco Fidecaro for their valuable support in the context of this work.

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Prabu Duplex had sailed as a marine engineer between 2005- 2013. He graduated from a Professional Doctorate in Engineering (PDEng) programme at the University of Twente, in the Netherlands. He also worked in a research group called "Dynamics Based Maintenance (DBM)" which actively focuses on developing innovative predictive maintenance methods for a wide range of industries. His work involved in developing physics based mathematical models to predict the life time of diesel engines components in maritime propulsion systems. He also has a Master's degree in Naval Architecture. Presently, he is looking for a career in design or research activities in naval, wind, offshore or predictive maintenance domains.

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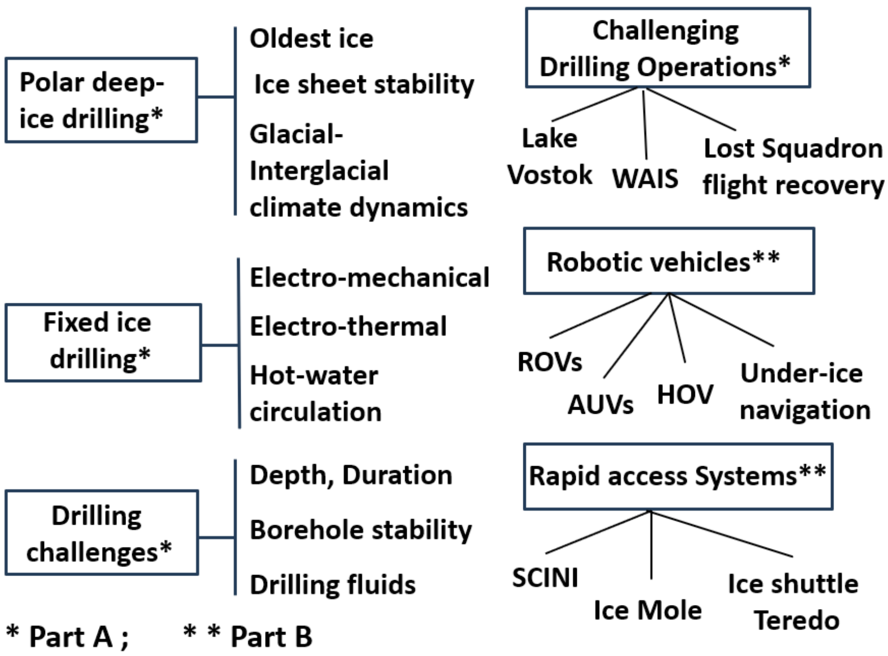
Technologies Enabling Polar Under-Ice Investigations – Part B

N. Vedachalam

Abstract: The accelerating pace of current climate change creates urgency to understand the behaviour of abrupt changes in the past as a guide to future changes, and also the need to predict rates of mean sea level rise. Glaciers, ice-sheets, and subglacial environments directly record, in layers, components of past atmospheres ranging from a single storm event to states of the Earth's climate system. Understanding glacial dynamics, stability of ice sheets and ice sheet response to climate change are imperative for predicting rapid sea level rise. The under-explored cryosphere realm is the only established archive that preserves the unique evolution and interaction of atmosphere, biosphere and geosphere for millions of years. For all of these areas of science, extracting this evidence involves deep-drilling and coring into and through glaciers and the Polar ice sheets, a specialised and challenging endeavour that requires innovative technology. Part-A discussed the progress in Antarctic research, ice-drilling challenges and fixed drill systems for under-ice sampling based on rotary, thermal and hybrid technologies. This part describes **robotic-based systems and upcoming unconventional drilling systems**.



Importance of Ice-related Polar research

Hitherto, the research conducted in the Polar regions include analysing the past climate changes in deep-ice cores and sedimentary sequences, role of sub-glacial environment in controlling ice-sheet dynamics and its contribution to sea level rise, role of the Southern Ocean in driving the deep-ocean conveyer belt, methane release to the atmosphere due to melting permafrost, global transport of pollution and contamination to the Polar regions and consequent impacts on biodiversity and changing eco-system patterns, molecular and genetic mechanisms of living systems that are coping with freezing conditions, presence and cause of the Ozone hole, the slowest spreading centre on the thinnest ocean crust on Earth and meteorological observations. The importance of ice-related research in the Polar Regions is summarised in **Figure.1.** They include Ice sheet stability, Oldest Ice (that provides novel records of past atmospheric greenhouse gases, the Mid-Pleistocene transition when glacial-interglacial cycles of 40 kyr duration shifted to 100 kyr cycles, and climate sensitivity under differing boundary conditions) and Glacial-Interglacial Climate Dynamics.

Oldest Ice
Records of past atmospheric greenhouse gases

Ice sheet stability
- Timing
- Speed
- Magnitude of ice loss
- Forcing mechanisms

Glacial-Interglacial Climate Dynamics
- **Mechanisms driving glacial interglacial cycles**
- **Abrupt climate change**
- **Forcing mechanisms**
- **Dynamics of global climate system**

Figure.1. Major areas of deep ice-drilling research

Under-Ice Observing Robotic Systems

Remotely-Operated Vehicles (ROV), Autonomous Underwater Vehicles (AUVs), hybrid vehicles and human occupied vehicles (HOV) are rapidly becoming the platform of choice for mapping underside of ice shelves, as well as for carrying out geological, biological and oceanographic measurements in the Arctic and Antarctic. The importance of robotic vehicles could be seen from the increasing number of AUVs recently involved in Polar research **(Figure.2).** The earliest purpose-built under-ice vehicle was the Unmanned Arctic Research Submersible System (UARS) in 1972 rated for 450m water depth, followed by ARCS that was developed by ISE to conduct bathymetric surveys in the Arctic.

In 1986, the most challenging achievement in terms of risk, technical difficulty, distance travelled, and navigation performance at extreme latitudes was made in the Spinnaker project in which the 10.7m long, 2000m depth-rated, 9.6t AUV Theseus developed by the International Submarine Engineering (ISE) that laid the 175 km long optical fibre under the fast-ice in the Canadian Arctic, from the North of Ellesmere Island to a scientific acoustic array in the Arctic Ocean **(Figure.3).**

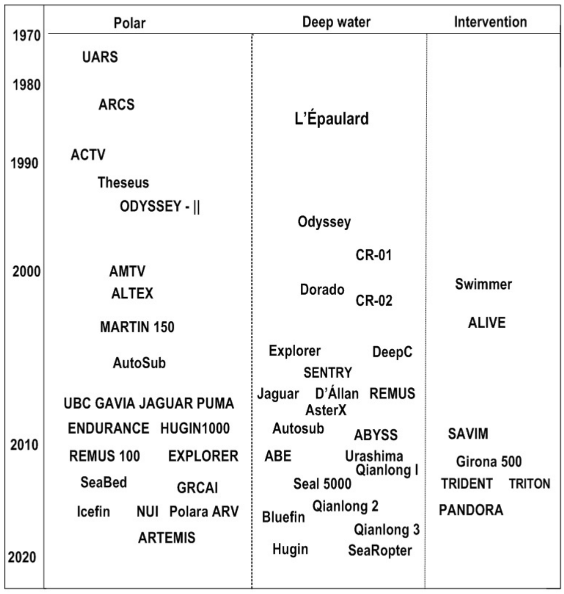


Figure.2. Evolution of AUVs used for Polar and other research

The ability of AUVs to operate autonomously of a host deployment vessel along with scientific payloads including geophysical, geochemical, imaging and oceanographic instruments enables them to be effective in carrying out exploration in the remote challenging polar environments. AUVs are classified based on construction, payloads, communication, navigation, power source, mission planning capability and buoyancy control mechanisms. The AUVs and gliders developed for Polar research indicating its mass and operating range is summarised in **Figure.2.**

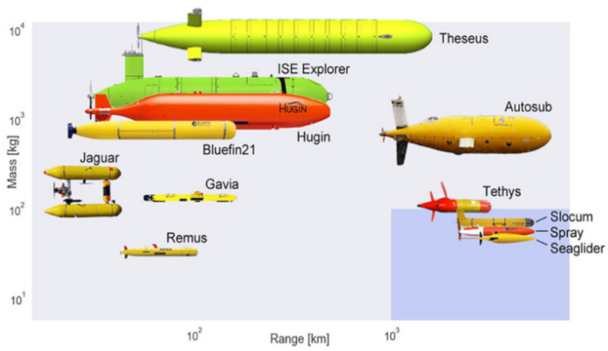


Figure.3. Under-ice robotic vehicles developed for Polar research

The autonomous conductivity-temperature vehicle and REMUS were used in the Winter Lead Experiment (LeadEx) and in the surface heat budget of the Arctic Ocean experiment programs in the Beaufort Sea during 1992 and 1998, respectively.

During 2005, the UK Natural Environment Research Council developed Autosub2 **(Figure.4b)** for studying the

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Fimbul Ice shelf located in the south eastern coast of the Wedell Sea in the Southern Ocean, and in the Petermann Ice Island in the Baffin Bay. The Autosub2 also mapped the glacial bed forms at 840 m water depth on the floor of Kangerlussuaq Fjord in the Western Greenland aimed at mapping the extent of the Greenland Ice Sheet during the last glacial maximum. Following the loss of Autosub2, Autosub3 was developed with increased robustness and redundancy of critical systems, and was deployed beneath the Pine Island Glacier in Antarctica in Jan 2009. The 6.8m long Autosub3 undertook six missions totalling about 510 km in 94h beneath the Pine Island Glacier in the WAIS at distances of up to 50 km from the ice front. The expedition instilled the technical confidence in achieving higher vehicle endurance, precise navigation, collision avoidance and excellent system reliability to gather under ice environmental data.

Following the success of the Theseus AUV, two ISE Explorer AUVs were built and deployed in 2010 in the Canadian Arctic to conduct bathymetric surveys to support Canada's claim to the extent of its continental shelf under the UN Law of Sea Convention **(Figure.4).** The AUV Explorer's navigation system comprised of DVL-aided INS, USBL, short-rang localisation system and a 1376 Hz homing system. Drifting of the remote ice cap and dead-reckoning error accumulation meant that Explorer's recovery location could be >30km away from the expected location. The custom homing solution proved successful at ranges of 50km, and was reported to function at ranges >100km. In total, Explorer logged ~1000km over 3 missions, at depths up to 3160m. During 2013, the Polar Autonomous Underwater Laboratory (PAUL), a Bluefin21 AUV, outfitted with a suite of physical and biogeochemical oceanographic sensors and a water-sampler collected data in the meltwater front of the marginal Ice Zone of Fram Strait.

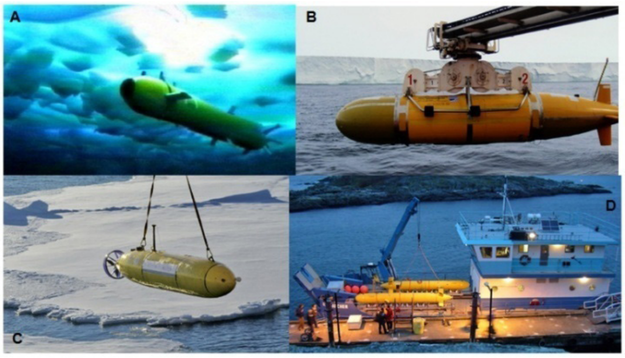

Figure.4. AUVs and gliders developed for Polar research

During 2015, the Nereid under-ice (NUI) lightly-tethered hybrid AUV/ROV (HROV) developed by WHOI and JHU capable of providing real-time human telepresence in the ice-covered waters up to 40kms lateral distances from the deployment vessel enabled under-ice morphology **(Figure.5)** and under-ice biological studies **(Figure.5a).** A 250µm diameter unarmoured lightweight expendable fibre-optic tether enabled real-time remote control by

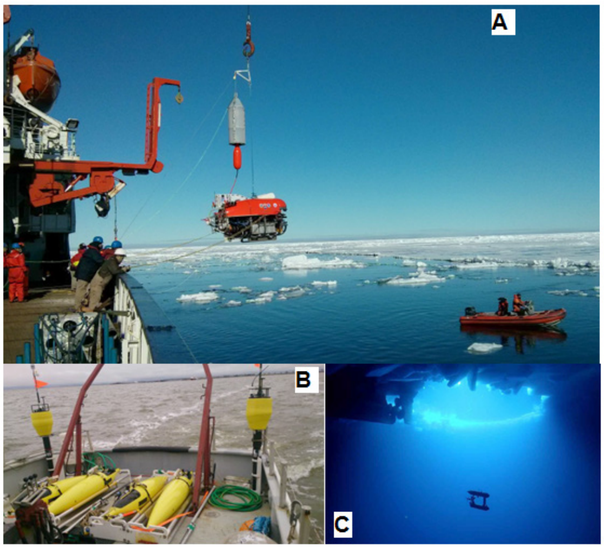

Figure.5. ROVs and gliders developed for Polar research

the ship-board human operators without imposing the constraints on the vehicle and ship motion typical of the traditionally tethered ROV systems. It was equipped with navigation suite including LBL, FOG-IMU and upward- and downward-looking DVL fused with ice-relative navigation algorithm deployed from ice breaker vessel F/S Polarstern. Under-ice light transmission data at the ice-ocean interface and under-ice seafloor surveys were carried out. The under-ice bathymetry done by NUI-HROV is shown in **Figure.6.**

The University of Washington's Applied Physics Laboratory deployed Sea glider in Davis Strait for over a decade **(Figure.5b).** In 2014, a multi-month deployment of Sea glider was conducted to monitor the seasonal melt in the MIZ near 72°N 145°W. An array of through ice-buoys, as well as autonomous surface craft outfitted with acoustic hardware to provide the gliders a means of localisation. Reliable beacon-glider ranges were achievable at distances of up to 400km, even when the gliders were not in the strong sound duct present at 100m depth. This work represents the longest-term under-ice deployment of autonomous vehicles hitherto.

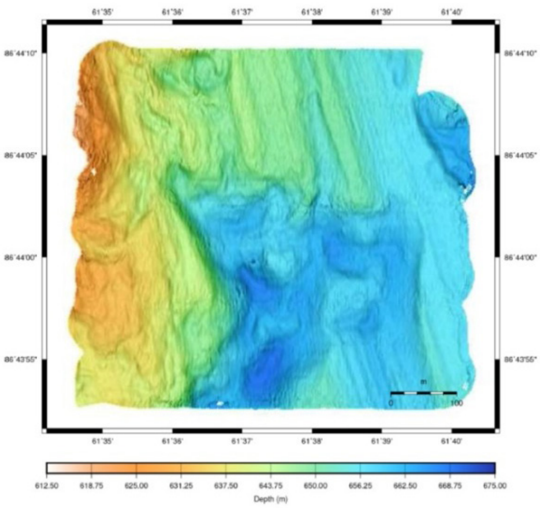

Figure.6. Under-ice bathymetry done by NUI-HROV

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Later in 2016, the Sea gliders were deployed for Stratified Ocean Dynamics of the Arctic (SODA) experiment, multi-year coordinated experiment to measure temperature, salinity, dissolved-oxygen and downwelling irradiance during one-year deployments in the ice-covered waters. During 2019 they achieved the longest excursion of 140km beneath the ice-shelf. In 2010 and 2012, WHOI Seabed-class Jaguar AUV **(Figure.5c)** was deployed in the Weddell and Bellingshausen Seas and East Antarctic waters to conduct high-resolution ice draft measurements. The vehicles utilised ice-relative navigation system, comprising of LBL beacons deployed beneath sea ice outside of the intended work volume, and the vehicles were outfitted with an upward looking DVL. The Jaguar AUV conducting an upward-looking multibeam survey of Antarctic Sea ice with the R/V Aurora Australis (is visible in the background).

The key challenge to AUV operations is the finite mission duration due to the limitation in the on-board energy and data storage. In order to overcome these limitations and to increase the subsea mission duration, underwater homing and docking (H&D) stations, connected to the mother ship of land facility, with provisions to recharge the batteries, upload the acquired mission data, and download the mission profile are undertaken.

Over the past two decades, the H&D technology is being demonstrated in various AUVs including WHOI-REMUS, MIT-Odyssey, ISE-Dorodo and ISE-Explorer based on a combination of acoustics, optical and electromagnetic techniques. Recently, an artificial intelligence (AI)-enabled short-range electro-magnetic homing guidance system (EMHGS) based on differential magnetometry principle was demonstrated in NIOT-MagHomer AUV. During 2022, scientists from German Research centre for Artificial Intelligence (DFKI) carried out field trials of EurEx-LUNa in Abisko, Sweden to prove the feasibility of the concept for autonomous under-ice navigation and H&D. During the qualification, AUV spent around 50h under the ice. **Figure.7a** shows the EurEx-LUNa with upward looking DVL enabling under-ice referenced navigation, 7b shows the picture taken in frozen Lake Torneträsk and 7c shows the AUV homing and docking below the ice.

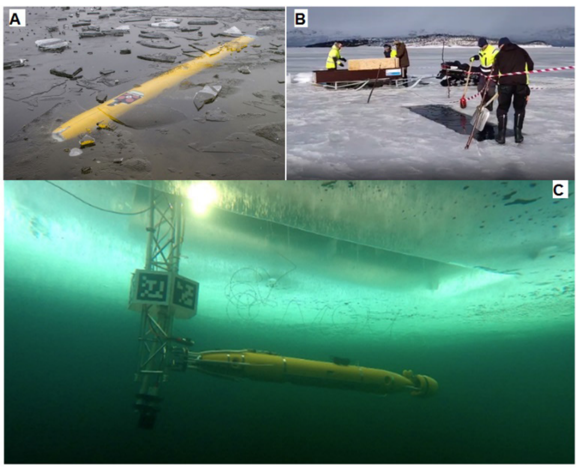

Figure.7. Under-ice bathymetry done by NUI-HROV

The AUV navigation system initialised with the position input from the GPS receiver (when at the ocean surface) works in dead- reckoning (DR) mode during the subsea mission. In DR mode, based on last known or computed position, the navigational algorithm operating on-board AUV controller estimates the current position based on the inputs from navigation sensor suite. The position is updated from the inputs from the APOS (normally USBL) continuously in real-time **(Figure.8).** The technological maturity of present AUV are summarised in **Table. 1.**

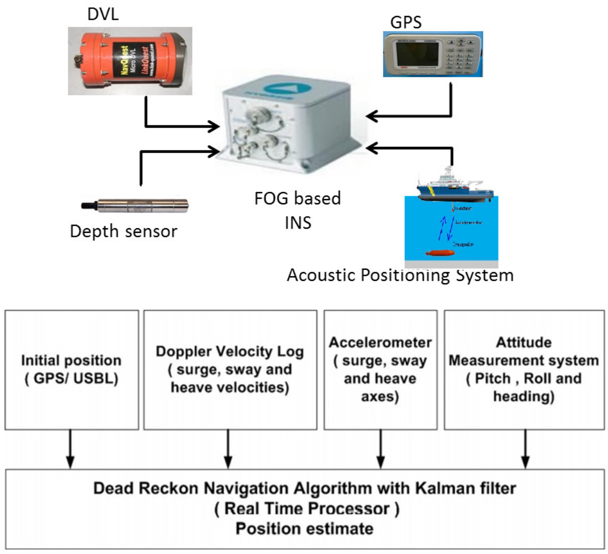

Figure.8. Architecture of Aided-INS

Table.1. Technological maturity of present AUV

Feature	Technological maturity
Navigation	0.01% of distance travelled with a CEP50, heading accuracy of 0.01° sec Lat
Positioning	USBL accuracy with 0.2% of slant range with CEP50
Acoustic telemetry	Data rates of 62kbps in shallow waters at 10W; 9 kbps at 6km range at 55W
Propulsion	~7kms/kWh for a 6m long, 1m diameter, 2T AUV at 3 knots speed;

The path and trajectory planning algorithms that are operational onboard the long-range AUVs are matured based on the mission objectives. With mission objective as inputs, the generic multi-level path and trajectory planning algorithm is shown in **Figure.9.** The mission planning is carried out with the dedicated on-board master mission controller which determines the way paints which serves as inputs for path planning. The path planning algorithm provides set points to the AUV controller which takes input from the vehicle navigation systems and other sensors.

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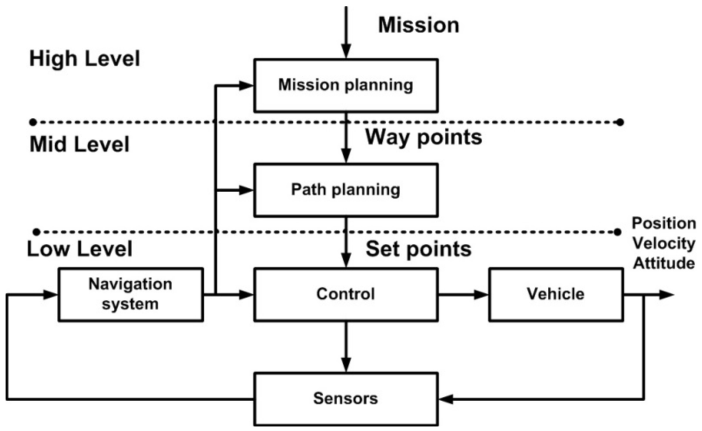

Figure.9. Path and trajectory planning algorithm

Estimating the optimal path requires defining the limits of the AUV operating region/ underwater work space definition, environmental model of the location and the AUV position determining mechanism **(Figure.10).** Path planning is finding the course of the points across which the AUV has to travel from the starting location to the target represented as North-East-Depth (NED) coordinates. The time history of the journey is referred as trajectory planning. The underwater path and trajectory planning require due consideration of the dynamic (time-varying) nature of the ocean currents, presence of obstacles and the morphology of the seabed. The objective anisotropic cost function is to minimise the travel time/lower energy consumption and the constraints including onboard energy availability, positioning accuracy, presence of obstacles, utilising/avoiding the prevailing water currents and vehicle manoeuvrability limitations/agility.

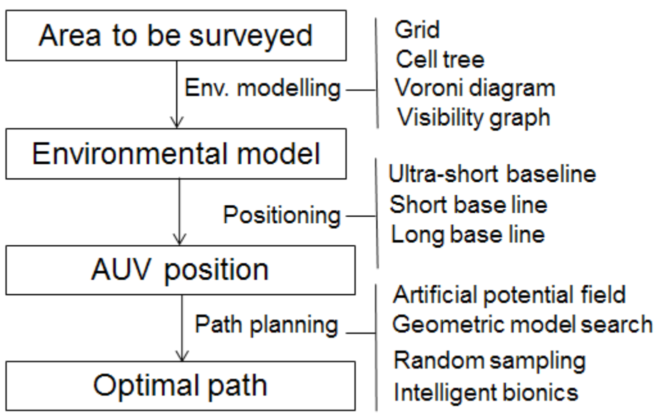

Figure.10. Requirements for way point/optimal path estimation

The under-ice navigation is enabled by the systems summarised in **Table.2.**

Table.2. Under-ice navigation aids

Sensing mechanism	Devices
On-board sensors	Inertial Navigation System, Doppler Velocity Log (including upward looking)
External aids	Acoustic transponders (USBL, LBL), Sonars
State estimators	Terrain relative navigation, Simultaneous Localisation and Mapping

Although the idea of using Human Occupied Vehicles (HOV)/ manned submarines to look at pack ice from underneath has been around since 1930s, it was not until 1958 that a nuclear-powered American submarine (Nautilus) became the first HOVto go under all the pack ice, crossing the North Pole. During 2007, the Russian MIR submersibles were deployed under the ice using the research vessel Akademik Fedorov which was supported by MIG-8 helicopters **(Figure.11).** In contrast to the normal submersible operations, when hydroacoustic beacons are mounted on the bottom, in the ice conditions, the beacons were hung under the ice on a kapron cord through holes frilled in the ice. HOV MIR made one test dive to a depth of 1300m during which the functionality of the systems were validated, as well as the trajectory of the submersibles back into the polynya (cut open ice zone) was practiced.

Figure.11. Manned submersible (MIR) deployed in Antarctica

Unconventional robotic drilling systems

Recently, several research centres have started developing automated rapid-access drilling systems to retrieve short ice core samples from difficult-to-access locations such as icebergs, crevassed glaciers, rugged or thin sea ice. The Submersible Capable of Under ice Navigation and Imaging (SCINI) ROV developed at Moss Landing Marine Labs was designed to allow exploration and research of the under-ice seafloor. Departing from the traditional model of ship-based underwater vehicles, during 2014, SCINI is deployed through holes drilled through a range of Antarctic ice **(Figure.12a)** to map spatial and temporal distributions of chlorophyll, crystal krill and Antarctic silverfish in the McMurdo Sound in Antarctica. A robotic platform comprising of modified commercial hex copter and a 25cm long auger coring system with an inner diameter of 7mm for ice sample collection

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Figure.12. Unconventional robotic systems under development

was developed and tested near Nuuk, Southwest Greenland **(Figure.12b),** is undergoing improvements.

Laser drilling is expected to have considerable potential for ice drilling. Stone Aerospace Labs are developing a 32mm diameter Direct Laser probe operable at varying power levels with a 1070nm ytterbium fibre laser **(Figure.12c).** A long tube served as the body, as the collimating and focusing optics were placed at its end. A laser power coupler, a beam collimator and an optical alignment stage were included in the top of the probe. The system was tested at power levels 50 to 2.5kW. The rate of penetration into an ice block of -26ºC for a laser power of 2.5kW was >12m/h.

Melt probes have been widely used for boring holes in glaciers, ice caps, and ice sheets since their first use in 1940–1941 at the Ross Ice Shelf, Antarctica. Melt probes enforce ice penetration by heating, such that the ice in the vicinity of the probe melts and the probe eventually sinks down. Manoeuvrable ice probe Ice Mole, is one of the successfully demonstrated robotic system having combination of both mechanical and thermal drilling features. The probe comprised a thermal melting head with a central rotating ice screw-driven servo-controlled electric motor and a gear system. The continuously rotating ice screw generated a driving force of >1kN, pressing the melting head against the ice. This enhances the conductive heat transfer into the ice

> *The continuously rotating ice screw generated a driving force of >1kN, pressing the melting head against the ice*

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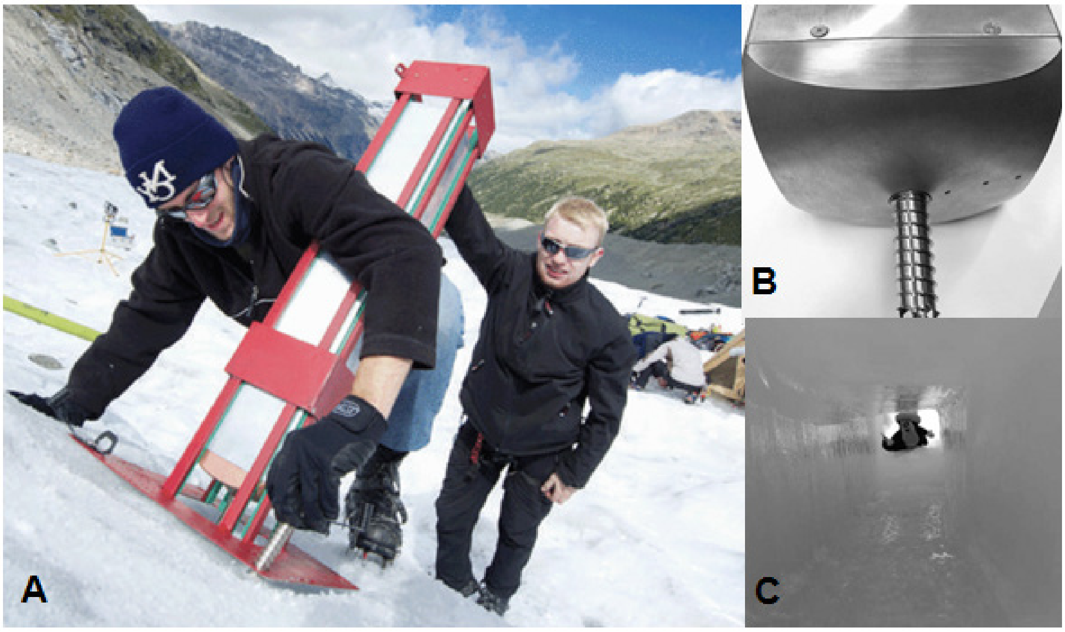

Figure.13. Field demo of the manoeuvrable Ice Mole

and aids steering in the desired direction, including probe motion upward against gravity. The probe when tested in Alps, Iceland and Antarctica showed the high engineering feasibility of this concept **(Figure.13).** A less expensive and simpler solution shown in **Figure.13a** involves a wire-line sidewall thermal coring system. The corer includes a driven unit, bendable core barrel, and thermal coring head. The sidewall coring system can be precisely positioned in the zone of interest. This system is designed to acquire smaller core sample than is possible with replicate coring drills.

There are ideas of using a thermal corer on top of an under-ice glider/AUV/ROV to acquire cores below Polar ice shelves. As the drill head melts the ice, the vehicle's buoyancy aids the corer to penetrate the ice. A finite-element analysis (FEA)-aided design, development and qualification of a 63mm inner diameter, 250mm long variable-power ROV-mountable electro-thermal inductive under-ice corer for collecting core samples beneath Polar ice shelves was developed by National Institute of Ocean Technology (NIOT), India **(Figure.14 a,b).** It comprises of an inner and outer sleeve, core catcher, Teflon-spacer, inductive thermal head and an inductive coil inside the thermal head. It was demonstrated in a controlled environment to have an ice penetration rate of 14mm/min with input electrical power of 1kW at 30kHz. With the corer, it is possible to collect an ice core of 51mm diameter below the ice, if mounted in the ROV with attitude control capabilities **(Figure.14c).**

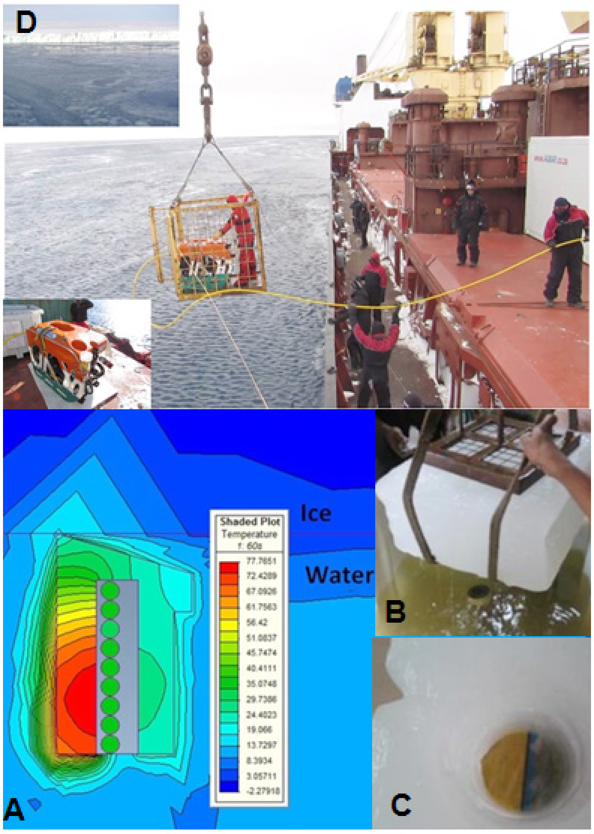

Figure.14. PROVe500 in Antarctica & static inductive ice corer

The FEA helps optimising the design of the corer by reducing the corer tip to coil clearance and ensure maximum flux linkage with the corer tip to ensure highest energy delivery into the corer tip. The design shall help to safely collect the ice for biological studies without affecting the living species inside the collected core. Plans are underway in integrating this corer on top of the NIOT-developed 500m depth-rated PROVe500 (that was deployed in new Indian ice shelf barrier region using the Russian Vessel Papanin during

the 34th Indian Scientific Expedition to Antarctica (ISEA) **(Figure.14a).** The physical properties of the ice shelf water were logged using the PROVe onboard sensors, and the sonar images, for the first-time revealed ice shelf thickness to be >62 m. Mounting this static inductive corer on the PROVe500 shall have drastic advantage over mechanical rotary head that requires precise ROV stability management systems to counter the reaction torque created by the rotary drill.

This huge ocean with an estimated depth of 100km is one of the most likely places for ET life in our solar system

Extra-terrestrial melt probes

The thermal probe developments undertaken for the exploration of sub-surface extra-terrestrial (ET) ice environments on Mars, Europa, Enceladus, and Titan also aid in pushing the technological boundaries of robotic melt probe drilling systems to be used for strategic Polar research. They include Cryobot, SIPR, Valkyrie, Splindle, Ice driver, Ice shuttle Teredo, etc. The Ice shuttle Teredo is an ice-penetrating robotic system to transport an exploration AUV into the Ocean of Jupiter's Moon Europa (Figure.15). **Planetologists predict an ocean of liquid water below an ice shield with 3-15 km thickness.** This huge ocean with an estimated depth of 100km is one of the most likely places for ET life in our solar system. These ET probes are being investigated for operation under low ambient pressure (conditions above the triple-point, which leads to sublimation of ice) and the effect of gravity on the melting process and probe velocity.

Conclusion

Hitherto, ice core obtained from Polar ice sheets and mid-latitude ice caps have improved our scientific understanding on past climate, ice dynamics, sea level rise, biology, planetary sciences, astrophysics and related phenomena. The Greenland ice sheet core that showed the possibilities of dramatic changes in climate that can occur abruptly, revolutionised climate science and had important implications for policy. The West Antarctic Ice Sheet Divide core established the benchmark CO_2 record for the most recent glaciation that helped to investigate the possibility of large sea level change in the near future. Bedrock below the summit of the Greenland Ice Sheet raised questions about the ice sheet's resilience to climate change. Thus ice cores studies will address a variety of questions that are crucial for understanding the processes that control the dynamic stability of glaciers and ice sheets that are crucial for predicting Earth climate, sea level rise and biogeochemical ecosystem. The observations and ice cores recovered from subglacial environments shows microorganisms that exist under permanently dark and cold conditions have broadened our understanding of the phylogenetic and metabolic diversity of life on Earth, and may help inform our search for extra-terrestrial life.

Figure.15. Assembled view of Ice shuttle Teredo

Strategic projects, such as the Askaryan Radio Array and Ice Cube (in the South Pole) require multiple boreholes drilled to at least 150m and 2500m, respectively for installing neutrino detectors. Although contemporary ice-drilling knowledge and techniques are now familiar, there remain many problems to be solved by advanced modern technology. Further, ultra-light drilling equipment are necessary for the extraction of ice cores from extremely remote polar and high-mountain locations, which have a limited logistical framework. Specific challenges related to improving old drilling methods and developing new emerging technologies are summarised in **Figure.16.**

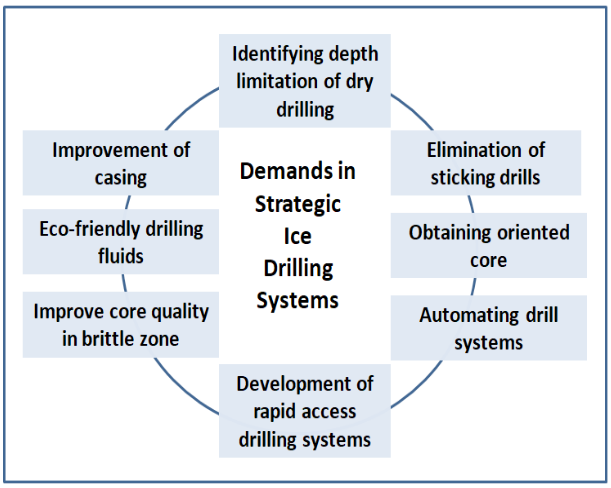

Figure.16.Technological demands in strategic ice drills

Motivated by the potential scalability, limited risk and cost-effectiveness of emerging autonomous underwater vehicles, World Climate Research Program (WCRP) is stimulating progress in this area by developing a Polar Challenge to push the boundaries of existing observing systems and scientific knowledge in both the Arctic and Antarctic. The WCRP and the Prince Albert II of Monaco Foundation are jointly promoting a Polar Challenge, which will reward the first team to complete a 2000km continuous mission with an AUV under the sea ice in the Arctic or Antarctic. The guiding rationale of the competition is to promote technological innovation (including, but not limited to, in AUV endurance, positioning, data collection and transmission) towards a future, cost-effective, autonomous and scalable observing network for sea-ice covered regions based on a fleet of such platforms.

Technology for collecting samples beneath the ice shelves is in the infancy stage. Adopting conventional rotary drilling tools for ROV-mountable under-ice coring is challenging in terms of weight, power requirements, induced vehicle dynamics due to the mechanical rotation, and other complex rotary mechanisms. To overcome these challenges in rotary drills, static drilling systems are required. Increased synergy between ice-science and engineering communities are essential to address various limitations and problems, such as relatively low penetration rates, limited depths, melt water refreezing, long project duration, eco-friendliness, performance, and reliability and safety improvements.

Abbreviations

AI	Artificial Intelligence
AIS	Antarctica Ice Sheet
AUV	Autonomous Underwater Vehicles
BH	Bore hole
DVL	Doppler Velocity Log
ET	Extra-terrestrial
FEA	A finite-element analysis
FOG	Fibre Optic Gyroscope
GIS	Greenland Ice Sheet
GMSL	Global mean sea level
H&D	Homing and Docking
HOV	Human Occupied Vehicles
HROV	Hybrid ROV
INS	Inertial Navigation System
IMU	Inertial Measurement Unit
ISE	International Submarine Engineering
kyr	Kilo-year
LBL	Long base line
MIZ	Marginal Ice Zone
NIOT	National Institute of Ocean Technology
NUI	Nereid under-ice
PAUL	Polar Autonomous Underwater Laboratory
ROV	Remotely-Operated Vehicles
SCINI	Submersible Capable of Under ice Navigation and Imaging
SODA	Stratified Ocean Dynamics of the Arctic
UARS	Unmanned Arctic Research Submersible System
USBL	Ultra-short base line
WCRP	World Climate Research Program
WHOI	Wood hole Institute of Oceanography

ACKNOWLEDGEMENTS

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Dr. N. Vedachalam is currently Scientist G in National Institute of Ocean Technology; Chennai. He is the Project Director for India's first indigenous deep-water human scientific submersible Matsya6000 developed under the Deep Ocean Mission of Govt. of India. His 30 years of experience include industrial power, process, offshore and subsea domains at Aditya Birla group, General Electric & Alstom Power Conversion in France. His research interests include energy, subsea robotics and reliability. He has more than 100 publications, holds international and national patents.

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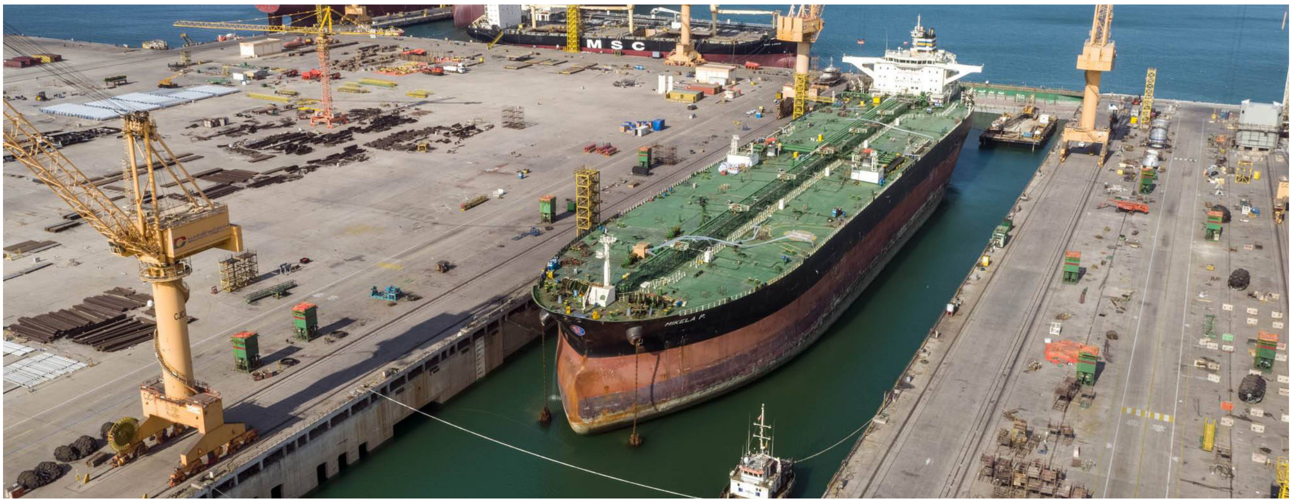
DEVELOPMENT OF A SHIP REPAIR AND RECYCLING FLOATING DRYDOCK FACILITY



Debashis Chatterjee

Abstract: This article explores the conceptualisation, design and operational planning of a Floating Drydock facility dedicated to ship repair and recycling. Given the increasing global focus on sustainable maritime practices and green recycling initiatives, the proposed facility aims to provide an environmentally responsible, efficient, and cost-effective alternative to conventional shipyards.

1. Introduction:

With aging fleets and evolving environmental regulations, there is a growing demand for responsible ship dismantling and mid-life repairs. Floating Drydocks offer a mobile and modular solution, particularly suitable for coastal regions with limited land-based infrastructure. These Notes present a comprehensive framework for a Floating Drydock that integrates ship repair and recycling capabilities.

2. Project Objectives:

Establish a modular floating facility for drydocking vessels up to TLC : 35000 t

Provide integrated services for ship repair, retrofitting, and recycling.

Ensure compliance with international environmental standards (e.g., IMO, EU, HKC, Basel Ban, MARPOL).

Create local employment and skill development opportunities.

3. Site Selection Criteria:

Proximity to maritime traffic lanes.

Calm waters with minimal tidal variation.

Accessibility to support infrastructure (e.g., ports, roads, utilities).

Environmental impact assessment and regulatory clearance.

4. Design and Technical Specifications:

Drydock Type: Modular Pontoon-based Floating Drydock.

Total Lifting Capacity : 35000 t

Ballasting/De-ballasting System: Automated, sensor-driven system.

Cranes: Two(2) Electric Travelling Cranes , one on each side wall of the dock , capable of lifting the maximum safe working loads of 30 tons at 27m.

Environmental Systems: Waste segregation units, bilge water treatment, sewage treatment setup.

5. Operational Planning:

Repair and maintenance bays.

Dismantling zones with containment systems.

Hazardous material handling protocol (asbestos, oils, batteries).

Crew/workforce accommodation and welfare facilities.

Safety Management System (SMS) in compliance with ISM Code.

6. Environmental and Regulatory Compliance:

Ship Recycling Plan (SRP) in line with the IMO, EU and Hong Kong Convention.

Pollution control measures (air, water, noise).

Recycling of steel and components.

Certification: ISO 14001, ISO 30000, HKC Compliance.

7. Economic and Social Impact:

Job creation for skilled and semi-skilled workers.
Development of ancillary industries.
Contribution to circular economy.
Training and certification programs for workforce development.

8. Conclusion and Future Scope:

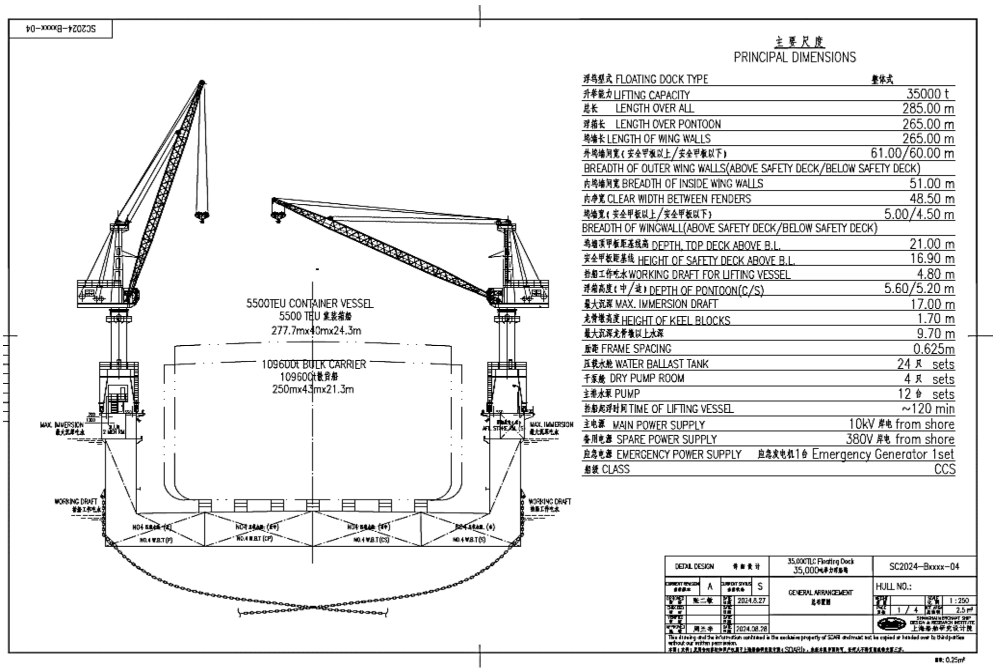
The Floating Drydock facility offers a sustainable maritime solution for ship repair and recycling, especially in regions lacking in fixed yard infrastructure. With scalable design and robust environmental controls, such a project aligns with global maritime sustainability goals. Future expansions could include green retrofitting for alternative fuel systems and hybrid propulsion units.

References:

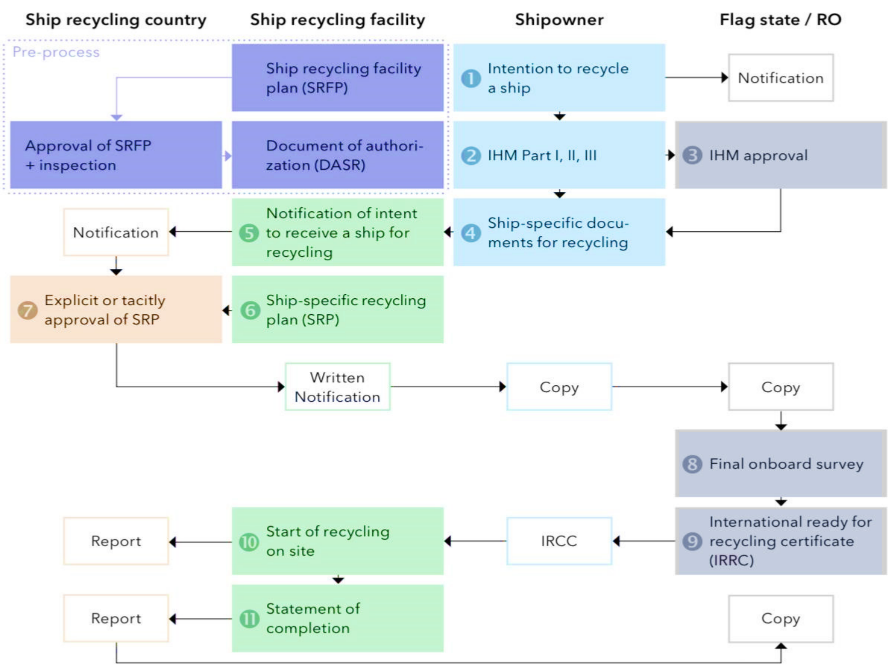
[Project Management Team, EEC Marine LLC, Abu Dhabi, UAE, Shanghai Merchant Ship Design and Research Institute, DNV Ship Recycling Guidance Paper]

Appendices:

Appendix A: Conceptual Design Sketch



Appendix B: Process Flow Diagram



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Appendix C: Cost-Benefit Analysis (CBA) Summary

Cost-Benefit Analysis Summary

1. Capital Expenditure (CAPEX)

Component	Estimated Cost (USD)	Notes
Floating Drydock Fabrication & Commissioning	$25 – $40 million	Modular, 30,000 DWT capacity
Tugboats & Support Vessels	$3 million	For manoeuvring and positioning
Cranes and Heavy Equipment	$2.5 million	Deck cranes, mobile lifts
Environmental Systems	$1.5 million	Waste treatment, pollution control
Accommodation & Welfare Facilities	$1 million	Onboard and onshore support
Setup & Licensing	$0.5 million	Permits, certifications
Total CAPEX Estimate	$33.5 – $48 million	Varies based on location and specs

2. Operational Expenditure (OPEX) (Annual)

Expense Head	Estimated Cost (USD)	Notes
Workforce Salaries & Training	$2 – $3 million	Skilled, semi-skilled, HSE training
Maintenance & Utilities	$1 – $1.5 million	Fuel, power, water, consumables
Environmental Compliance	$0.5 million	Monitoring, audits, waste disposal
Insurance & Safety	$0.3 million	Equipment and facility insurance
Administration & Misc.	$0.2 million	Office operations
Total OPEX Estimate	$4 – $5.5 million/year	Economies of scale possible

3. Revenue Projections (Annual)

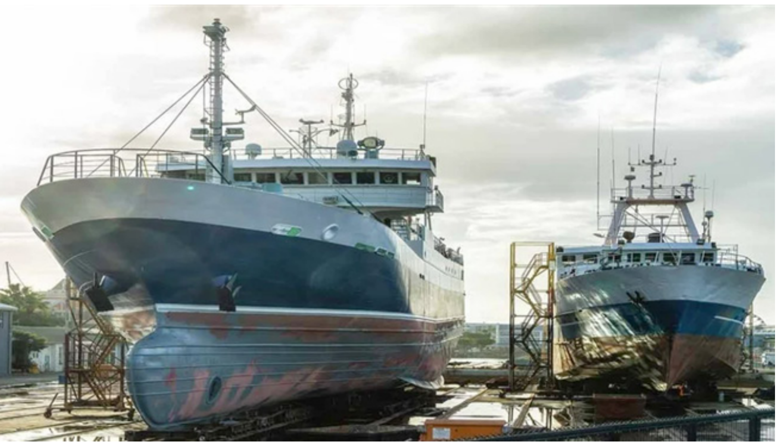
Income Stream	Estimated Revenue (USD)	Notes
Ship Repair Services	$5 – $8 million	Based on 20–30 vessels/year
Recycling Income (scrap sales)	$3 – $5 million	Steel, equipment resale
Component Recovery & Resale	$1 – $2 million	Engines, machinery, spares
Ancillary Services	$0.5 – $1 million	Mooring, logistics, storage
Total Annual Revenue	$9.5 – $16 million	Dependent on capacity utilisation

4. Payback & ROI Estimate

Break-even period: 4–6 years (at 70–80% utilisation)
Internal Rate of Return (IRR): 12–18%
Net Present Value (NPV): Positive NPV within 6–8 years based on conservative estimates

5. Intangible and Strategic Benefits

Environmental Impact Mitigation: Reduced coastal pollution and sustainable shipbreaking
Job Creation: 300–500 direct and indirect jobs
Compliance & Brand Positioning: HKC and ISO certification enhances credibility
Scalability: Facility design allows future upgrades (LNG retrofitting, alternative fuel modules)



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Debashis Chatterjee (F-5863) graduated from DMET (1977-81). At present involved with a project management for new building floating dry dock, EEC Marine LLC, Abu Dhabi, UAE and will be involved in the new building orders for the floating dry dock. He is an experienced Chief Engineer having worked for Laurel Ship Mgmt. Pt. Ltd., Singapore. (CE on board VLOCs , Cape Size Bulk Carriers), Anglo Eastern Ship Mgmt. Pt. Ltd, Hong Kong (CE on board Kamsarmax, Panamax Bulk Carriers) and Orient Ship Mgmt. Pt. Ltd., Hong Kong (CE on board Panamax Bulk Carriers). He was awarded as 'Chief Engineer of the Year, 2022' by Laurel ship Mgmt. Pt. Ltd, Singapore and QSHE Award on board Anglo Eastern vessels. He is also a Fellow of Institution of Engineers (India).

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Navigating the High Seas: Occupational Therapy Strategies for Managing Stress and Improving Well-being among Marine Seafarers (Part 2)

(Supporting Seafarers' Mental Health in the Demanding World of Maritime Work)

Neha Jain, Yash Jain

Occupational Therapy Interventions for Maritime Personnel

In this section, we will provide an overview of some of the different occupational therapy interventions that can be used to support seafarers' well-being and enhance their quality of life.

Cognitive-behavioural therapy (CBT) is a common intervention used by occupational therapists to help seafarers manage stress and improve their mental health. CBT involves identifying and changing negative thought patterns and behaviours that can contribute to stress and other mental health problems. This approach has been shown to be effective in reducing symptoms of depression, anxiety, and post-traumatic stress disorder (PTSD) in seafarers. [1][4]

Mindfulness is another intervention that has been shown to be effective in reducing stress and promoting well-being among seafarers. Occupational therapists can teach seafarers mindfulness techniques such as meditation and breathing exercises. [2]

Relaxation techniques such as progressive muscle relaxation and guided imagery can also be effective in reducing stress and promoting relaxation among seafarers. Occupational therapists can teach seafarers these techniques. [3]

Occupational therapists also work collaboratively with other healthcare professionals, such as physicians, psychologists, and social workers, to provide comprehensive care for seafarers. This multidisciplinary approach can help ensure that seafarers receive the support they need to manage physical and mental health concerns, as well as other challenges they may face while at sea.

In conclusion, occupational therapy interventions such as CBT, mindfulness, and relaxation techniques can be effective in promoting the well-being of seafarers. By working collaboratively with other healthcare professionals, occupational therapists can provide comprehensive care for seafarers that addresses their unique needs and challenges.

Cognitive-behavioural therapy (CBT) is a common intervention used by occupational therapists to help seafarers manage stress and improve their mental health

Collaborative Care Models for Supporting Seafarers' Mental Health

The mental health of seafarers is a complex issue that requires a collaborative and interdisciplinary approach to address. Collaborative care models can help to improve access to mental health services and support the well-being of seafarers both at sea and onshore. This section explores the different collaborative care models that can be used to support seafarers' mental health, including multidisciplinary teams and telehealth services.

Multidisciplinary Teams: A multidisciplinary team (MDT) approach involves healthcare professionals from different disciplines working together to provide comprehensive care to patients. In the context of seafarers' mental health, MDTs can include occupational therapists, mental health professionals, physicians, and other healthcare providers. MDTs can work together to identify and address seafarers' mental health needs, provide education and training on mental health and well-being, and develop individualised treatment plans. MDTs can also work to promote mental health and well-being among seafarers through health promotion and prevention programs.

Telehealth Services: Telehealth services, such as telemedicine and teletherapy, use technology to deliver healthcare services remotely. Telehealth services can be a valuable tool for supporting seafarers' mental health, especially for those who are unable to access in-person mental health services while at sea. Telehealth services can include video conferencing, remote monitoring, and digital health platforms. Telehealth services can also facilitate communication and collaboration between seafarers and their healthcare providers, as well as between different healthcare providers.

> *"Collaborative care models offer several benefits for supporting seafarers' mental health, including improved access to mental health services, enhanced communication and collaboration between healthcare providers, and the provision of comprehensive care"*

Benefits and Challenges: Collaborative care models offer several benefits for supporting seafarers' mental health, including improved access to mental health services, enhanced communication and collaboration between healthcare providers, and the provision of comprehensive care. However, there are also several challenges associated with implementing collaborative care models in the maritime industry. These challenges can include limited resources, difficulty coordinating care across different settings, and the need for specialised training for healthcare providers. [5][6][7][8]

Safety and Injury Prevention for Maritime Workers

Seafarers face a range of safety concerns that are unique to their work environment. From hazardous weather conditions to accidents related to heavy machinery, there are numerous risks that seafarers face on a daily basis. In this section, we will explore some of the safety concerns faced by seafarers and the strategies that occupational therapists use to promote safety and injury prevention.

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Venue

Vivanta Ernakulam, Marine Drive, Kochi

Organised by

The Institute of Marine Engineers (India), Kochi Branch

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The Risk of Accidents and Injuries

Seafarers work in a challenging and dynamic environment, which exposes them to a range of risks that can lead to accidents and injuries. Heavy machinery such as cranes, winches, and forklifts are commonly used in the maritime industry, and can pose a significant risk to seafarers if not operated properly. Slippery decks, extreme weather conditions, hazardous cargo, and the risk of falls and drowning are other examples of risks that seafarers face on a daily basis. In addition, seafarers may face health risks related to the long periods of time spent at sea, including mental health concerns such as stress and depression. Accidents and injuries can have serious consequences for seafarers, including long-term disability, loss of income, and reduced quality of life.

Preventing Injuries and Promoting Safety

Occupational therapists, along with seafarers, identify potential hazards in the workplace, develop strategies to reduce the risk of accidents and injuries, and provide education on safe work practices. Some of the strategies that occupational therapists use to promote safety and injury prevention for maritime workers include:

Education and training: Occupational therapists educate seafarers about the risks they face and provide training on how to operate the machinery safely, handle hazardous cargo, respond to emergencies and also on safe work practices, such as proper lifting techniques and the use of personal protective equipment.

Ergonomic assessments: Occupational therapists can assess the work environment to identify potential ergonomic hazards, such as awkward postures or repetitive motions, and develop strategies to reduce the risk of musculoskeletal injuries.

Environmental assessments: Occupational therapists can assess the physical work environment, such as the lighting and ventilation, to identify potential hazards and make recommendations for improvements.

Fitness for duty evaluations: Occupational therapists assess the physical and mental fitness of seafarers to perform their job safely.

Rehabilitation services: Occupational therapists provide rehabilitation services to seafarers who have been injured on the job to develop rehabilitation plans and support, helping them to recover and return to work safely.

In summary, seafarers face a range of safety concerns in the maritime industry, and occupational therapists play a critical role in promoting safety and preventing injuries. By identifying potential hazards and developing strategies to minimise risk, occupational therapists can help to ensure that seafarers are able to work safely and effectively. It is important for the maritime industry to prioritise safety and injury prevention in order to protect the well-being of seafarers and maintain a productive workforce. [9][10][11][12][13]

References

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About the Authors

Dr. Neha Jain is a Professor at Mahatma Gandhi Occupational Therapy College in Jaipur, India and holds a PhD in Occupational Therapy. She has over 10 years of experience and is an active member of the All India Occupational Therapists Association (AIOTA). She has published several papers in national and international journals and has received awards for her clinical and research excellence. She also holds an MD in Yoga and has authored the book 'Barriers and Facilitators of Geriatric Smart Home Technology Implementation.'

Yash Jain (F13831) is a Mechanical Engineer from Jaipur, India, holding a BE from Govt. College Bikaner and a PGD in Marine Engineering from MERI, Mumbai. He has served as an Assistant Plant Engineer for the Mumbai Metro Rail project and is currently a sailing marine engineer officer in Njordships Management India Pvt. Ltd. Yash's research interests include marine renewable energy and holistic wellness practices. He has co-authored the book 'Barriers and Facilitators of Geriatric Smart Home Technology Implementation.'

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Going Astern into MER Archives…

The OPINION starts with comments on a 1984 Report by Chairman of Salvage Association that mentions on 'economies' being the direct/indirect cause of incidents (some disastrous). The next piece under the column is interesting. It talks about 'robot ship' being developed by Japan Ship Machinery Development Association (sail assisted; remotely controlled) intending to operate between Tokyo and Los Angeles. There is a mention of Defence (UK) operated vessels remotely operated from 65 miles away. The autonomous vessel concept germination can be traced maybe further down the times.

The first article is on thyristor controlled starting. All marine engineers will be familiar with the concepts of impedance, resistance and the starting current characteristics in induction motors. This is an educational piece on induction motors.

Fig 5: Starting torque comparison between DOL and solid-state soft starter for a typical cage motor.

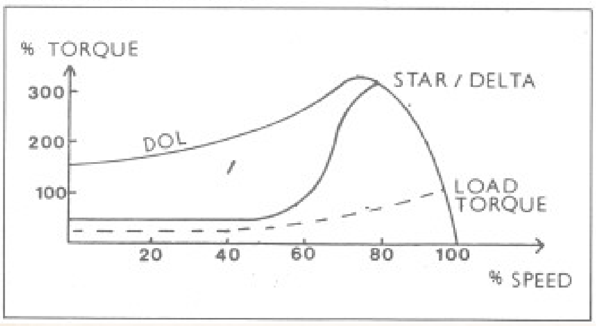
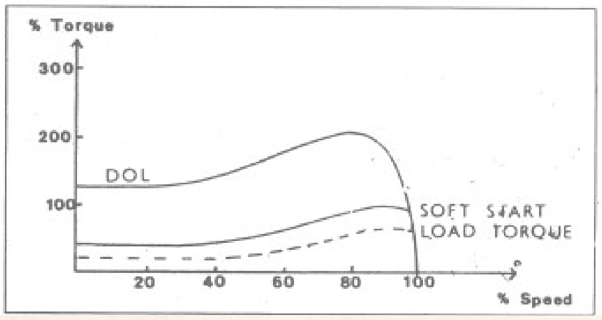


Fig 6: Acceleration time comparison between DOL and solid-state soft starter for a typical cage motor.

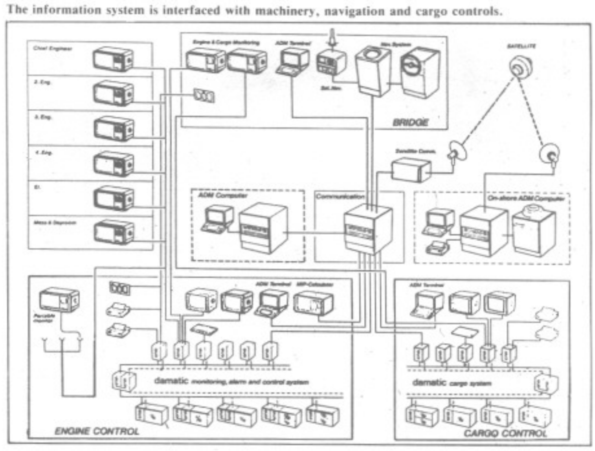


The next article on fault-finding in microprocessors will certainly be of use to young marine engineers. This is followed by another three articles on Instrumentation & Controls (boiler/protection of shipboard electronics/ computerised data.

Table 1: Main causes of malfunction.

- Faulty component manufacture, leading to early failure. This should normally be avoided by the manufacturer's 'burn-in' tests before installation.
- Electromagnetic interference caused by radio-frequency radiation from electrical equipment. Screening, earthing and filtering are used to prevent it. Screening normally includes metal enclosures and conductive braiding. Conductive plastic foam is now being introduced. Any breaks in screening can cause problems, so conductive door seals and cable screening joints require careful attention. Screens should be earthed to a common point.
- High temperatures will cause most chips to malfunction. Since the latter generate their own heat, adequate cooling is essential, and the airflow round enclosures must not be obstructed.
- Contamination, such as by condensation and dust, can cause short circuits, so attend to seals round doors and cable entries etc.
- Vibration can cause odd signals, especially at connection points. Edge connectors are particularly vulnerable and should be rigidly and robustly connected to the board. Excessive interchanging of boards can wear out the gold flashing.
- Other causes include power line disturbances, induced currents in nearby conductors (crosstalk), and electrostatic discharges. These discharges, often from people, especially in low humidity, can ruin some chips (eg CMOS).

The information system is interfaced with machinery, navigation and cargo controls.

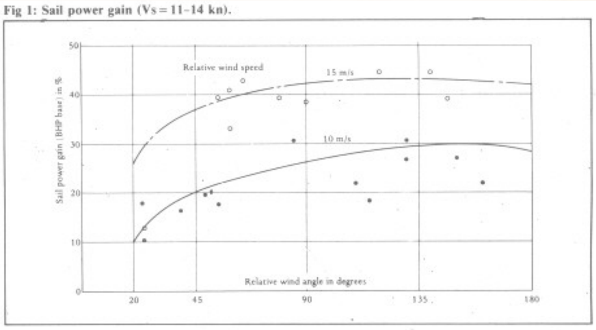


The next article on fuel saving results of a sail-fitted (parallel, furling, aerofoil sails) bulk carrier. This is followed by more wind power information from 'Windtech 85' forum. This is quite informative and will be of interest to engineers engaged in wind power energy projects.

Table 1: Fuel oil consumption results of 'Usuki Pioneer'

Item		To America	To Japan	Average
Navigation distance		4568 miles	4396 miles	
Navigation days		14·96 days	16·2 days	
Mean navigation speed		12·7 kn	11.3 kn	12·0 kn
Mean load % including sail use		59·8%	66·9%	63·4%
Mean FOC (Main engines)		12·5 t/day	13·9 t/day	13·2 t/day
Min	FOC (Main engines)	6·3 t/day	9·0 t/day	
	Load % (Main engines)	40·3%	43·4%	
	Ship speed	11·5 kn	11·4 kn	
	Navigation miles/day	270 miles	278 miles	
Mean FOC (Total ship)		14·0 t/day	15·85 t/day	14·93 t/day

Fig 1: Sail power gain (Vs = 11–14 kn).



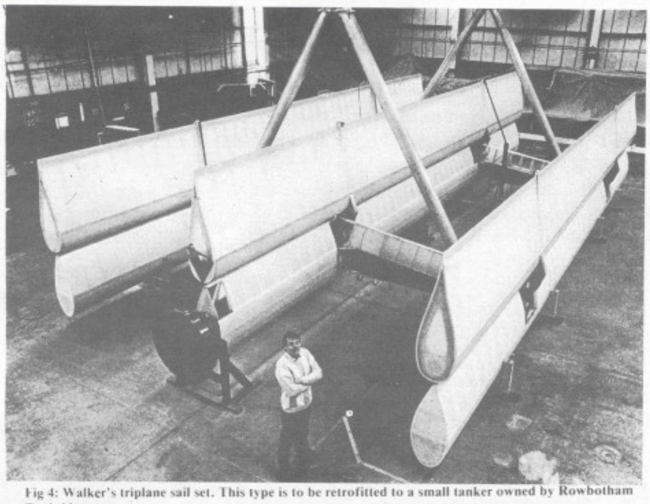
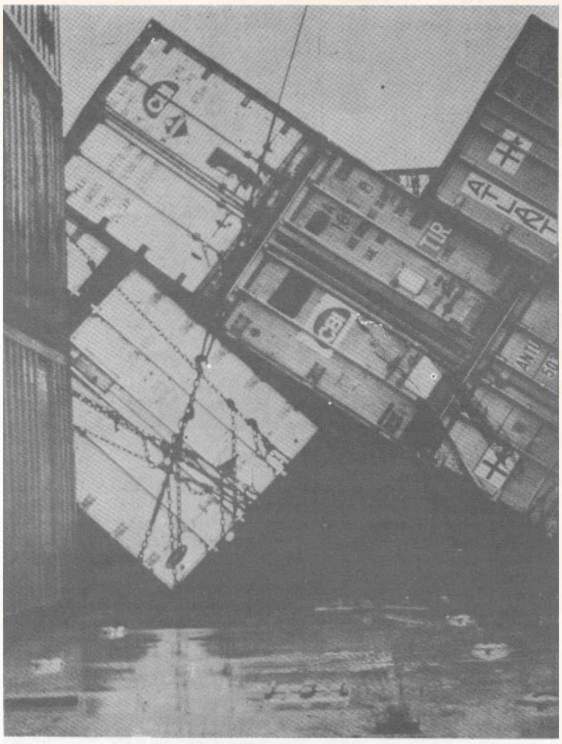
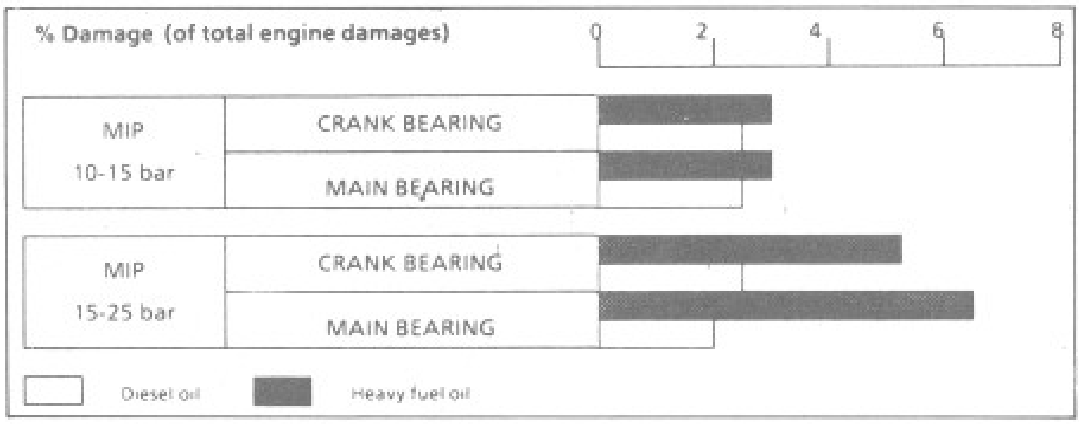


Fig 4: Walker's triplane sail set. This type is to be retrofitted to a small tanker owned by Rowbotham Tankships.



Severe damage as a result of inadequate securing devices

The next article on container safety on board has currency to the present times. There is one brief report on engine bearing damages worth looking at. I have inserted three book review worth having a look at.



We invite observations, discussion threads from readers, taking cues from these sepia-soaked MER pages. – Hon.Ed.

IME (I) GOVERNING COUNCIL, BRANCH, AND CHAPTER COMMITTEE ELECTIONS 2025-27

As the elections for The Institute of Marine Engineers (India) approach, we wish to notify all Corporate Members of the following procedures:

Dear Member,

Members who are eligible to vote in the upcoming elections will receive an email from the official CDSL email ID gogreen@cdslindia.co.in on **12th July 2025** . The email will be sent under the name **"The Institute of Marine Engineers"** with the subject line: **"The Institute of Marine Engineers E-voting Instructions."**

This email will contain the procedure for e-voting for the ongoing elections for the **2025–2027 Term**.

We request members to also check their **spam or junk folders**, in case the email is not found in the inbox.

The email will include:

- Details of the election for the **posts of President and Vice-President.**
- Details of the **Mumbai Branch elections** for the posts of Chairman, Vice Chairman, Honorary Treasurer, Governing Council Members, and Executive Committee Members.
- Your **login credentials**, including the password for e-voting.

Please follow the instructions provided in the email from CDSL carefully.

Kindly note:

- No other emails will be sent from CDSL regarding e-voting.
- You will **not** be asked to share any personal details such as **DEMAT account number, trading account number, or PAN**

For any difficulties or queries, please write to **administration@imare.in** with a copy to **electionofficer@imare.in**

Regards,
Election Officer
The Institute of Marine Engineers (India)

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