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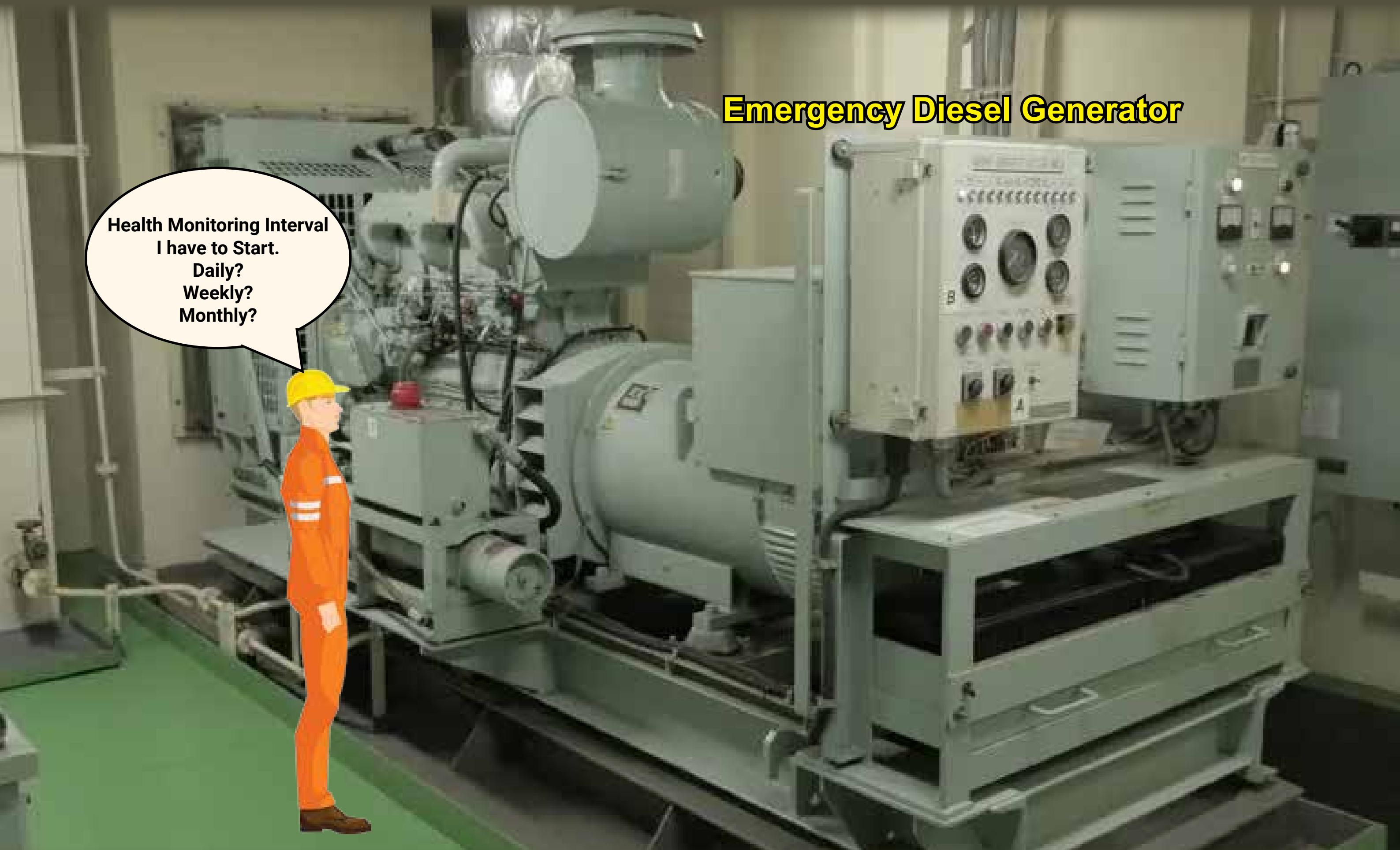

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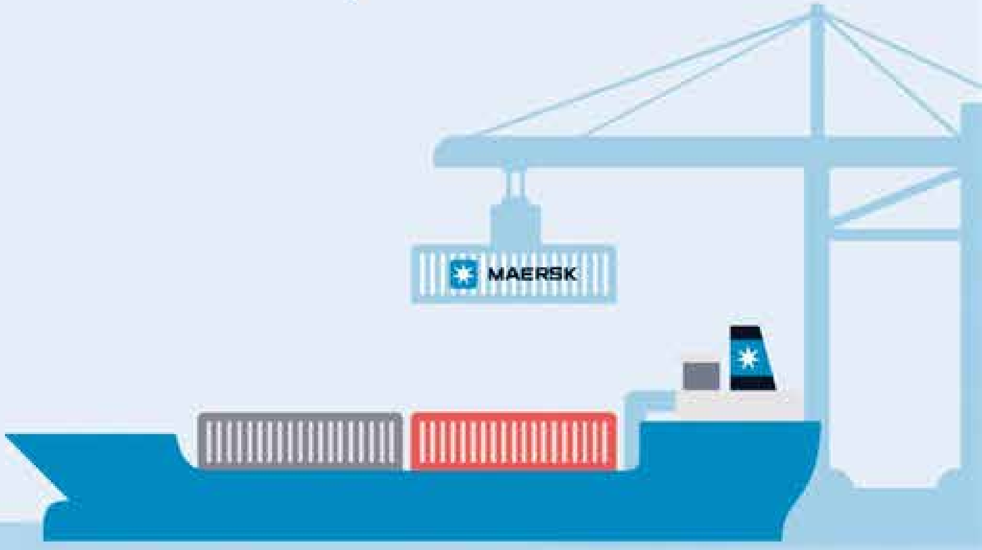

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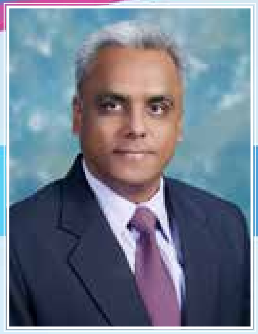
EDITORIAL



Life's roughest storms prove the strength of our anchors.
-Anonymous

It will not be a hyperbole to say that financing the shipping sector is to finance the finance fountain. The Maritime Development Fund has been conceptualised to boost the shipbuilding sector and push the single digit Indian tonnage towards double digits. Apart from shipbuilding, the elements of this ambition-anchorchain include ship leasing, financing for ship-ownerships, National flagging etc. The initial corpus could be to the tune of INR 25000 crores. This would certainly need a thick budget wad from the national purse.

Tapping external sources is another way to add heft to the funding chest. As an enabler, the Gujarat International Finance Tec-City (GIFT City) opened up for international shipping companies to set shop. A few Companies have come in, but the GIFT City must be as good as it looks to turn attention from the comfortable markets of Dubai, Singapore and the like. Favourable tax laws and concessions, lesser operational expenses (lesser wages/rentals/power costs) have to work to win the confidence of the market players. The International Finance Services Centres Authority (IFSCA), who has fashioned this framework for making the Indian shipping industry as multibillion-dollar behemoth might still have some more thinking to do.

The latest shackle connecting up is the Non-Banking Financing model, which is to be nested under the Sagarmala scheme of things. Though this is a familiar model, the Indian systems' weariness to ship financing has to be overcome. Bitten with the experiences of shipping yards and shipping companies going belly up, Indian financing has been in a benighted mode when it comes to ship financing. In this, India could learn its lessons from Japan and Korea who had shown resilience during recession phases and made progress relying on shipping. The forging of this financial anchor-links must withstand the tests of times. This is imperative as India looks at all avenues (and waterways) to progress.

In this issue...

We start with an interesting discussion on monitoring the health of Emergency Diesel Generators. Authors Dr. Veda and Suresh Kumar begin with the familiar SOLAS regulations and explain the approaches in determining the reliability requirements. Then scenario based Probabilistic Reliability Assessment (PRA) approaches are explained. The discussions are extended for integrity management analyses in stages. The methodologies using probabilistic modelling and field failure data will be an interesting read for both researchers and practicing marine engineers.

This is followed by an educative article on microplastics. Dr. Thangalakshmi et al., discuss the distribution patterns of microplastics in marine coastal systems, the decomposition mechanisms, quantify the pollutants and remedial absorbents which could be employed to mitigate the microplastics' menace. Not to be left out, the harmful effects of these pollutants are also explained. This is an easy read though lengthy.

Next, we pack in with an article in continuity with the last issue on fisheries. Sherry Koshy Verghese takes us through the maladies of illegal fishing, overfishing and generally attributes these to 'primarily because of unsustainable fishing practices and lack of implementation and execution of adequate fisheries regulatory action'. There are references to the Schemes promulgated by the Government and how they may bring benefits. The article has quite some fishing related data and is an easily digestible read.

MER Archives has one interesting article on simulator (based on Sulzer 6RND90M). This can be a discussion topic for the present day marine engineers juxtaposing the modern simulators. The Transaction on neutral/earthing of electrical systems on board is one more write-up that could be of interest to practicing marine engineers.

Our Olympic burlap from Paris has more marine material (bronze). It is still bronze age but with a silver lining. While hopes thrive, here is the September issue for your reading pleasure.

Dr Rajoo Balaji
Honorary Editor
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MARINE ENGINEERS REVIEW INDIA

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Approach to Integrity Management of Marine Emergency Diesel-Generators

N. Vedachalam, C. Suresh Kumar

Abstract

According to International Maritime Organization - Safety of Life at Sea convention, in the event of ship/ platform power black-out, emergency diesel generators must power the emergency loads. The healthiness monitoring interval to ensure their availability during a black-out is seldom defined by the regulatory agencies, and hence based on subjective judgements.

The article, for the first time, describes a probabilistic reliability and safety-centered methodology based on IEC61508 standards to quantitatively determine the Safety Integrity Level and Health Monitoring Interval for well-maintained emergency diesel-engine driven generators used in marine/offshore applications, to ensure their available on-demand.

By numerical modelling and simulations, with field-failure data as input, it is identified that, in a marine/ vessel power system with fully-redundant power generation capacity, diesel-engine driven emergency power generators should have a system health monitoring interval of ~1 day and ~7.5 days to comply with Safety Integrity Level 3 and 2 of on-demand reliability.

Introduction

Increased regulatory requirements, spiraling maintenance costs and enhanced Health, Safety and Environmental (HSE) requirements have led marine organisations to proactively manage their offshore assets. Integrating reliability and safety requirements during the design/ system engineering and operational phases helps organisations to effectively optimise their life-time value **(Figure 1).** The objective is to identify a trade-off between the cost and effectiveness in terms of performance, reliability and safety, and to ensure that the risk to human, equipment and the environment are within the acceptable level.

The increasing technical complexity and their operations in challenging offshore environments demand precise quantification of reliability and safety. Compared to the qualitative methods, **Probabilistic Reliability Assessment (PRA)** is a robust and proven methodology that provides quantitative results that support asset owners in improving reliability, safety and gaining visibility on the assets that are most critical to safe operations.

As indicated in **Figure 1,** survivability of the crew during an emergency situation is one of the key requirements, in which the Emergency Diesel Generator (EDG) set/s play a pivotal role. **Based on the International Maritime Organization (IMO) - Safety of Life at Sea - SOLAS 74 convention, in the event of ship/platform mains failure, EDG must provide power to critical loads including**

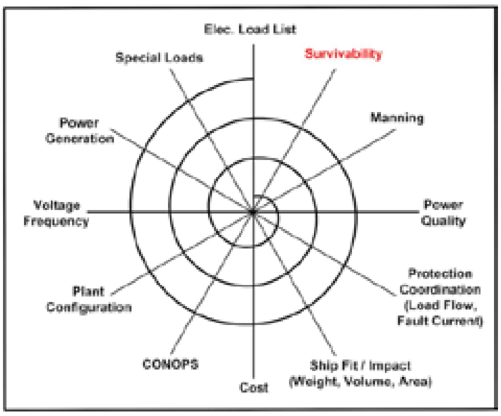

Figure 1. Iterative system engineering of marine power systems

> *According to the SOLAS-19 regulations, these EDG sets shall be self-contained and independent of the other engine room systems*

emergency lighting, navigation and communication equipment, steering gear, fire and sprinkler pumps, bilge pump, water-tight doors and lifts.

According to the SOLAS-19 regulations, these EDG sets shall be self-contained and independent of the other engine room systems. They need to have independent systems for starting, fuel oil, lubrication oil, cooling, preheating capable of starting at an ambient temperature of 0ºC and operating with a vessel list and trim of 10º and 22.5º, respectively.

The SOLAS recommends the automatic starting system and the characteristics of the prime-mover should ensure that the EDG carries the required load as quickly as is safe and practicable, and within a maximum period of 45 seconds, and cater continuous power (18h for cargo and 36h for passenger vessels). The EDG failure-to-start during an emergency/crisis leads to catastrophic conditions, and hence it should always be available on-demand.

Determining Reliability Requirements

The methodologies for determining the reliability requirements for a system based on deterministic and probabilistic approaches are represented in **Figure 2.**

In deterministic approach, the System Engineering is based on **straight-forward safety principles** for the operational requirements.

In the probabilistic approach, the adequacy of the reliability and the risk-reduction are verified and accepted with the aid of **quantitative reliability and risk assessment** methods. The PRA tools are scenario-based risk assessment techniques that quantify the likelihoods of various possible failure scenarios and their consequences. Thus quantitative PRA estimations using numerical methods based on field-failure data & published failure models serve as a yardstick for comparing alternate technologies, continuous improvements and maintenance planning of time-critical systems.

The failure rate of a system defined in Failure-In-Time (FIT), is usually represented as λ, and expressed in failures per billion hours. Given the number of failures and the cumulative operating period, λ is calculated as (Number of failures/Total operating time in hours) x 10^9. For the system/component whose failure follows an

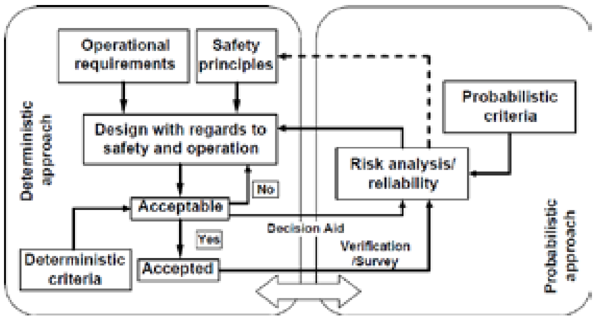

Figure 2. Determination of reliability and safety requirements

exponential distribution with a constant failure rate of λ, the probability that the system is unavailable at time t is,

$$Q(t)=1-e^{-\lambda t}$$

FIT estimates should be based on engineering and historical data and the stated probabilistic estimate has to include a measure of uncertainty. The initial estimates of Probability of Failure (PoF) are made by comparison of similar equipment, historical data(heritage), handbooks and expert elicitation.

When historical data are available, the reliability can be reconstructed according to different methods like Median Ranks, based on which estimation of the parametersof one or several probability distributions can be done. The exponential distribution in commonly used, while Weibull distributionis best suitable for components experiencing ageing. Appropriate distribution should be selected and it should be available in the reliability modelling and simulation tool that is being used.

The overview of the qualitative and quantitative reliability analysis methodologies is represented in **Figure 3.** Advanced analytical reliability models based on Boolean models, Markov Graph (MG) and Monte-Carlo (MC) simulations use PRA techniques with system/component failure rates as inputs. The PRA is thus a comprehensive, structured and logical analysis used for identifying and assessing risks in complex technological systems for the purpose of cost-effectively improving their safety and performance.

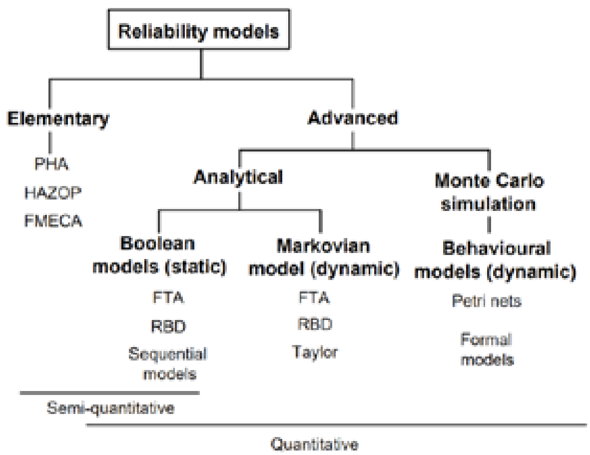

Figure 3. Reliability assessment methods

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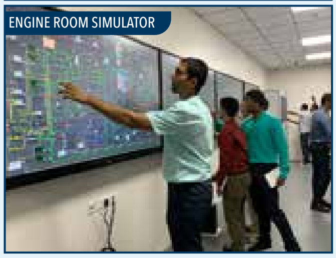

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In static models, including Fault Tree Analysis (FTA) and Reliability Block Diagram (RBD), the relationships linking its state to the states of its components do not depend on time. In dynamic models, the system jumps from state to state after random delays related to failure, repair or any other event and this is modelled using stochastic methods such as Markov.

When simulating FTA, the failure/degradation patterns can be programmed for the individual components, which could be exponential, linear, power law, Weibull shape factors, constant failure rate, non-homogenous Poisson process, etc. If the failure rate is constant, then the component failures follow an exponential distribution. For the Weibull distribution, the failure rate is increasing for $\beta > 1$, decreasing for $\beta < 1$ and constant for $\beta = 1$.

Determining Safety Requirements for Time-Critical Systems

IEC 61508/11 is a standard proven framework for implementing instrumented safety systems using the principles of Safety Life Cycle (SLC) and concepts of the Safety Integrity Level (SIL). Protection systems need to perform their intended operations on-demand. The SIL defines the degree of safety protection required by the process/operation and consecutively the on-demand reliability (ODR) of the system necessary to achieve the function. SIL has four levels, 1 to 4. The safest being the highest level. **Table 1** summarises various SIL levels with corresponding PFD (low-demand, when demand is <1/year) and PFH (high demand, when demand is >1 year).

According to IEC 61508 HSE standards, SIL requirements are computed based on the severity level (accident consequence), unavailability of alternate protection mechanism, human occupancy in the location to be protected and the likely demand on the system.

Based on the severity level, the consequence parameter (C) can be Catastrophic, Extensive, Serious, Considerable, or Marginal. Based on the availability or unavailability of alternate protection system, the parameter "P" is assigned the value of either 0 or 1, respectively. Based on the human occupancy, the parameter "F" takes the values 2, 1 or 0, corresponding to continuous, occasional and rare human presence. The demand rate (W) on the system depends on the frequency of demand on the safety system **(Table 2).**

Table 1. PFD for low- and high-demand systems

SIL	PFD/PFH	
	Low demand	High demand
1	$>10^{-2}$ to $<10^{-1}$	$>10^{-6}$ to $<10^{-5}$
2	$>10^{-2}$ to $<10^{-3}$	$>10^{-7}$ to $<10^{-6}$
3	$>10^{-3}$ to $<10^{-4}$	$>10^{-8}$ to $<10^{-7}$
4	$>10^{-5}$ to $<10^{-4}$	$>10^{-9}$ to $<10^{-8}$

Table 2. Factors for SIF demand rate

Demand rate		Factor (W)
W9	Often > 1/year	9
W8	Frequent 1/1-3 year	8
W7	Likely 1/ 3-10 year	7
W6	Probable 1/10-30 year	6
W5	Occasional 1/30-100 year	5
W4	Remote 1/100-300 year	4
W3	Improbable 1/300-1000 year	3

Table 3. SIL level computation using RGM

Consequence		F+P+W					
Severity Level	C	1,2	3,4	5,6	7,8	9,10	11,12
Catastrophic	F	NR	1	2	3	4	-
Extensive	E	NR	NR	1	2	3	4
Serious	D	NR	NR	NR	1	2	3
Considerable	C	NR	NR	NR	NR	1	2
Marginal	B	NR	NR	NR	NR	NR	1
Negligible	A	NR	NR	NR	NR	NR	NR

NR-Not Required

The summed-up values shall be plotted against the consequence factor in the risk graph matrix (RGM) shown in **Table 3** to obtain the required level of SIL.

GRIF Modeling and Simulation Software

Thus probabilistic estimates of operational reliability and ODR using numerical methods based on field-failure data and published failure models serve as a yardstick for comparing alternate technologies, continuous improvements and maintenance planning of the time-critical marine systems. GRIF (GRaphical Interface for reliability Forecasting) is a proven modelling and simulation software suite for determining the reliability

According to IEC 61508 HSE standards, SIL requirements are computed based on the severity level (accident consequence), unavailability of alternate protection mechanism, human occupancy in the location to be protected and the likely demand on the system

and dependability - RAMS (Reliability, Availability, Maintainability and Safety). The tool is extensively used in the offshore sector for determining the HMI for the tsunami early warning systems, optimisation of subsystem design for deep-ocean submarines and dynamic positioning systems and offshore moorings. We have used FTA and SIL modules of GRIF for modelling and simulations. In GRIF, advanced Boolean models employed for quantitatively computing the PoF and PFD of a system for a definite period uses Binary Decision Diagram (BDD) technique. The Fault Tree (FT) is converted into BDD which represents an efficient storage of the Boolean equations for the top event. The BDD calculates exact top event probabilities based on disjoint decomposition compared to traditional kinetic tree approaches that employ many approximations such as truncation, rare-event approximations, and intermediate minimal cut steps and delete term approximations.

Approach for Integrity Management of EDG to Ensure ODR

In vessel/platform-based power systems, EDGs are used during mains blackouts and emergency situations. Hence it is important to determine the Probability of Failure on-Demand (PFD) and the Health Monitoring Interval (HMI) for ensuring the required SIL of the EDG. The methodology based on IEC 61508 adopted for computing the HMI essential for maintaining their ODR in various SIL for EDG is shown in **Figure 4.** The key parameters include the failure rate of the power plant generators, configuration of the power plant including essential and redundant generators, failure rates and demand frequency of the EDG.

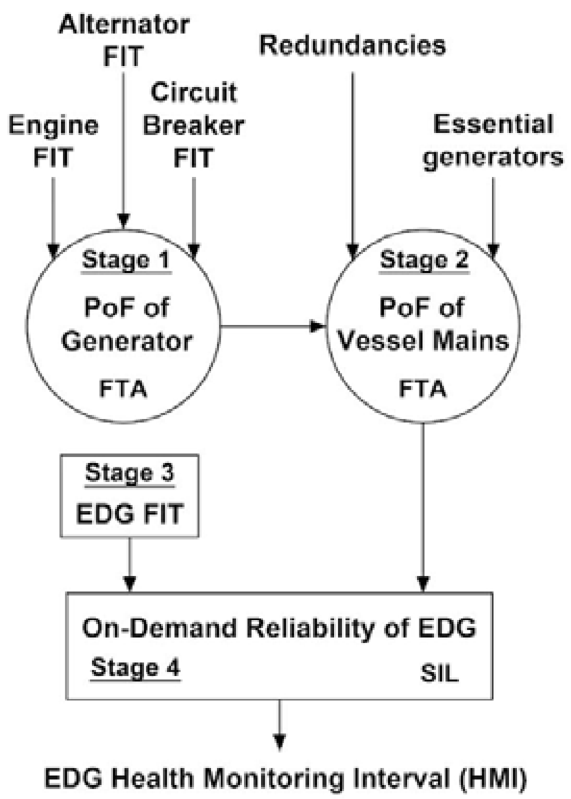

Figure 4. Methodology for identification of HMI for EDG

Stage-1: Computation of POF of DG forming part vessel/platform power generating system

The failure rates for the DG sets were initially reported by Iado National Engineering Laboratory (INEL, under US Department of Energy) based on the failure returns from about 100 generators collected during 1987–1993 clocking ~1000 machine-years involving 64,000 demands-to-start (statistically every 5 days). The failure rate is computed to be ~250000 FIT (Failure-In-Time) and the corresponding Mean Time Between Failure (MTBF) is ~0.5 years. During 2007, IEEE-493 reported DG failure rates of ~20000 FIT, the MTBF of ~6 years.

A study was made by Power Secure company based on the failure returns during 2014–18 from about 2000 generators (including a dozen major manufacturers) running >14h/day during the period 2016-18 clocking ~5000 machine-years. Based on this study, the failure rate is computed as ~19000 FIT. The corresponding PoF and MTBF are 14% and 7 years, respectively. The failure rate for DG computed based on the DNV-OREDA database with aggregated offshore in-service time of ~0.27 million hours hitherto, works out to 17000 FIT, is taken as an input for this study. The failure rates of the alternator, circuit breaker, bus couplers, power management system are obtained from IEEE-493 Recommended practice for the design of reliable industrial and commercial power systems 30-year database. The identified reliability indices are summarised in **Table 4.**

The contribution of subsystems to DG failure is shown in **Figure 5.**

Stage-2: Mains failure probability and DG redundancy

Based on the propulsion and utility power requirements, the vessel/platform power generation plant comprises of multiple multi-megawatt capacity DG sets. The power distribution network architecture is designed to ensure maximum availability of the power plant for vessel/ platform operations. **Providing redundant generators in the power generation plant decreases the PoF of the**

Table 4. Failure rates of DG subsystems

Subsystem	FIT	Source
Diesel engine	17000	DNV-OREDA
Alternator	11000	IEEE-493
Circuit breaker	1552	
Bus coupler	1450	
Bus bars	2166	
Power Management System including instrumentation	17217	

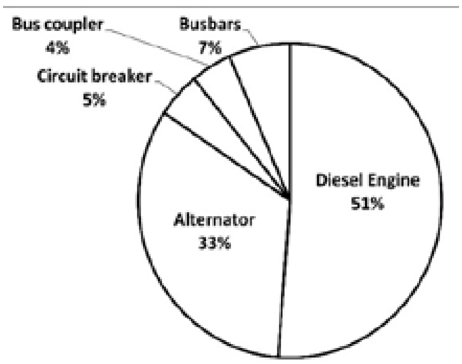

Figure 5. Contribution of subsystems to DG failure

The power distribution network architecture is designed to ensure maximum availability of the power plant for vessel/platform operations

power plant. Hence identifying the trade-off between the required reliability, number of generators, footprint, cost, and weight of the redundant DGs is essential. PRA based on FTA helps to identify the PoF for multiple combinations of essential generators required to meet the peak loads and identify redundancies.

Modelling and simulations are carried out using GRIF-FTA module for architectures involving various combinations of essential DG requirements and redundancies, following exponential degradation pattern. The FTA simulation results showing the PoF for a fully-redundant (2 operational +2 standby) power plant DG configuration (represented as gate K-out-of-N3 in **Figure 6**) in a period of 1 year is 3.78%. The redundancy helps to reduce the PoF from 63% to 3.78% in 1 year. The relationships for calculating the PoF in OR, AND and K-Out-of-N (e.g. the 2/3 voting gate) is expressed in below equations.

$$P(A\ OR\ B) = P_A + P_B - P_A . P_B$$

$$P(A\ AND\ B) = P_A . P_B$$

P(2oo3 system)

$$= Pa\ Pb + Pa\ Pc + Pb\ Pc - 2\ Pa\ Pb\ Pc$$

The advantage of having redundancy in DG subsystems is summarised in **Figure 7.** By means of redundancy, the PoF of both diesel engines failing at the same time in a period of 1 year could be reduced 6.5 times, like-wise, alternators by 6.5 times and PMS by 5.4 times. The contribution of the subsystems to DG failure with and without redundancy is shown in **Table 5.**

The FTA is carried out for various combinations of redundancy and the simulation results are plotted in **Figure 8.** It is identified that, in a power plant comprising 4 DG sets, 1, 2 and 3 redundant DG units shall reduce the PoF from 25%, 8% and 2.8%, respectively. The MTBF of the power generating plant is shown in **Table 6.**

Stage-3: Computation of PoF of EDG

The failure-rate of the well-maintained EDG set (failure-to-start and/or failure-to-load) during a demand is obtained from the data published by National Renewable Energy Laboratory (NREL), in which a MTTF of 2410 hours was computed based on frequentist analysis with 90%

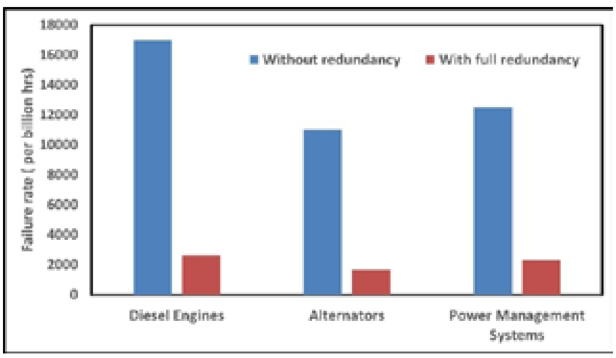

Figure 7. Reduction in failure rates through redundancy

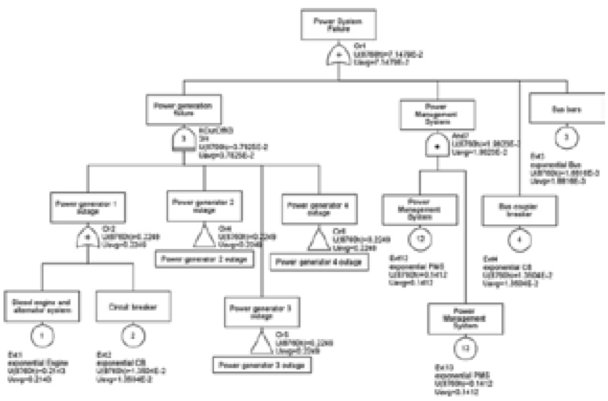

Figure 6. FTA for identifying the PoF for 3oo4 configuration

Table 5. Failure contribution with and without redundancy

Subsystem	Contribution to DG failure	
	Without redundancy	With full redundancy
Diesel engine	37%	22%
Alternator	24%	14%
PMS	-	20%
Circuit breaker	5%	13%
Bus coupler	4%	12%
Bus-bars	7%	19%

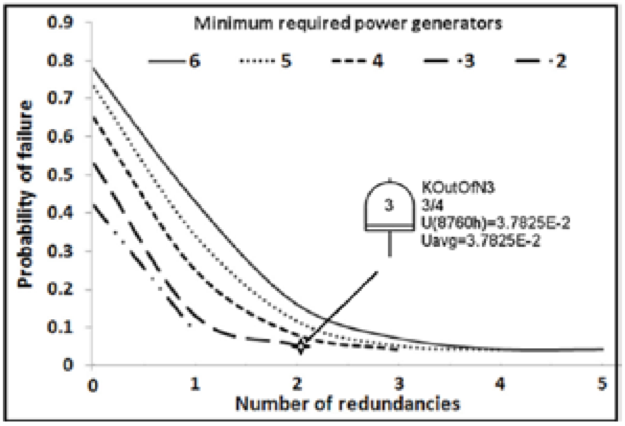

Figure 8. Redundant generators in reducing the PoF of power plant

Table 6. Influence of redundancies in 4 DG power plant

Redundancies	PoF	MTBF
0	65%	~1 year
1	25%	3.5 years
2	8%	12 years
3	2.8%	32 years

confidence interval, which indicates a PoF in a period of 1 year as 97.4%. They were based on 239 EDG sets for 1281 EDG-years, involving capacities in the range 10 kW to 2 MW, having recorded ~34000 EDG start attempts. The failures in the diesel engine included faults in the fuel oil circuit, lube oil lines, speed governor, failure-to-start, shut-down circuit and starting circuits, exhaust line problems, and cooling systems. The exciter and automatic voltage regulator (AVR) failures dominated alternator failures

Stage-4: Determining SIL Requirements and HMI for EDG

In this stage, let us consider two practical scenarios for likely demand for the EDG in a ship/offshore production platform.

For a typical power plant with 4 DG sets, with 1 redundant DG set, the probability of a complete black-out and warranting EDG is 3.5 years **(Table 6)** is considered as Scenario-A **(Table 7).**

For a 4 DG power plant with 3 redundant DG sets, the probability of a complete black-out and warranting EDG is 32 years **(Table 6)** is considered as Scenario-B **(Table 7).**

For both the scenarios, the summed-up values are plotted (in bold with asterisks) against the consequence factor in the risk graph matrix (RGM) shown in **Table 8** to obtain the required level of SIL, for the ODR of the EDG system should comply. Thus Scenario-A and B should comply with ODR of SIL3 and SIL2, respectively.

The ODR analysis is carried out using GRIF FTA module for a configuration with redundant EDG sets to determine

Table 7. Scenarios considered for analysis

Scenario	Description
A	Likely once in every 3–10 years, in which the sum of P, F and W is 10 (1+2+7).
B	Occasional once in every 30-100 years, in which the sum of P, F and W is 8 (1+2+5).

Table 8. SIL level computation for two likely scenarios

Consequence		F+P+W					
Severity Level	C	1,2	3,4	5,6	7,8	9,10	11,12
Catastrophic	F	-	-	-	-	-	-
Extensive	E	-	-	-	-	**3***	-
Serious	D	-	-	-	-	**2****	-
Considerable	C	-	-	-	-	-	-
Marginal	B	-	-	-	-	-	-
Negligible	A	-	-	-	-	-	-

*Scenario-A; **Scenario-B

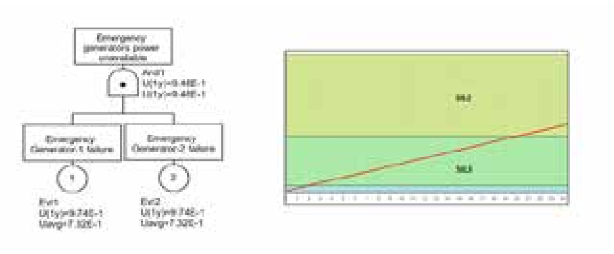

Figure 9. PFD for redundant EDG sets

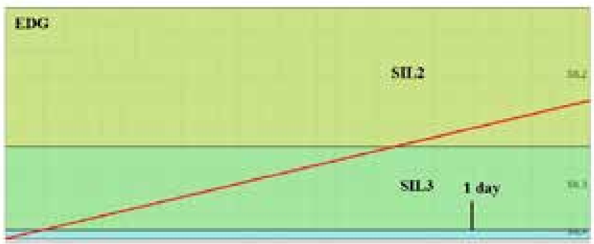

Figure 10. HMI for redundant EDG sets

the HMI requirements. The FTA is modelled with two EDGs and simulated and the PoF is ~95% in a period of 1 year **(Figure 9).** Based on the identified PoF, the ODR analysis is performed using GRIF SIL module **(Figure 10)** and it is found that an HMI of 21h (~1 day) is required to maintain the EDG in SIL3 and 7.5 days to maintain the EDG in SIL2.

Conclusion

Ensuring on-demand availability during mains black-out is one of the key requirements for emergency diesel engine driven generators used in ship and offshore production platforms. To achieve this, the healthiness of the emergency diesel generator system has to be

confirmed in regular intervals. Through probabilistic modelling and field failure data, a first-of-its-kind methodology for determining the healthiness monitoring of these well-maintained generators is presented in this article. Modelling and simulations done on a power plant (with 4 DGs) indicate health monitoring interval of ~1 day (with 1 redundant DG set) and ~7.5 days (with 3 redundant DG sets) to comply with Safety Integrity level 3 and 2 of on-demand reliability, respectively. However, based on the presented guidelines, healthiness monitoring interval for any specific configuration could be computed based on relevant data.

Abbreviations

BDD	Binary Decision Diagram
C	Consequence Parameter
DG	Diesel Generator
DoE	Department of Energy
EDG	Emergency Diesel Generator
EHS	Environmental, Health and Safety
FIT	Failure-In-Time
FTA	Fault Tree Analysis
GRIF	Graphical Interface for reliability Forecasting
HMI	Health Monitoring Interval
INEL	Iado National Engineering Laboratory
IMO	International Maritime Organization
IEEE	Institute of Electrical and Electronics Engineers
MC	Monte-Carlo
MG	Markov Graph
MTBF	Mean Time Between Failure
NIOT	National Institute of Ocean Technology
NREL	National Renewable Energy Laboratory
ODR	On-Demand Reliability
PFD	Probability of Failure on-Demand
PFH	Probability of Failure per Hour
PoF	Probability of Failure
PRA	probabilistic Reliability Assessment
RAMS	Reliability, Availability, Maintainability and Safety
RBD	Reliability Block Diagram
RGM	Risk Graph Matrix
SIL	Safety Integrity Level
SLC	Safety Life Cycle
SOLAS	Safety of Life at Sea
SR	Safety Reliability

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An In-Depth Analysis of Microplastics' Effects on the Marine Ecosystem

S. Thangalakshmi, K. Sivasami, Rajoo Balaji

Abstract: Microplastics, or pieces of plastic smaller than 5 mm, have recently become an important issue in aquatic environments across the world. Human-caused and land-based sources have contributed to a rise in microplastics in waterways, which has led to worries about the prevalence of these particles in aquatic creatures. Multiple research studies have extensively recorded the existence of significant amounts of microplastics in the discharged waste from wastewater treatment facilities around the globe. Therefore, it is essential to use a lifetime strategy in order to effectively and sustainably handle plastics.

This article provides an overview of the origins and worldwide dispersion of microplastics in the oceans, as well as their effects on marine organisms, particularly within the food chain. Moreover, the control mechanisms being explored are the ones devised by both national and international environmental organisations to counteract the effects caused by microplastics. The aims of this systematic review encompass several key areas. Firstly, it seeks to provide a concise overview of the various types, characteristics, and distribution patterns of microplastics within marine and coastal ecosystems. Secondly, it aims to elucidate the alterations in microplastic characteristics following decomposition, as well as the prospective biological processes underlying such changes. Thirdly, it attempts to summarise the amounts of pollutants found in marine and coastal environments globally, drawing upon existing literature on environmental surveillance. Fourthly, it aims to explore what variables influence the absorption of pollutants onto microplastics.

Lastly, it aims to provide a brief examination of the potential impacts of microplastics on aquatic life. This study seeks to offer a more comprehensive understanding of the destiny of microplastics upon entering the marine ecosystem. The information presented can serve as a valuable point of reference for the formulation of policies aimed at managing the risks associated with microplastics.

Keywords: microplastics, marine pollution, coastal ecosystem, ecotoxicology, floating litter

Introduction

The rise in population has led to a significant concern regarding trash management, which has become a prominent issue. Additionally, recent research has shed light on another critical problem, namely marine litter [1]. The accumulation of human-generated garbage in marine environments has been observed, resulting in the presence of significant quantities of microplastics in various water bodies, including rivers, lakes, seas, and oceans. The breakdown of plastics due to weathering processes occurring on beaches leads to the embrittlement of their surfaces and the formation of microcracks [2]. Consequently, these microcracks generate microparticles that are transported into water bodies through the action of wind or waves.

> *"Previous studies have indicated that ultraviolet light and low temperatures play a significant role in the degradation of conventional plastic materials, resulting in the formation of tiny fragments commonly known as microplastics"*

Previous studies have indicated that ultraviolet light and low temperatures play a significant role in the degradation of conventional plastic materials, resulting in the formation of tiny fragments commonly known as microplastics [3].

These microplastics subsequently find their way into marine ecosystems through drainage pathways. They are often comprised of various polymers such as polyvinyl chloride (PVC), polyethylene terephthalate (PET), polystyrene (PS), and nylon. **Due to their diminutive dimensions, measuring less than 5 µm, microplastics has the capacity to be consumed by a diverse array of marine creatures, hence presenting the possibility of inducing adverse effects** [4].

Due to inadequate management practices, the accumulation of such debris is escalating at a concerning pace, hence exerting detrimental effects on both the marine ecosystem and its inhabitants. The hazards connected with the consumption of microplastics by creatures are not solely attributed to the physical properties of the material, but also to its capacity to absorb and accumulate environmental toxins present in saltwater [5]. Consequently, these contaminants can be transferred through food chains. Furthermore, the presence of microplastics has the potential to exert an impact on other ecological processes.

Plastic debris has recently been acknowledged as a growing form of pollution, posing a significant threat to marine biodiversity on a global scale [6]. **Figure 1.** illustrates the fragmented micro-plastics extracted from a toothpaste cover, whereas **Figure 2.** presents an electron microscopic imagery of the tiny plastic particles.

Recent studies have revealed that marine environments in proximity to urban centers have elevated concentrations of microplastics. **Additionally, aquatic organisms residing in these regions have demonstrated a notable propensity for accumulating microplastics within their tissues.** Moreover, there have been reports indicating that various water contaminants, including coloring agents, toxic metals, and other chemical substances, have the tendency to readily adhere to microplastics. Consequently, these microplastics serve as a conduit for transporting additional pollutants into the bodies of aquatic organisms, ultimately infiltrating the food chain.

Figure 1. Microplastics: toothpaste (left) and broken plastic bits (right) [7].

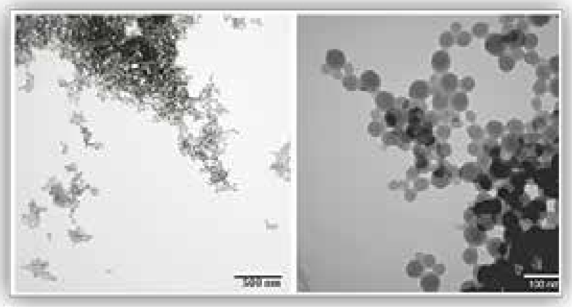

Figure 2. Photographs taken with a transmission-electron-microscope show 70 nm nano-sized polystyrene clusters in both freshwater (left) and saltwater (right) [8].

This paper offers an extensive investigation of microplastics, encompassing their distribution, persistence, and detrimental impacts on both the environment and marine ecosystems.

Microplastics, which are plastic particles measuring less than 5 mm, have harmful effects on both the natural landscape and our physical well-being. The maritime fraternity has access to just a small amount of data on the contribution of ports and shipping operations to the pollution caused by microplastics, as well as how to effectively address this issue. The objective of this study is to aid stakeholders in the marine sector in identifying feasible and effective measures to mitigate the impact of plastic on the ocean.

The Origins of Microplastics

Microplastic particles found in aquatic environments vary in magnitude, specific weight, chemical structure, and style. Primary microplastics may be found in common goods like paints and face washes, whereas secondary microplastics are created when bigger macroplastic trash breaks into smaller fragments in the environment.

Primary Microplastics

Primary microplastics refer to microplastics that are intentionally produced to have a tiny size for specific industrial or residential purposes [9]. The substances encompass plastic fragments utilised in facial cleansers, toothpaste, resin pellets, and cosmetics such as shower/bath gels, scrubs, peelings, eye shadow, perfume, blush powders, cosmetics basis, eye makeup, shaving lotion, baby products, bubble bath lotions, hair colouring, nail polish, repellents for insects, and sunscreen [10]. Additionally, they encompass synthetic apparel, abrasives present in household cleaners, drilling solutions, and so on. These consumer items are classified as "open use" since they are designed to be rinsed off and ultimately disposed away in drains [11]. There has been a growing number of reports on the use of microplastics in medicine

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as carriers for pharmaceuticals. **Primary microplastics include virgin plastic manufacture pellets, which are generally 2–5 mm in size** [12].

Secondary Microplastics

Microplastics are the result of the gradual disintegration of larger pieces of plastic that have accumulated on land and in the ocean over time [13]. Secondary microplastics describe these particular kinds of microplastics. The dimensional stability of macroplastic waste is reduced and eventually fragmented as a result of a multitude of chemical, biological, and physical reactions. The rate at which macroplastic waste breaks down depends on a number of external variables, including temperature and sunshine, as well as the characteristics of the polymers itself, including its dimensions and weight [14,15]. The sun's ultraviolet (UV) light enables plastics to photodegrade, especially when bigger pieces of plastic waste are exposed to it. The bond is cleaved because the polymer strand is oxidised by the sun's ultraviolet radiation. The combination of strong ultraviolet radiation, physiological abrasion from waves, air availability, and turbulence makes coastlines ideal for the formation of microplastics by disintegration into smaller fragments [16].

Consequently, these microplastics serve as a conduit for transporting additional pollutants into the bodies of aquatic organisms, ultimately infiltrating the food chain

Transport and Degradation

Microplastics can enter the marine ecosystem in four major ways, depending on their source:

1. **Plastic garbage is carried as surface runoff** when it is discarded on ground and then transported by rainwater runoff. Approximately 40% of the overall microplastics entering the marine ecosystem are transported by surface runoff.
2. **Transportation through wind**, which carries plastic debris from land to the seas and oceans through air currents. Wind transport contributes to 10-15% of the overall release of microplastics into the marine ecosystem.
3. **Wastewater discharge,** which allows microplastics to enter water bodies, accounts for approximately 35% of the total release.
4. **Direct disposal of plastic waste** into the marine environment is responsible for 5% of the microplastics released.

The direct dumping of plastic trash include activities such as washing clothing in rivers, particularly in rural regions. Coastal tourist activities, including fishing and recreational activities, contribute to the generation of disposable cups and litter. Additionally, commercial fishing leads to the accumulation of nets and litter.

Plastic trash experiences environmental degradation, leading to the creation of microplastics and possibly smaller pieces known as nanoplastics. The degradation routes may be categorised into abiotic and biotic processes.

Abiotic Degradation Route

Abiotic degradation route refers to the process by which a substance breaks down or decomposes without the involvement of living organisms [17]. Mechanical forces, rising temperatures (thermal degradation), chemical breakdown, and exposure to light (photodegradation) are all examples of abiotic processes that cause physical harm to plastic garbage.

Mechanical degradation: It is the process by which outside forces, like as wind currents, wave action from the ocean, or physical wear and tear, lead to the disintegration of plastics. Plastic debris on coastal areas is subject to contact and abrasion with beach pebbles and grains due to the movement produced by wind and ocean currents. In

Figure 3. Shows a detailed picture of the different kinds of microplastics.

colder regions, the cyclical process of thawing and freezing of ice can lead to the deterioration of the plastics that have collected within the ice. This may ultimately lead the plastics to be released back into the marine environment [18].

Thermal degradation: It refers to the process of breaking down or deteriorating due to exposure to high temperatures. Plastic debris that is scattered on the coastlines is subjected to higher temperatures, resulting in a process called thermo-oxidative degradation of the plastic. This occurs when heat is absorbed, causing the polymeric chains to break and results in the release of radicals that combine with oxygen in the atmosphere to form hydroperoxide. Eventually, the hydroperoxide breaks down into hydroxyl and alkoxy free radicals, which lead to the production of aldehydes, ketones, esters, or alcohols, which in turn cause the deterioration of plastic [19]. The heat degradation process is caused by the breaking of chemical bonds within the polymer chains and the formation of new bonds between different polymer chains. Within the ecological context of beaches and coastal shorelines, the gradual breakdown of plastics through heat and light exposure can lead to an accelerated deterioration of plastic materials.

The rate at which macroplastic waste breaks down depends on a number of external variables, including temperature and sunshine, as well as the characteristics of the polymers itself, including its dimensions and weight

Chemical degradation: The atmosphere contains chemical pollutants such as sulphur dioxide, nitrogen dioxide, ozone, and volatile organic compounds. Similarly, the marine environment is affected by chemical pollutants such as acidity and salt. Atmospheric pollutants can directly deteriorate plastics or accelerate the generation of radicals through photochemical processes, resulting in the breakdown of plastics. Sulphur dioxide and nitrogen dioxide can promote the production of ozone in the air by the absorption of ultraviolet radiation and the subsequent reaction of chemicals with oxygen [20]. Ozone can cause the carbon double bonds in plastic polymers to break through a process called chain scission. In the maritime environment, the pH level of the water can accelerate the breakdown of plastics, such as polyamides.

Photo-degradation: The process of photodegradation in plastic occurs when it is exposed to UV radiation from sunshine. This exposure leads to the creation of free radicals and oxidation of the plastic polymers [21]. As a consequence, peroxides are formed, which inevitably break down into alkoxy and hydroxyl radicals. This degradation mechanism is comparable to the process of thermal degradation. Photodegradation in the environment leads to the generation of free radicals that break down various plastics based on their specific chemical compositions.

Biological Degradation Route

The presence of microorganisms in the marine ecosystem leads to the biological degradation of plastic trash, causing the breakdown of plastic materials. Polymeric plastics must undergo conversion into monomers before they may be processed by biological agents during the process of degeneration. The dimensions of plastics at the molecular level, also known as polymers, exceeds the diameter of the pores in the cell membrane of microbes. Therefore, it is necessary to break them down into smaller bits by depolymerisation in order for them to be ingested and biodegraded by microbial cells. Consequently, the tiny pieces of plastic that are produced by non-living processes may be broken down by microbes due to their suitable size. The maritime environment is mostly inhabited by bacteria, fungus, and algae [22-24].

Bacteria: Bacillus species are often seen in the marine ecosystem, such as Bacillus subtilis and Bacillus cereus. The bacteria were discovered to release extracellular hydrolytic enzymes, including lipase, xylanase, keratinase, chitinase, and protease, which result in the destruction of plastic.

Methanosarcina barkei has the ability to breakdown PVC, which is the most prevalent plastic polymer. They have the ability to stick to the PVC surface and secrete exopolymeric chemicals, resulting in the formation of a biofilm on the PVC. This is then followed by the release of enzymes that break down the plastic by hydrolytically cleaving the polymeric linkages [22].

Fungi: Fungi can potentially contribute to the biodegradation of plastics. As an illustration, scientific studies have demonstrated that Aspergillus clavatus is capable of biodegrading LDPE (low-density polyethylene). The primary fungus species in the oceans, Zalerion maritimum, is capable of breaking down polyethylene (PE).

Like bacteria, fungi primarily degrade plastic by adhering to its surface, where they proliferate to create a biofilm and secrete enzymes that dismantle the chemical bonds within the plastic [23]. These enzymes have the ability to facilitate oxidation-reduction processes and degrade plastic into smaller particles.

Algae: Certain types of algae have demonstrated the ability to generate secondary metabolites that are capable of breaking down microplastics through biodegradation. Phormidium lucidum and Oscillatoria subbrevis have the ability to biodegrade polyethylene (PE) and low-density polyethylene (LDPE). Algal biofilms composed of Discostella spp., Navicula spp., Amphora spp., and Fragilaria spp. have been seen to break down LDPE, PP, and PET in the marine ecosystem. Upon establishing a biofilm on the plastic surface, algae exploit the carbon content inside the plastic as a nutritional resource, therefore diminishing the structural integrity of the plastic and rendering it brittle. In addition, algae secrete extracellular polymeric compounds and enzymes, such as PETase, which facilitate the breakdown of PET [24].

> *Abiotic degradation route refers to the process by which a substance breaks down or decomposes without the involvement of living organisms*

The Fate and Distribution of Microplastics

The dispersion and ultimate destiny of the deteriorated plastic and microplastic in the marine ecosystem are ascribed to human activities (such as tourism and the discharge of treated wastewater) in the form of initial microplastics [25,26]. Ambient variables contribute to the entry of secondary microplastics into the aquatic ecosystem. As an illustration, the **effluent from the wastewater treatment facility discharges about 7 million microplastic fragments on a daily basis**. Therefore, the marine environment acts as the main repository for microplastics [27]. Upon entering the aquatic system, the building up and dispersion of microplastics are influenced by several factors such as density, size, form, and chemical composition, as well as environmental conditions including air and ocean current velocity [28,29]. The destiny of microplastics is intricately linked to their initial method of disposal, and they have the ability to migrate to far locations such as Arctic waters and places covered in ice. The microplastics may continue floating in the top layer of water or plunge into the deep sludge, depending on their concentration.

Horizontal Distribution: Things like ocean currents, raindrops, and the breeze are what propel the plastic from the shores and along the coasts into the sea system. When macroplastics get into the seawater, they can break down even more because of ocean wear and tear or biological breakdown. What happens to microplastics—those that are moved from land to sea or that form when plastics break down in the ocean—depends on what they are made of and the conditions where they are. The velocity and course of the regional water and wind currents determine whether these microplastics are carried to faraway places or brought back to the coasts and beaches. This causes microplastics to build up in the oceanic and local water gyres in the marine realm. Between 5 and 13 million tonnes of plastic trash end up in the ocean every year, and between 7 and 35 thousand tonnes of microplastics stay in the water at the top.

In other words, the rest of the plastic trash was moved, possibly along horizontal or vertical distribution paths.

Vertical Distribution: As was already said, microplastics that are heavier than the water in the coastal area may sink to the bottom of the ocean. Vertical swirling interaction, biota transference (through fish or other marine animals), biological foul (sometimes referred to as biofouling), and aggregate creation all play a role in this mechanism. Biofouling is when microbes, plankton, algal growth, tiny algae, and other microscopic sea creatures stick to plastic trash or microplastics. What happens next relies

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on the microplastic's kind of polymers, its area of contact, and its dimensions. It also relies on the microorganisms that live in the ocean, its temperature, salt, the pH level, nutrients and metallic substances, and the amount of oxygen present in the seawater.

Harmful Consequences of Litter on Marine Organisms

Marine life entanglement is a global phenomenon. One of the earliest documented instances of marine trash entanglement was likely a shark ensnared in a rubber car tyre in 1931. Active fishing gear is responsible for the death of a significant number of marine birds and animals, amounting to hundreds of thousands. Interconnected creatures may lose their ability to get nourishment and evade predatory creatures, perhaps leading to exhaustion, starvation, or drowning. Even if the organism does not experience immediate mortality, injuries, impaired mobility, and diminished foraging capacity will significantly impact the ensnared creature.

The presence of marine debris on the seabed can have diverse impacts on the local plant and animal life, which we categorise as 'smothering' rather than 'entanglement'. Within the intertidal zone, the presence of debris can exert pressure and block sunlight, resulting in the potential destruction of delicate salt marsh flora and the reduction of necessary light levels for development. Consequently, this can lead to the formation of bare regions within these vulnerable and protected habitats.

Marine species can purposely or unintentionally consume plastics. The reasons why certain animals deliberately consume plastic waste might be influenced by several circumstances, which can differ across different animal species. Several elements that might influence the outcome include the hue, age, and gender. Furthermore, there is a possibility of unintentional and subsequent consumption of microplastics. Plastic consumption can lead to death or have a gradual harmful impact on animals through physical and chemical consequences that are not immediately deadly.

Strategies for Dealing with Microplastics and Potential Remedies

In order to reduce the introduction of microplastics into the aquatic ecosystem, it is necessary to identify the primary sources and types of plastics and microplastics that reach the marine ecosystem. In addition, disseminating knowledge through educational initiatives targeting the general public, business institutions, and government agencies will significantly contribute to enhancing awareness of microplastics.

Utilising Microorganisms to Address the Issue of Microplastic Pollution in Affected Ecosystems

An essential step towards the development of effective mitigation strategies is to accurately identify the potential contributors to plastics and microplastics, both from the sea and land. Alternatively, a more favourable strategy might involve harnessing microorganisms capable of breaking down microplastic polymers through the process of biodegradation, which is the utilisation of microorganisms to break down manmade polymers. Microorganisms utilise polymers as a carbon and energy source. Bacteria have a high degree of opportunism, allowing them to infiltrate and acclimatise to many environments. Multiple bacterial species have been documented to break down plastic polymers. The researchers found that microorganisms collected from Andhra Pradesh and Telangana locations in Hyderabad were capable of breaking down polyethylene, as demonstrated by the clear zone and weight loss technique of assay. This suggests that these microorganisms have the capacity to breakdown microplastics. These microorganisms have the potential to be utilised as a reliable and ecologically friendly method for breaking down microplastics. These microorganisms might be used to treat sewage effluent, hence reducing the amount of waste generated from household sources. They might potentially be utilised for the purification of polluted surroundings.

Marine Canopies – A possible Trap to Microplastics

A research study has found that "Marine canopies" created by seagrass and other coastal vegetation ecosystems may effectively capture microplastics, making them excellent particle traps [30]. The findings indicate that marine canopies have the capacity to function as barriers or traps for microplastics under particular bio-physical circumstances. The likelihood of retention typically rises with higher seagrass shoot density and polymer specific density, whereas it decreases with increased flow rate. The presence of microplastics in aqueous canopies may result in negative ecological implications, including unintentional consumption by species and acting as carriers for other pollutants. Therefore, it is important to prioritise the study of seagrass meadows and other aquatic ecosystems that form canopies when assessing the exposure and impact of microplastics on coastal regions. These habitats have the potential to amass significant concentrations of microplastic particles, which might have negative effects on the species that depend on them.

Periphytic Biofilms' Ability to Degrade Microplastics

Periphytic biofilm degradation is a widely used biotic method for breaking down microplastics, which relies on the biofilms epiphyton and epixylon as its foundation. Carbon fixation and nutrient cycling are crucial functions performed by biofilms in aquatic habitats. Biofilms have been extensively utilised in ecotoxicological studies due to its significance as a bioindicator for assessing the effects of pollution on aquatic environments. Periphytic biofilms in freshwater environments consist of a diverse array of microorganisms, such as cyanobacteria, algae, diatoms, and protozoans, together with debris that is

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either adhered to submerged surfaces or floats freely in the water column.

The five main varieties of periphytic biofilms are categorised according to the substrate they inhabit: epiphyton (plants), epilithon (rocks), epipelon (sediments), epixylon (wood), and epipsammon (sand). Photoautotrophic benthic microbial biofilms serve as the main source of primary production in aquatic environments.

Periphytic biofilms can generate a variety of alterations to the structure and function of microplastics. **Biofilms utilise microbial enzymes to modify and break down surface properties, break down additives, and generate metabolic by-products.** Enzymes that break down microplastics employ either surface modification or degradation as their mechanisms. Certain enzymes, including as oxidases, amidases, laccases, hydrolases, and peroxidases, directly break down polymers. Meanwhile, other enzymes are involved in the process of modifying the surface. It is plausible to assume that bacteria consume smaller components of large polymers once those polymers have been broken down outside of their cells through the secretion of certain enzymes.

Adsorption as a Method for Eliminating Microplastics

Adsorption is a surface phenomenon that may be utilised to remove both organic and inorganic pollutants through a single procedure. Adsorption has garnered significant interest as a cost-effective, highly efficient, and straightforward method for eliminating microplastics. The distinctive physical and chemical characteristics of biochar, including its porous composition, large specific surface area, and propensity to modify its surface, have generated significant attention in recent years. This interest mostly stems from its potential as an adsorbent for removing microplastics.

Using an Advanced Oxidation Process to Break Down Microplastics

A lot of research and use has been done on and use of advanced oxidation methods to get rid of a wide range of tough environmental toxins recently. Because they are very good at oxidation, such procedures are able to break down or mineralise many different types of toxins, including dyes, medicines, and persistent organic pollutants [31]. The main type of mixed advanced oxidation process is photocatalytic breakdown. It is a strong way to get rid of pollutants that can be used in normal situations.

Membrane Bioreactors

Membrane bioreactors (MBR) have great potential in the removal of microplastics, as well as other persistent organic pollutants (POPs) and heavy metals. The use of MBR technology is becoming more prevalent in the treatment of municipal and industrial wastewater. Recent research have examined MBR technology for the purpose of removing microplastics, and have demonstrated a significant rate of microplastic removal.

Conclusion

Microplastics are minute plastic particles that enter the marine ecosystem primarily through two primary pathways: cosmetic products and the breakdown of bigger plastic trash into smaller fragments. Typically, this variety of plastic infiltrates the marine ecosystem through streams, channels for drainage, discharge from wastewater treatment facilities, and by the forces of wind, current, and tides. Microplastics are ubiquitously dispersed across the world's seas, where they accumulate. Large-scale dispersion is prevalent in water columns, waters at the surface, and deposits. Microplastics, because

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of their tiny size, are readily consumed by marine species and have been seen to build up in tissues, blood vessels, and brain. The potential risk of microplastics to the overall biosphere is significant due to their absorption by many marine organisms and their presence in saltwater. This is a matter of great worry since microplastics may inflict substantial damage on marine species and people. Microplastics diminish the recreational, aesthetic, and cultural significance of an area, and it is unavoidable that these particulates will continue to proliferate in the future, since effective methods to eliminate their presence have not been attainable. In order to address the issue of microplastics, it is imperative to engage the general public, socio-economic sectors, tourists, and waste management firms. Furthermore, investigations are underway to examine the potential of marine-derived bacteria in breaking down microplastics found in the marine environment. This study addresses the formulation of additional regulations and explores various solutions.

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Initiatives for Sustainable Fisheries

Sherry Koshy Verghese

Background

Human activities in the ocean space have introduced pollution, invasive species, ocean warming and acidification due to shipping, habitat losses due to overfishing, and coastal development.[1] These activities will largely result in the depletion of fisheries and marine biodiversity hence, a consequential loss of coastal habitats. This will also pose a significant threat to the food supply of millions of people.

According to the U.N. Food and Agriculture Organization (FAO), over 70% of the world's monitored marine fish stocks are either fully exploited or depleted. In the Indian context, a study by Central Marine Fisheries Research Institute (CMFRI) scientists in 2011, indicates that the Indian marine fishery has grown from a subsistence level to an industrial one. The study claims that the fisheries production has increased manifold. It has increased from a meagre 0.6 million tonnes in 1950s, it has crossed 3.0 million tonnes in 2008. The major contributors to the marine fisheries production of the country have been Kerala, and to a lesser extent, Karnataka (having 12% of the total coastline and contributing 30-35% of the production).

> **These are primarily because of unsustainable fishing practices and lack of implementation and execution of adequate fisheries regulatory action**

The fishing vessels' mechanisation while has increased the fisheries production but has depleted the fish stock in the region. The unsustainable practices along the coast have even led to threats of complete losses of certain species. Towards this, the regulatory bodies in India have not undertaken any comprehensive study about the total stock *vis-a-vis* certain species. Therefore, there has been no action plan that has been put in place for the restoration or conservation of the stock level.[2] Lately, some of the scientific institutions have undertaken region-specific studies but no firm action plan and its implementation for restoring.

It is also an accepted fact that most of the world's most valuable fish stocks are either fully exploited or overexploited.[3] The 25% of the stocks that remain underexploited tend to comprise of low value species. Therefore, globally there has been a wakening regarding depletion and the collapsed fish stocks in the light of loss of biodiversity. Studies classifies species depleted if they have declined more than 50% over the baseline abundance, collapsed if more than 90% and extinction if it is 100%.[4]

The southwestern Indian coast has witnessed depletion of many major species as per the above mention criteria. The FAO's has presented many documents which are primarily following the recommendations of the UN Conference on Environment and Development (UNCED) June 1992. The lesser-scale study undertaken by the Indian scientific institutes has indicated alarming data. Once again, the CMFRI study off the Kerala coast's 19 species indicates only 37% of the species to be in healthy status whereas, 47% were in declining status. Similarly, in Karnataka, only 32% of the stocks were in a healthy state.[5] These are primarily because of unsustainable fishing practices and lack of implementation and execution of adequate fisheries regulatory action. Such a situation makes the fisheries industry largely an unorganised sector in India.

Around 200 million tonnes of fish and seafood are produced world over, majority comes from the wild fish catch and few from fish farming

Causes of Marine Fisheries Decline

There is adequate data available for the decline in marine fisheries stock all along the Indian waters. The quantity of catch that the fishers were able to get during just daytime fishing in the past now despite of advanced technology available requires multi-day fishing efforts today. The causes of this decline are many but largely it is due to overfishing fishing down the food web, highly efficient fishing technology, unsustainable fishing practices and technic, by-catches, overcapacity, habitat degradation, climate changes, acidification of oceans, increased maritime activities, lack of awareness among fishing communities etc.

Overfishing

To meet the global fish demand, it is estimated that worldwide seafood production has quadrupled over the past 50 years.[6] **Over three billion people around the world rely on fish as their primary source of protein. It is also estimated that most people consume approximately twice as much food as they did 50 years ago.**[7] Globally, 30% of the commercially fished waters (Regions) are classified as being overfished.[8] **The fish being extracted due to lack of scientific studies are not likely to be replaced at the same rate.** The United Nations Sustainable Development Goal (SDG 14), and FAO are working towards sustainable fishing, however, it is up to the local governments to implement the practices.

The supranational organisation's persistent efforts ensured the WTO banned fishing subsidies in July 2022 as one of the perceived initiatives. Around 200 million tonnes of fish and seafood are produced world over, majority comes from the wild fish catch and few from fish farming.

According to FAO, the major seven fish producing countries contributes to almost 50% of total world catch. China produces 15%, Indonesia and Peru 7% respectively, India's standing is at 6%, Russia and US produce 5% respectively and Vietnam at 3%. Also, the world protein demand has increased fish consumption on an average annual rate of 3.1% from 1961 to 2017,[9] twice the annual world population growth rate that was 1.6 percent. This is continuously and greatly pressurising the fish producing industries all over. The International Union for Conservation of Nature (IUCN) has produced red list of threatened species. According to IUCN at least 37% of the world's sharks and rays, 33% of reef corals, 26% of mammals are threatened with extinction. The other red list includes, Vaquita exclusive dolphin found in Gulf of California, Right Whale of North Atlantic, Yangtze Finless Porpoise of Yangtze River in China, Hawaiian Monk Seal, Hawksbill Turtles and Kemp's Ridley Turtles, Giant Manta Ray, Whale Shark, Northern Fur Seal, the Atlantic Southern Bluefin tuna, and Dugong.[10]

The overfishing has affected the global reef systems which in turn affects the fish stock level in the area. However, the reef systems have been hit not only due to overfishing (bottom trawling) but also because of rising ocean temperatures and acidification. The shrinking of coral cover has translated into a 60% loss in reef biodiversity and hence a toll on coastal population.

Illegal, Unreported and Unregulated (IUU) fishing represents 11–26 million tonnes of fish,[11] which roughly amounts to 12–28% of fishing worldwide. The other ill effect of overfishing particularly the IUU is the discarding of by-catch by the fishers. A large amount of undesired fish is captured which are discarded for the economy of operations, however, this is causing the unwarranted loss of billions of fish and sea creatures. An estimated 38.5 million tonnes of by-catch are discarded each year.[12] The Code of Conduct for Responsible Fisheries, the initiatives by the UN FAO and the Kyoto Convention are guiding principles for sustainable fishing. Also, the 2030 Agenda by FAO targets the monitoring of fisheries and aquaculture in achieving food security and nutrition.

"However, the reef systems have been hit not only due to overfishing (bottom trawling) but also because of rising ocean temperatures and acidification"

Highly efficient fishing technology

New technologies allow fishing fleets to double their potential power every 35 years, however, the average catch amounts remain the same with the depleting stocks in the region[13]. **The availability of Global Positioning System (GPS), fish-finders, echo-sounders or acoustic cameras have increased the capability of fishing vessels.** The increase in the fishing power or the 'technology creep' is required to be studied by the regulatory bodies and set up policies in place with regard to days/hours and technique each type of fishing vessels to exercise in a given period in a region of operation.

The new technology therefore is causing a decline in the fish stock whereas the technology enabler is required to enhance the efficiency of the fisheries industry. The 1982 UN Convention on the Law of the Sea (UNCLOS) had set out responsibilities for the coastal states regarding exploitation of marine resources including the fish stock within their Exclusive Economic Zone (EEZ).

Therefore, Ecosystem Based initiatives based on studies are must for sustainable fishing operations for their requirement. Also, the coastal states and the supranational organisations must take initiatives to curb the IUU fishing menaces. The stock information and monitoring technology should act as game changer in this direction. The GPS, increased capacity 'big-data' storage, sharing and analysis, the Internet of Things (IoT), robotics, Vessel Monitoring System (VMS) should help in meeting the global demand of fish production in a sustainable manner. Though these force multipliers are presently limited due to its cost but larger implementation will help in larger production and its associated economy of scale.

Globalisation

Advent of globalisation has provided the nation states and the agencies to undertake fishing beyond the national jurisdiction. This has in turn provided opportunities to the criminal networks and utilise the IUU fishing practice to pretence their crimes like drug trafficking, human trafficking, gun running etc[14]. This is causing a global marine security concern and each State takes actions deemed fit for curbing the security threats emanating from such activities. The undesired targets are therefore the fishing communities. Also, as the fish stocks become scarcer, fish quotas tend to decline further for law-abiding vessels thereby creating unfair competition from vessels fishing illegally. A collaborative initiative regionally among the coastal states would help in this regard.

This has also opened a new facet of international maritime security. The increasing global demand for the protein has made agencies to venture deeper into the global common space. This has caused competition among the fishers thereby increasing their presence in such space. The criminal agencies utilise such weak targets and employ them for all criminal intends viz. drug paddling, human trafficking, gun-running and even piracy.

Unsustainable Fishing Practices

Over a period of time the unsustainable fishing practices will both decrease the amount of wild fish available to anglers and have huge consequences for the environment. Lack of corrective measures would disrupt the food chain, lead to harmful algal blooms. Such impacts are alarming in various places like that with Florida's red tide threatening aquatic plants and animals in the area. This will have negative impact on the health of the species in the body of water and hence may even close down the fishing industry in the area.

> *A large amount of undesired fish is captured which are discarded for the economy of operations, however, this is causing the unwarranted loss of billions of fish and sea creatures*

In order to ensure sustainability in fisheries, the regulatory bodies should undertake scientific studies in coordination with the scientific agencies for establishing the species stock level in each area. Thereafter, plan out policies for the fisheries raising above all the impediments considering the maximum sustainable yield. Also, implement the same on ground for ensuring right-based fisheries management. Ensure regulating the correct fishing methods without spoiling the environment viz. bottom trawling, dynamite fishing, cyanide fishing etc.

In the case studies of the Yellow Sea and East China Sea, the multi-decadal shift in fish community structure resulting from overfishing appeared to promote the production of pelagic fish species, indicative of 'fishing down the food web' as hypothesised by Pauly and Christensen, as the abundance levels of predators' species decline through overfishing.

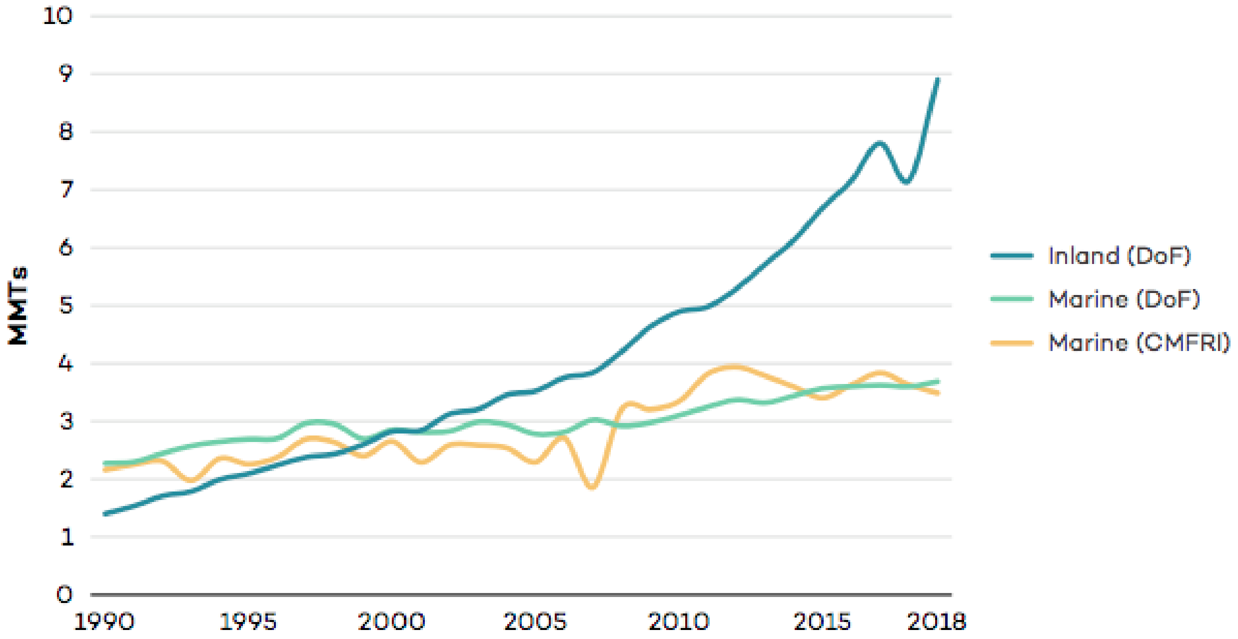
Climate Changes and Acidification of Oceans

An increase in greenhouse gas emissions into the atmosphere from fossil fuel and other human activities has contributed to climate change. The increasing water temperature has shifted the ranges of marine species in certain areas[15] and is likely to affect the stock level of certain species.[16] Also, many species are expected to decline in number or leave areas that are no longer favourable for them.[17] Though these studies were undertaken in US waters but it is true for all other waters and even in Indian waters. This implies that there will be a serious impact on the marine ecosystem and hence the fishing communities.

In the 200-plus years since the industrial revolution began, the concentration of carbon dioxide in the atmosphere has increased due to human actions. The ocean absorbs about 30% of the Carbon dioxide that is released into the atmosphere. During this time the pH of surface ocean waters has fallen by 0.1 pH units. This might not sound like much, but the pH scale is logarithmic, so this change represents approximately a 30 percent increase in acidity. This affects both calcifying and non-calcifying organisms. The ocean acidification is affecting the entire ocean, including coastal estuaries and waterways. This will have negative impact on the food being obtained from the oceans.[18]

Government Initiatives towards Sustainable Marine Fisheries

The marine fisheries are shared responsibility between the State and the Central Government in India. The initiatives towards the sustainable marine fisheries



Source: CMFRI, n.d.; DoF, 2020a.

production will therefore have to be done collectively done by the coastal States, Union Territories (UTs) and the Centre. The divergent approach by the two leads towards undesired results.

The marine fisheries sector has plateaued as shown in the graph. Therefore, if the centre and the state government do not take collective measures, production may start to even decline. **The Sagar Parikrama by Shri Parshottam Rupala, hon'ble Union Minister for Fisheries, Animal Husbandry & Dairying has done a great deal in integrating the State and the Centre's initiatives towards sustainable fisheries efforts.**

National Fisheries Policy 2020. This policy by the Government of India is keeping the sustainability of the resources at the core of all actions. This is envisaged to meet the social and economic goals and well-being of the fishers and fish farmers. This policy encompasses the entire land and the EEZ of the country and is set in a time frame of ten years (2021-2030). The policy is envisaged to ensure ecosystem health and integrity by regulating pollution, including plastics and ghost nets in the waters, arresting habitat degradation and increasing resilience against climate change, and minimising negative impacts of the development of fishery-related infrastructure. The policy intends to develop cooperative action among the regional maritime states bordering our EEZ. Overall it is an initiative towards obtaining greater opportunity of the Blue Economy.

Pradhan Mantri Matsya Sampada Yojana. The Pradhan Mantri Matsya Sampada Yojana (PMMSY) is a mega scheme to bring about Blue Revolution through sustainable and responsible development of the fisheries sector. The scheme is for five years from 2020 with a fund allocation of Rs 20,050 crores. It focuses on fish production and productivity, quality, technology, post-harvest infrastructure and management, modernisation and strengthening of the value chain, and traceability. This umbrella scheme has two components viz. Central Sector Scheme (CS) and Central Sponsored Scheme (CSS).

MPEDA and Network for Fish Quality Management and Sustainable Fishing (NETFISH). The land resources being limited the Central Government is encouraging marine fisheries. The institution like Marine Products Export Development Authority (MPEDA) along with the Network for Fish Quality Management and Sustainable Fishing (NETFISH) coordinate between the centre and the state government. They are embarked on providing training for sustainable and ecosystem-friendly fishing techniques.

Capability Development in Fisheries Sector. The development of capacity alone will not meet the desired objective therefore, the development of capability through skill development and a knowledge base is imperative. Institutions like the Fisheries Survey of India (FSI) conduct assessments of fish stocks for sustainable exploitation and management. The Central Institute of Fisheries, Nautical & Engineering Training (CIFNET) provides technical training for deep-sea fishing. The institution also provides technical support for making fishing vessels capable of such operations. The National Institute of Fisheries Post Harvest Technology and Training (NIFPHATT) helps in providing a knowledge base to reduce post-harvest losses. The Central Institute of Fisheries Education (CIFE) acts as the Fisheries University for all the institutions providing research and education.

Port Development and Fisheries Layoff Areas. The Ministry of Fisheries along with the Ministry of Shipping plans to develop modern ports to drive the desired economic development. These ports are required to

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provide adequate berthing space for deep-sea vessels, repair facilities, cold storage, processing services etc. These facilities are aimed at port-led coastal community development. The blueprints of such projects have been prepared and they are at different levels of environment clearances and technical development stages.

Problem Areas and Way Ahead

All the above initiatives require various stakeholders and smooth coordination among them would only bring-in the desired results. At the Central Government various ministries viz. Ministry of Environment, Forest and Climate Change, Ministry of Agriculture and Farmers' Welfare, Ministry of Fisheries, Animal Husbandry and Dairying, Ministry of Shipping and Ministry of Commerce besides other smaller institutions' support are required for the realisation of any of the above projects.

All the above-mentioned initiatives are viewed by a few of the fishermen's community as not cost-effective with near nil subsidies by the government. This makes the practices away from the desired objective of sustainable goals. Therefore, stronger fisheries management is imperative towards long-term social and economic objectives for fisheries. Towards this, the stocks are to be made healthy and sustainably harvesting the same. Strong regulatory practices already proved in the other regions would be a solution.

Also, India is surrounded by South Asia maritime nations' oceanic space, India may take the lead under the aegis of the South Asia Co-operative Environment Programme (SACEP) to develop a regional marine and coastal biodiversity strategy

Marine and Coastal Biodiversity Strategy and Marine Protected Areas. The Marine Protection Area (MPA) are many types depending on intend of its creation. Certain MPAs allows people to use the area in a way that do not damage the environment (targeted intend), some ban complete fishing and few do not allow any human entry into the area. It may have different names viz. marine parks, marine conservation zones, marine reserves, marine sanctuaries and no-take zone. India has about 24 MPAs in peninsular India and many on the Islands space.

The 7517 Km long coastline of India support an estimated 250 million human population living within the 50 Km wide swathe of the coastline.[19] This huge population is largely dependent on the rich coastal and marine resources. Very understandably despite these declarations of these MPAs India's coastal and marine ecosystems are under threat.[20] Also, these MPAs like Marine National Park, Gulf of Kutch, Gulf of Mannar Marine National Park, Sunderbans National Park, Gahimatha (Marine) Wildlife Sanctuary, Mahatma Gandhi Marine National Park near Wandoor, etc are mostly declared under the Wildlife (Protection) Act 1972 which for conservation of marine biodiversity in a fragile ecosystem. However, none of them directly intend to recharge or develop lost fisheries stock in the area. Therefore, some scientifically studied areas are to be found wherein fishing bans and restrictions on any kind of pollution should be imposed with certain relaxation to artisanal fishermen and tourism visitation. Declare such area as a protected area through Central Fisheries law at the National level. Also, India is surrounded by South Asia maritime nations' oceanic space, India may take the lead under the aegis of the South Asia Co-operative Environment Programme (SACEP) to develop a regional marine and coastal biodiversity strategy. This will address the climate change, microplastic and other marine pollution issues in the region due to heavy shipping traffic. This is the need of the hour even under the Convention on Biological Diversity (CBD), UNEP's Regional Sea Program and UN Sustainable Goal objectives. The collaboration could be in line with FAO's Regional Commission for Fisheries (RECOFI) and South West Indian Ocean Fisheries Commission (SWIOFC). This will help in controlling extra-regional agencies involved in IUU fishing and illegal trading.

Conservation of Coastal Reef and Artificial Reefing. Artificial reef are set of structures deployed intentionally on the seabed to enhance the growth of marine flora and fauna benthic communities thereby promoting increase the resident population of fishes within the sheltered structure. These are practiced all over the world where the human activities particularly unsustainable fishing practices have spoiled the marine ecosystem. The first International Conference on Artificial Reef and Related Aquatic Habitats was held in Texas, USA in 1974 and subsequently the conferences have helped in developing several artificial reef management guidelines for European waters (OSPAR 1999, UNEP-MAP 2005, London Convention and Protocol – UNEP 2009, OSPAR 2009).[21]

Lack of training among the fishing communities has led to a lack of knowledge and unsustainable fisheries practices

In India ICAR and CMFRI has been working on habitat enhancement through this technique. The efforts are limited and concentrated on certain places. A detailed study by the scientific community and a strong action plan by the Central Government in coordination with the State Government would go a long-way in reinstatement of fisheries stock in Indian waters. The best practices from the other part of the world with a working group from Central Government consisting of participants from all coastal states, regulatory bodies would lead the nation towards desired objective.

Species Exclusive devices. The by-catch and unintentional catch are major problem in any fishing operations. In India there are only certain areas and period of time were this has been made compulsory. Certain Turtle Excluder Devices (TED) is being introduced but they only in certain parts of Indian waters. Therefore, it requires stricter provisioning by the Centre and the State regulatory bodies. A strict implementation of approved Bycatch Reduction Devices (BRDs) implemented through enactment of law will achieve higher efficiencies and stock level in the regional waters.

Mandatory Training and Skill development of at least 50% of Fishing vessel Crew. India being a maritime nation thrives to expand on its ocean-based economy or the Blue Economy. Under the ocean-based economy, the major stakeholder is the fisheries sector and hence sustainable fisheries cannot be ignored at the cost of other stakeholders. Lack of training among the fishing communities has led to a lack of knowledge and unsustainable fisheries practices. Therefore, the existing marine fisheries need enhancement of skill development and initially target to have at least 50% of the fishing crew be trained and certified in fisheries operations. It requires a major awareness campaign by all maritime states and the centre to encourage these initiatives. This is *sine-qua-non* for optimal and sustainable utilisation of marine fisheries resources available in Indian waters. This would address the increasing number of migrant labourers in the marine fisheries operations causing security concerns and uneconomical and unsustainable fisheries operations. Certification of skills would also instil a sense of pride among the fishermen community who are in large numbers not practicing their traditional profession for want of being perceived more recognised profession. This will indirectly stop the migrant labourers in the fishing operations.

Organised regulation of Fishing Operations. The Fisheries is largely an unorganised sector making this sector highly susceptible to fall prey in the hands of

antisocial agents. The lack of incentives reaching the fishing crew keeps them poor making them fall into the hands of drug traffickers, human trafficking, gun running and other illegal gangs for want of insignificant material incentives. Bringing this sector in an organised manner, making shore authorities responsible for the fishing crew will help in making the fishing operations more transparent and less action by the security agencies on such operations.

Conclusion

The development of sustainable fisheries sectors globally in general and in India particularly therefore is inescapable to meet the growing human protein requirement. No nation in the future can be developed without a strong and developed fisheries sector. The challenges are many and they are to be addressed in a time-bound manner to achieve the desired objective. In order to make a robust fisheries sector there has to be strong capacity building and capability building among all the stakeholders. The ill factors like poverty among the Indian fisheries is major concern therefore require immediate addressing. The fisheries stock requires to be restored for ensuring its sustenance for the future generation and the depleting land-based food security. Hence a strong ocean governance is an imperative for the existence of the mankind on this planet and needs awareness and its implementation in a time bound manner.

[This paper was presented in IMU's MARPOL CC Conference/February 2024]

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Marine Renewable Energy Scenario in India: Prospects and Challenges (Part 3)

Yash Jain

6. Government Initiatives and Stakeholder Endeavours

In the realm of Marine Renewable Energy (MRE) development in India, several government agencies have played instrumental roles in promoting research, technology innovation, and project implementation. This section will delve into the specific contributions and initiatives of key government agencies, the importance of public-private partnerships, and the role of research institutions and academia in advancing MRE technologies.

6.1 Role of Government Agencies in Promoting MRE

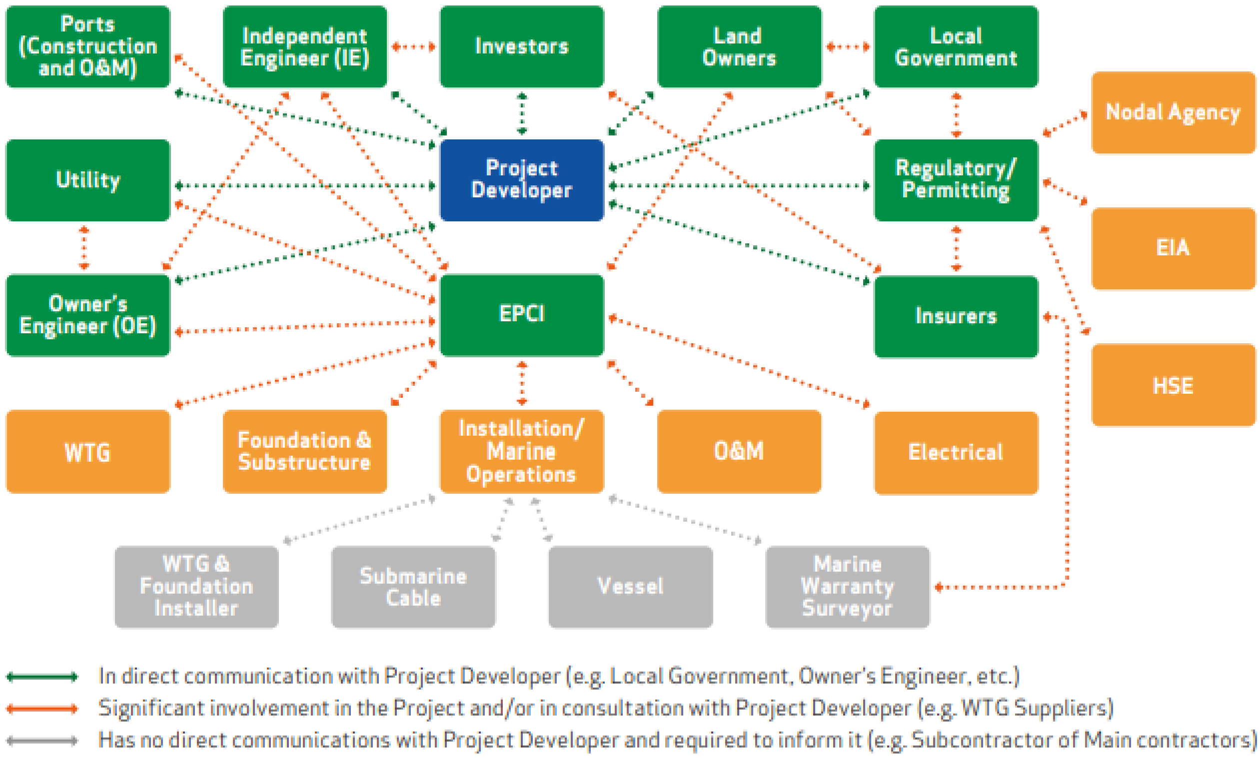
The Ministry of New and Renewable Energy (MNRE) and the National Institute of Wind Energy (NIWE) are pivotal government bodies driving the promotion and implementation of MRE initiatives across India. MNRE, as the apex ministry responsible for renewable energy development in India, has formulated strategic policies and frameworks to foster the growth of MRE. Notably, MNRE has sponsored research projects, including Met-Ocean measurements and feasibility studies, to assess the potential of offshore wind and other MRE resources. Moreover, MNRE has provided financial incentives and subsidies to support the deployment of MRE technologies, aiming to achieve the national renewable energy targets [1].

NIWE, an autonomous research institution under MNRE, has been instrumental in conducting resource assessments, research, and technology demonstrations to advance MRE projects. NIWE's Met-Ocean measurement campaigns and research studies have provided critical data for project developers and policymakers, enhancing the feasibility and implementation of MRE initiatives. NIWE's initiatives include LiDAR-based measurements campaigns in the Gulf of Khambhat and Gulf of Mannar to characterise wind profiles and assess offshore wind potential [2].

6.2 Public-Private Partnerships and Industry Collaborations in MRE Projects

Public-private partnerships (PPPs) and collaborations with industry stakeholders have been vital in accelerating the deployment of MRE projects in India. Initiatives such as the Offshore Wind Energy Consortium and collaborations between MNRE and industry players have facilitated knowledge exchange, technology transfer, and project funding [2]. Industry participation in pilot projects and technology demonstrations has enabled scalability and commercialisation of MRE technologies in Indian waters.

Furthermore, joint ventures between Indian and international companies, supported by government-backed schemes, have brought global best practices and technology innovations to India's MRE sector. These partnerships leverage private sector expertise and capital to drive innovation and project development, complementing government efforts. For instance, Suzlon Energy and other renewable energy companies have partnered with government agencies to explore offshore wind projects along India's coastline.



Stakeholder Analysis chart. *Image by DNV GL*

6.3 Contribution of Research Institutions and Academia in Technological Advancements

Research institutions and academia have played a crucial role in advancing technological advancements and knowledge dissemination in the MRE sector. Institutions like the Indian Institutes of Technology (IITs), National Institutes of Technology (NITs), and research centres have conducted studies on wave dynamics, turbine design, and environmental impact assessments. These efforts have contributed valuable insights to project planning and policy formulation.

Academic-industry collaborations have also fostered innovation and talent development in MRE technologies. Research projects funded by government grants and industry sponsorships have led to breakthroughs in materials science, control systems, and marine ecology, addressing critical challenges in MRE deployment [3,4].

In conclusion, the coordinated efforts of government agencies, public-private partnerships, and research institutions have been instrumental in driving the prospects of marine renewable energy in India. Collaborative endeavours have not only accelerated technological advancements but have also paved the way for sustainable development and energy security.

7. Financial and Economic Considerations

Marine renewable energy (MRE) projects involve specific financial and economic considerations that impact their feasibility and implementation. This section explores key aspects related to capital costs, operational expenditures, economic benefits, and cost-effectiveness compared to conventional energy sources.

7.1 Capital Costs and Operational Expenditures of MRE Projects

Marine renewable energy projects typically entail higher capital costs compared to conventional energy projects due to the specialised nature of marine technologies and installation processes. The capital costs include expenditures for equipment procurement, construction, installation, and grid integration. For instance, offshore wind farms require substantial investments in offshore infrastructure, such as turbines, foundations, and electrical systems [5].

Operational expenditures (OPEX) for MRE projects encompass ongoing costs associated with maintenance, repairs, monitoring, and decommissioning. The harsh marine environment presents unique challenges, including corrosion and biofouling, which contribute to higher operational costs over the project lifespan [4].

7.2 Economic Benefits

Marine renewable energy projects offer significant economic benefits, including job creation and local economic development. The development and operation of MRE projects require a skilled workforce, ranging from engineers and technicians to project managers and support staff. Studies have shown that the

Technology	Techno-Economic Status	Challenges	Benefits
Offshore Wind	Mature Technology, Available, Commercially Viable	Need for large marine area use an issue for large-scale farms	Leverage local marine and offshore capabilities (e.g., ship building, etc.)
Tidal Range (e.g., Barrage)	Mature Technology, Commercially Viable	Very high environmental impact for dam-like structures; Tide range >4 meters needed to be economically viable	Very predictable; technology similar to hydropower
Tidal Stream	Pre-Commercial, Turbine Technology High TRL	Technology costs need to be reduced	Very high predictability (18.6 years); resource not affected by weather; suitable for island regions
Ocean Current	Prototype and Pilot Systems	Limited sites; can be remote offshore	Can be baseload
Wave	Prototype and Pilot Systems	No technology convergence to scale (yet)	Niche applications; can be coupled to hybridize wind projects
OTEC	Prototype and Pilot Systems	Still very high LCOE (high CAPEX) even at 10 MW scale	Can be baseload supply
Salinity Gradient	Prototype and Pilot Systems	Still high LCOE. Needs co-application/integration (e.g., energy recovery in desalination plants) to make economic sense	Synergistic niche applications (aquaculture, salt production, desalination) and areas may be pathway to commercialization

CAPEX = capital expenditure, LCOE = levelized cost of energy, MW = megawatt, OTEC = ocean thermal energy conversion, PV = photovoltaic, TRL = technology readiness level.

Sources: International Renewable Energy Agency (IRENA). 2014. *Ocean Energy: Technology Readiness, Patents, Deployment Status and Outlook*. Abu Dhabi; IRENA. 2020. *Fostering a Blue Economy: Offshore Renewable Energy*. Abu Dhabi; IRENA. 2020. *Innovation Outlook: Ocean Energy Technologies*. Abu Dhabi; and IRENA. 2021. *Offshore Renewables: An Action Agenda for Deployment*. Abu Dhabi.

Marine Renewable Energy Technologies and Their Status

renewable energy sector, including MRE, generates more employment opportunities per unit of energy produced compared to fossil fuel-based energy sources [3,6].

Moreover, MRE projects contribute to local economic development by stimulating investments in infrastructure, manufacturing, and supply chain activities. Local businesses benefit from increased demand for goods and services related to MRE project development, leading to broader economic growth and diversification in coastal regions [3,4].

7.3 Cost-Effectiveness Compared to Conventional Energy Sources

The cost-effectiveness of MRE projects relative to conventional energy sources depends on various factors, including technological advancements, economies of scale, and regulatory frameworks. While initial capital costs for MRE projects may be higher, advancements in technology and economies of scale have led to significant cost reductions over time.

Furthermore, MRE projects offer long-term cost advantages, such as fuel cost savings and reduced exposure to volatile fossil fuel prices. Studies have demonstrated the potential for cost-competitive MRE, particularly offshore wind, compared to traditional energy sources like coal and natural gas [7].

8. Potential Benefits of Marine Renewable Energy

Marine renewable energy holds significant promise for India in terms of energy security, environmental sustainability, and global climate change mitigation. This section explores the potential benefits of marine renewable energy, including its role in reducing reliance on imported fossil fuels, mitigating greenhouse gas emissions, and contributing to India's commitments to global climate change goals.

8.1 Energy Security: Reducing Reliance on Imported Fossil Fuels

Marine renewable energy offers a viable alternative to traditional fossil fuels, which are largely imported, to meet India's energy needs. By harnessing the abundant marine resources along its vast coastline, India can enhance its energy security and reduce its dependence on imported fuels [6]. According to the National Institute of Wind Energy (NIWE), India's offshore wind potential alone is estimated to be around 70 GW [2]. Developing marine renewable energy resources can provide a stable and indigenous energy source, thereby reducing exposure to volatile international energy markets and geopolitical risks associated with fossil fuel imports.

8.2 Greenhouse Gas Emissions Reduction and Carbon Footprint Mitigation

The deployment of marine renewable energy technologies offers a pathway to significantly reduce greenhouse gas (GHG) emissions associated with electricity generation and other energy-intensive activities. Unlike fossil fuel-based power generation, marine renewable energy sources such as offshore wind,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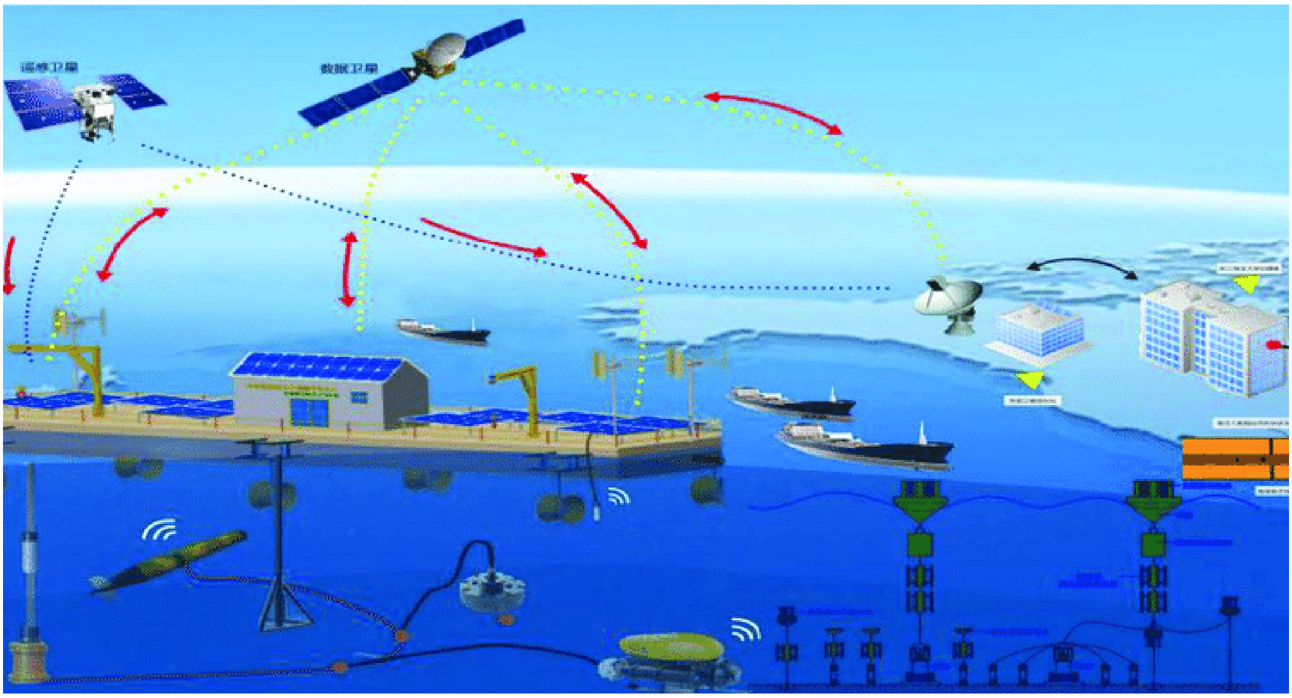

tidal, and wave energy produce minimal to no greenhouse gas emissions during operation. Studies have shown that transitioning to marine renewable energy can lead to substantial reductions in carbon dioxide (CO_2) emissions and other pollutants, thus contributing to cleaner air and mitigating the carbon footprint of the energy sector [4,8].

8.3 Contribution to India's Commitments to Global Climate Change Goals

India has made ambitious commitments under the Paris Agreement to reduce its carbon intensity and increase the share of renewable energy in its overall energy mix. Marine renewable energy technologies play a pivotal role in helping India achieve its climate change mitigation targets by facilitating the transition towards a low-carbon economy. The International Energy Agency (IEA) emphasises the importance of scaling up marine renewables to align with global climate objectives and limit the rise in global temperatures [7]. By expanding its investment in marine renewable energy projects, India can demonstrate leadership in combating climate change on the international stage.

In summary, marine renewable energy presents compelling benefits for India, ranging from enhanced energy security through reduced reliance on imported fossil fuels to substantial reductions in greenhouse gas emissions and alignment with global climate change goals. By prioritising the development and deployment of marine renewable energy technologies, India can unlock multiple economic, environmental, and social advantages while advancing its sustainable energy transition.

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About the Author

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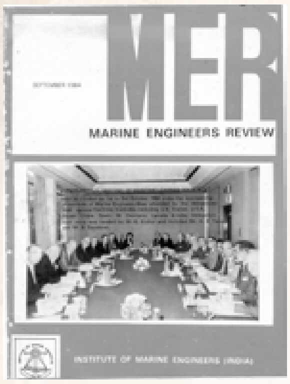
Going Astern into MER Archives…



The Editorial highlights a meeting which had taken place in London. Maritime Learned Societies (guess it is a name handle to refer to the group that had assembled) apparently had members from India, UK, France, USA, Spain, japan, China, West Germany and Canada (as mentioned in the Editorial) to discuss cooperation. Organising symposia, conference and mutual cooperation were the elements of discussion. Evidently, IMarE had been the force behind the initiative. Though it is not clear which all Societies participated, one could guess.

Fig. 1 'Drawing' on the screen via electronic pen on a tablet.

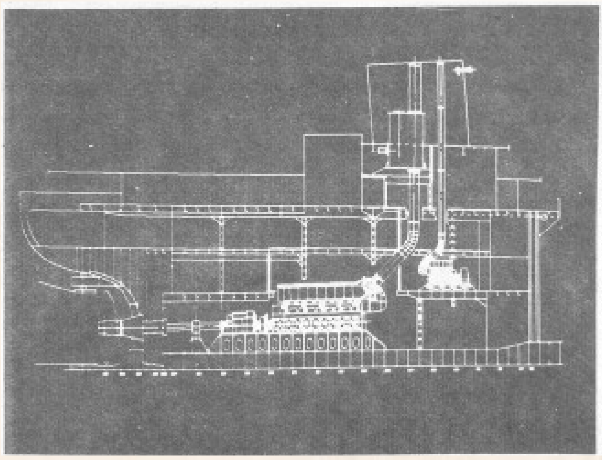


Fig. 3 Elevation produced at half way through the design.

Similar initiative can be fashioned (e.g., WMTC 2024 at Chennai this December?) and many more. (The Maritime Learned Societies need to be defined).

The 'Opinion' talks about extending subsidy to the shipping sector, especially to ship building. An idea circulated (as in the Opinion) is that cargo ships be built which can be easily converted into defence vessels.

The shrinking British shipbuilding is the concern being deliberated upon. Will the move to privatise warship-building division and part of the composite yards benefit the British Shipbuilding is (was) the question. The last part of the 'Opinion' talks of a remote controlled vessel sailing across oceans and the costs it may entail.

The trail of articles include discussions on future shipbuilding (can robots build ships?), CAD in Marine Engineering and one on how Kockums Shipyard (of Sweden) had maintained productivity and kept ahead. The answer emerging was that the modernisation techniques had made the difference.

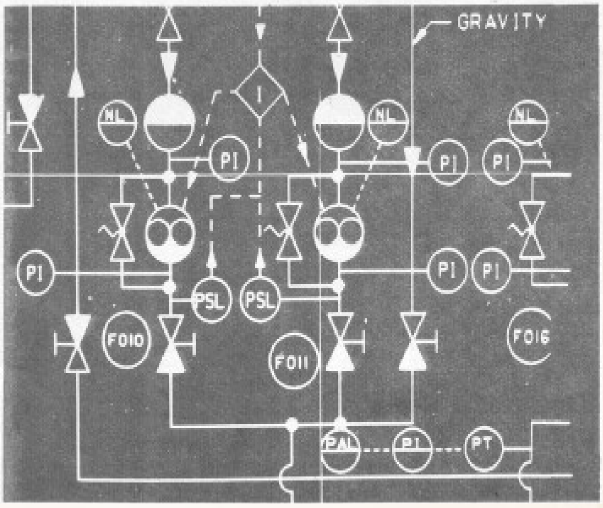


Fig. 2 Part of the fuel oil system.

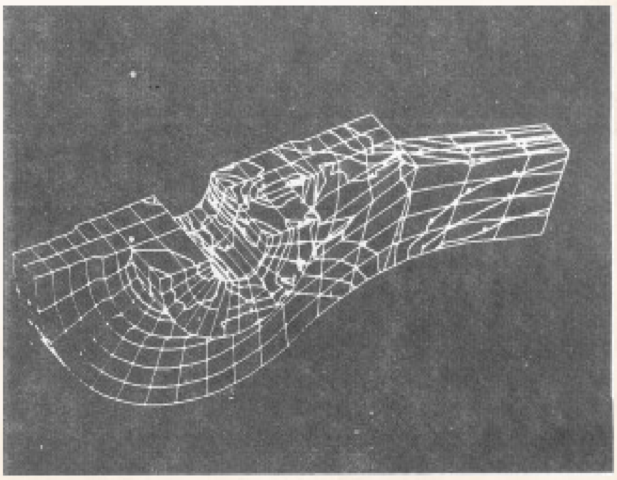
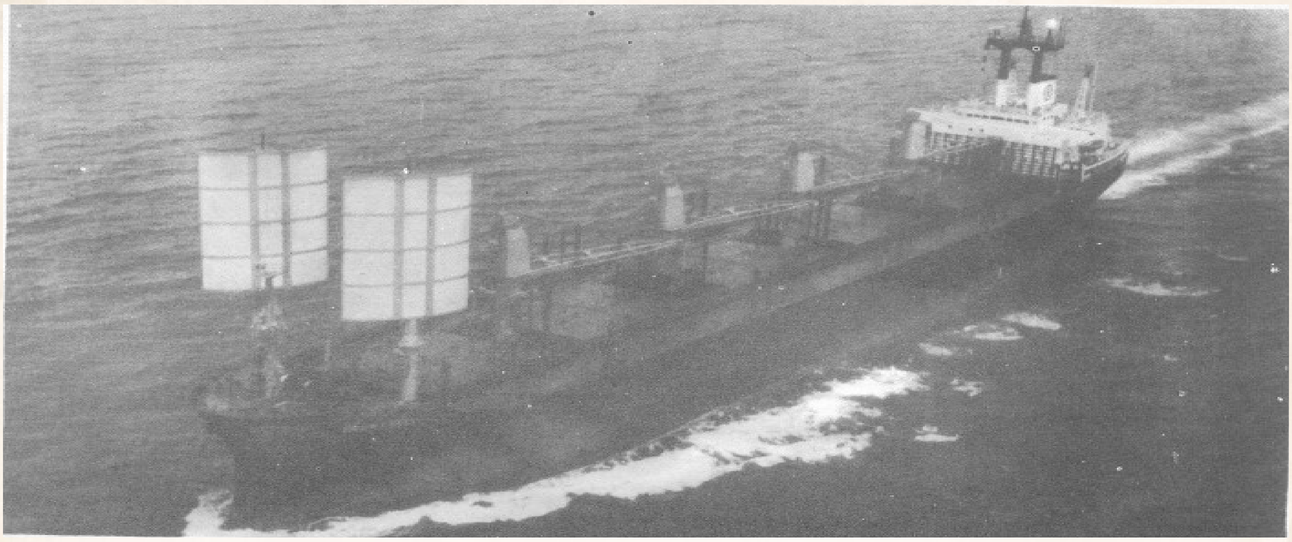


Fig. 4 Even components, like this conecting rod, can be designed and analysed.

There is one article on a marine simulator modelled on a SULZER 6RND90M engine. This can be an interesting one if we compare the modern simulators and their scope for training. And there are article on ocean-going sail-equipped bulk carriers. This can be a look back into the future (since there are designs emerging with similar ideas).



We project a Transaction on, 'Neutral Earthing of Marine Electrical Power Systems', which can be of interest to engineers preparing for exams and others.

The POSTBAG, has a n interesting letter from M/s Moss Rosenberg on LNG vessel cargo containment tank construction features. There is one discussion on boiler failure and IGS on tankers. And there is a report on asymmetric stern arrangement for container ships.

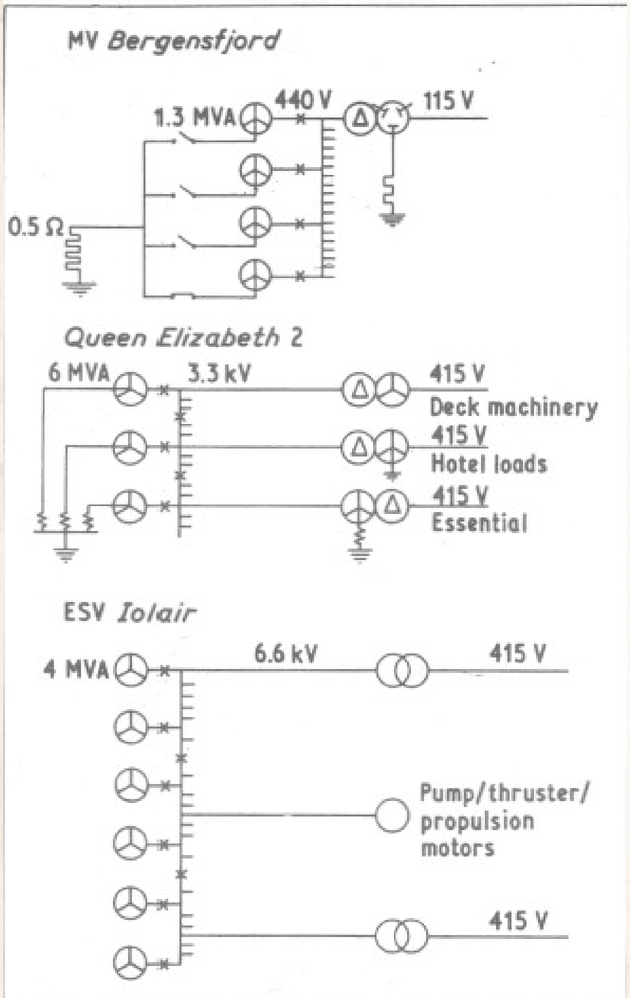


Fig. 1 Neutral earthing arrangements

Table I: Earthing of marine power system neutrals: summary of regulations

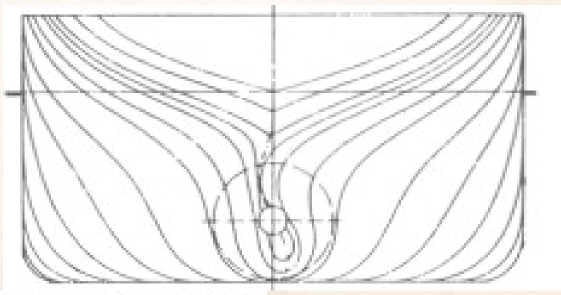
REGULATORY BODY	LOW VOLTAGE General	LOW VOLTAGE Tankers	HIGH VOLTAGE General	HIGH VOLTAGE Tankers
LRS	E	—	E(2)	E(1)(2)
ABS	E(3)	E(3)	E(3)	E(3)
DNV	E	—	E	—
BV	E(3)	—	E(3)	—
RINA	E(3)	—	E	E(1)(3)
NKK	E	E(1)	E	E(1)
IEC	E	—	E	E(1)
IEE	E	—	E(2)	E(1)(2)
IEEE	E	E(1)	E	E(1)

Key

E Earthing of neutral permitted.
LRS Lloyd's Register of Shipping.
ABS American Bureau of Shipping.
DNV Det Norske Veritas.
BV Bureau Veritas.
RINA Registro Italiano Navale.
NKK Nippon Kaiji Kyokai.
IEC International Electrotechnical Commission.
IEE Institution of Electrical Engineers.
IEEE Institute of Electrical and Electronics Engineers.

Notes

(1) Providing any possible resulting current does not flow through a hazardous area.
(2) Earth fault current to be limited to full load current of largest generator.
(3) Earth fault current in electric propulsion systems to be limited to typically less than 20 A.



The asymmetrical stern.

POSTBAG

LNG tanks

Sir

In your June 1984 edition (p35) there is an item entitled 'Membrane LNG carrier test results.' It says that the membrane types referred to, namely Technigaz Mk I and Mk III, have a 20-year proven superiority to Spherical tank-type LNG carriers in safety performance. How is this possible as no LNG carrier with Technigaz membrane type Mk III has ever been in service?

Moss spherical tank type LNG carriers have a total service experience, measured in m³ LNG × nmiles, which far exceeds the experience of any other LNG carrier type. None of the 25 spherical type LNG carriers in service have ever been taken out due to non-performance of the cargo tanks.

In the item, NKK states that, compared with spherical tanks, the Mk I and Mk III construction costs can be reduced by up to 8% and 15%, respectively. How can NKK know? They have never built and delivered any LNG carrier, neither with membrane tanks nor with spherical tanks.

A detailed cost comparison made together with one of our licensees well experienced in building membrane type LNG carriers, showed no significant building cost difference between the membrane type and the spherical type LNG carriers in question. Assuming that the tank insulation costs of a membrane type LNG carrier amount to some 8% of the total carrier construction costs, it is very hard to believe that the latter can be reduced by 7% as the claimed difference between Mk I and Mk III.

Halfdan H Iversen

Moss Rosenberg
Oslo

● *All claims in the June item were made by NKK and they have been invited to respond to Mr Iversen's letter*—Editor

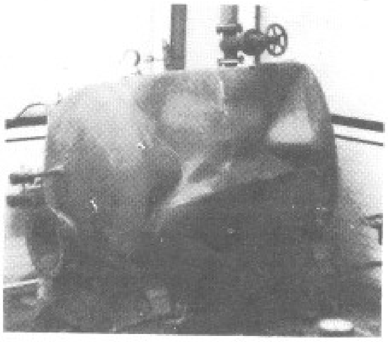
Boiler failure

Sir,

Further to Peter Kennedy's description of a failure of a small hot water boiler, (Postbag March 1984) I would suggest that in failures of this type, changes of pressure can occur so rapidly as to render normal-sized safety valves, vent pipes, etc, inadequate.

I enclose a photograph of a copper calorifier which collapsed due to vacuum. The vessel was fitted with an anti-vacuum valve cold feed (the lagged pipe underneath) and an open vent on the flow side, all ostensibly of adequate size, yet these in combination did not prevent the collapse.

Similar failures to Mr Kennedy's have been recorded on low-pressure hot-water systems with cast-iron sectional boilers which have failed in a spectacular manner following restoration of cold feed to an overheated boiler. But whether the final failure was due to pressure, thermal shock or hydrogen production, is matter of conjecture.



B A Fewtrell

Bury, Lancs.

Tanker safety

Sir,

Mr G Victory has drawn attention to the conflict between the International Safety Guide for Oil Tankers and IMO Regulations with specific reference to inert gas installations. I agree with his remarks on VLCCs but think there is room for criticism of IMO too.

The 1978 protocol produced regulations based on the lowest standard of debate in the history of international marine regulation. Issues were debated that had already been settled by a US Presidential Initiative; this forced the US delegation into error on many issues in order to defend the indefensible. Now that we are in a period of consolidation of existing legislation, this should include revisionary work on the more obvious excesses.

While the value of IGS on large crude carriers is recognized, its application to product tankers of 20 000 to 40 000 dwt should be re-examined.

Masters on these ships are concerned about the additional hazards which IG introduce in their routine operations. During mopping up and inspection procedures prior to receipt of the next clean cargo, the problem of venting the tanks for safe entry and re-inerting after inspection is not free from risk and involves a very considerable loss in ship time.

Some companies are venting tanks at the same time as others are being inerted in order to reduce lost time and masters ask 'Is this safe?'

As such ships are mostly on relatively short voyages, the operations occur frequently and this accentuates the lost time into a large reduction of operating efficency.

This factor, in itself, significantly increases overall risk, since another ship must be exposed to the total risk climate to make up the deficiency. Moreover, since an IMO rule is applied to the whole world fleet, any major loss in efficiency of a large class of ships will increase the risk climate in all ports visited. These transferred risks were not evaluated by IMO as they should be for any measure which involves very high cost or significant loss in transportation efficiency.

Examining the case for extension of IG to these smaller ships, there were two cases discussed, the US and OCIMF's. The US case was accepted by IMO and was based on two main premises:

that with IG aboard, properly maintained and properly operated, there would be a marked reduction in the incident rates;

2 since incident rates did not vary much over the size range, this benefit would apply independently of size.

Philosophically, there are two things wrong with this. Incident rates are only part of the risk equation, and the expected reduction in incident rate with IG aboard does not appear in end-result analyses.

On either count the argument must fail.

Herbert Spencer, in his 1884 book 'Man Versus The State', observed that 'Confusion of ideas caused by looking at one face only of the transaction may be traced through all legislation.' Here, 100 years later, we have another example. And, in this case, the basic facts are not even believable.

The other face of the transaction is 'associated risk per incident.' This fully supports the SOLAS 1974 decision to inert all tankers over 100 000 dwt; it does not support the extension to 20 000 dwt as OCIMF showed in their brief on this subject. Since the OCIMF brief only included 'associated risks' directly related to the incident itself and not those which result from high cost, efficiency loss, and the IG system, their results must be regarded as having a bias in favour of IG.

It should be the cornerstone of IMO policy that error in the formulation of any regulation should not be condoned. Otherwise we are governing shipping by humbug.

E E Bustard

Naval Architect
Oakville, Ontario

Readers will have perhaps noted the error, concerning ownership of the *QE2*, in last month's Opinion. She is, of course owned by Cunard, not P&O. Our apologies are extended to both companies.

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

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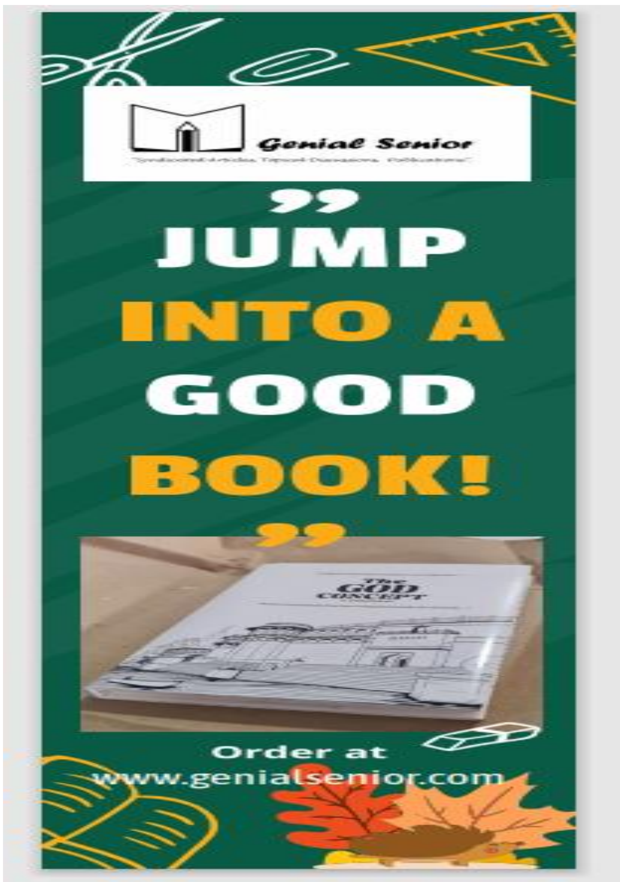

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