Volume 1, 2016

Annual Technical Volume of

Marine Engineering Division Board

Theme:
Technological Development in Maritime Sector

The Institution of Engineers (India)

Marine Engineering Division Board (2015-2016)

About the Division Board

The Institution of Engineers (India) has established Marine Engineering Division in the year 1978. This Division consists of quite a large number of corporate members from Government, Public, Private sectors, Academia and R&D Organizations.

Various types of technical activities organized by the Marine Engineering Division include All India Seminars, All India Workshops, Lectures, Panel Discussions etc., which are held at various State/Local Centres of the Institution. Apart from these, National Convention of Marine Engineers, an Apex activity of this Division is also organized each year on a particular theme approved by the Council of the Institution. In the National Convention, several technical sessions are arranged on the basis of different sub-themes along with a Memorial Lecture in the memory of "Rear Admiral T B Bose", the renowned Marine Engineer, which is delivered by the experts in this field.

In order to promote the research and developmental work taking place in the field of architectural engineering, the Institution also publishes Marine Engineering Division Journal twice in a year, where mainly the researches and its findings are focused. Due to multi-level activities related to this engineering discipline, this division encompasses the following emerging and thrust areas:

- Recent Technological Development of Marine Diesel Engine
- Control System and Platform Management System on Marine Platforms
- Environmental Protection, Initiatives & Implementation through InternationalRegulations
- Application of Electronics, Hydraulics and Workshop Practice related to Shipping
- Super Conducting Materials related to Marine Applications
- Greater Manpower Availability with thrust on Training & Regulation
- Piracy and Security at Sea
- Innovative Design for Under Water Vehicles
- Safety of Life at Sea (SOLAS) Requirements
- Port Safety
- Innovations in Ship Building Technology
- Development of Fuel Efficiency Engines and Energy Saving Devices
- Sea-Plane/Hydro-Plane/Hovercraft
- Inland Water Transport
- Indian Maritime Heritage
- Ocean Observation System

In order to promote the research and developmental work in the field of Marine Engineering, the Institution also publishes Journal of The Institution of Engineers (India): Series C in collaboration with M/S Springer which is an internationally peer reviewed journal. The journal is published four times in a year and serves the national and international engineering community through dissemination of scientific knowledge on practical engineering and design methodologies pertaining to Mechanical, Aerospace, Production and Marine engineering.

Annual Technical Volume

2016

Technological Development in Maritime Sector

The Institution of Engineers (India)

Marine Engineering Division Board

The Institution of Engineers (India)

AN ISO 9001 : 2008 CERTIFIED ORGANISATION

(ESTABLISHED 1920, INCORPORATED BY ROYAL CHARTER 1935)

HEADQUARTERS : 8 GOKHALE ROAD, KOLKATA - 700 020, INDIA

Ph : (91) (33) 2223 1979 • **E-mail :** president@ieindia.org • **Web Site :** http://www.ieindia.org

H C S Berry, FIE
PRESIDENT

"97 years of Relentless Journey towards Engineering Advancement for Nation-building"

It is a matter of immense pleasure that Marine Engineering Division Board of the Institution has successfully published the first Annual Technical Volume on the theme 'Technological Development in Maritime Sector'.

Moreover, it's a matter of proud that our learned Corporate Members attached to the Marine Engineering Division have contributed papers for this publication related to different aspects of Marine prime movers, modes of shipping, ballest water treatment, shipbuilding and repair, maritime education etc.

On this occasion, I would like to take the opportunity to congratulate the Members of Marine Engineering Division Board for their sincere efforts and whole hearted support in bringing out this Annual Technical Volume.

I sincerely believe that the practicing professionals in the relevant fields will be immensely benefitted from this compilation and be a part of competent workforce for future maritime development of the country.

H C S Berry

Resi. : 'Shantikunj', 406 Karoran Road, Naya Gaon, Chandigarh - 160103
Phone : (0172) 2785755 / 2785855, **E-mail :** hcsberry@rediffmail.com

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"97 years of Relentless Journey towards Engineering Advancement for Nation-building"

Prof (Dr) N R Bandyopadhyay, FIE, FAScT

Chairman

Committee for Advancement of Technology and Engineering (CATE)

I am glad to learn that as approved by CATE/Council, the Marine Engineering Division Board of The Institution of Engineers (India) has successfully brought out its first Annual Technical Volume on the theme "Technological Development in Maritime Sector", which is very relevant in the present context of maritime industries. The volume consists of papers contributed by the Corporate Members attached to the Marine Engineering Division of the Institution highlighting various aspects of topical interest in the field of shipping industry.

At the outset, I congratulate the Chairman and the Members of the Marine Engineering Division Board for their sincere efforts in bringing out this exclusive collection of articles. I sincerely believe that the articles in this volume will be interesting to the academicians and practicing professionals in the field of marine engineering and will also facilitate further researches initiative in this emerging field of technology.

N R Bandyopadhyay

Editor in Chief

Message from Consulting Editor

The Maritime commercial shipping industry is the key motivator for a major percentage of world trade. Subject to free market force, maritime industry has achieved higher efficiency and subsequently contributed for expanding global economy, which enable the low cost movement of goods across the globe.

It is well known that the container ships are one of the most preferred forms of transport for manufactured goods from the Asian countries, who have a major market share in manufacturing. The growing demand for resources and continuing climate change are expected to create new opportunities for resource exploration, production and shipping of goods in different coast lines and shipping regions.

According to the Ministry of Shipping, around 95 percent of India's trading by volume and 70 percent by value are obtained through maritime transport. The Ministry of Shipping announced a massive investment in Indian Ports and road sector, which is likely to help boost Indian economy. Government also plans to develop ten coastal economic regions as parts of plans to revive the country's ***Sagarmala*** (string of ports) projects.

It's a matter of immense pleasure that the Marine Engineering Division Board of the Institution, as per laid down norms by CATE/Council has published the first Annual Technical Volume of Marine Engineering Division on the theme 'Technological Development in Maritime Sector', where the papers have contributed by the professionals both from industry and academia on contemporary maritime issues.

I deeply appreciate the effort taken by the Members of the Marine Engineering Division Board to bring out the publication. Hope that this publication will felicitate sharing of knowledge and experience amongst maritime engineering fraternity which results onward progress in maritime sector.

Last, but not least, it's a proud privilege for us to release this publication of the Marine Engineering Division Board on the onset of Centenary Celebration of The Institution of Engineers (India).

With warm regards,
Yours sincerely,

Dr K Gopalakrishnan
Chairman
Marine Engineering Division Board
The Institution of Engineers(India)

Annual Technical Volume of

Marine Engineering Division Board

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Maj Gen S Bhattacharya, VSM (Retd), FIE
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Publication Office

The Institution of Engineers (India)
8 Gokhale Road, Kolkata 700020
Ph : 2223-8311 /14-16 / 33-34
Fax : (033) 2223-8345
website : www.ieindia.org
e-mail : technical@ieindia.org

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Contents

Clean Electricity- Hybrid Power Generation

Avijit Sharma, Kamal Yadav, Himanshu Sharma
B W Maritime Pvt. Ltd.
Mumbai, India
✉ *avijitsharma94@gmail.com*

Abstract

Energy is critical in the entire process of evolution, growth and survival and it plays a vital role in the socio-economic development of a country. Energy is a ‘strategic commodity’ and any uncertainty about its supply can threaten the functioning of the economy. India is on the threshold of a growth trajectory. In order to sustain economic growth there is an enormous demand of energy resources. India faces a peculiar challenge of increasing output while minimizing the production cost. At the present rate of growth the energy demand is set to increase by nearly two folds by 2020. Nearly 54% of the total installed electricity generation capacity is coal based. Renewables energy such as wind, geothermal, solar, and hydroelectricity represent a 2 percent share of the India’s electricity generation capacity. Also nuclear holds a one percent of this share. The total potential for renewable power generation in the country by 2013 was estimated as 89774 MW. This has motivated research, development, demonstration, innovation and dissemination of knowledge to contribute in minimizing pollution and providing clean energy. The hybrid energy system has received much attention over the past decade. It is a viable alternative solution as compared to a system which relies entirely on hydrocarbon fuel. It will not only overcome hydrocarbon fuel consumption but also give clean and eco-friendly electricity. This paper aims at analysing the feasibility of the above and gives a conceptual design of a hybrid micro power grid which will serve the port facilities. Port loads considered here are office buildings, residential buildings, water pump house, air conditioning, tower lamps etc. The pattern of electrical load of Tolani Maritime Institute (TMI) campus has been studied and suitably modelled for optimization of the hybrid energy system and implemented to a port having a similar load distribution in order to reap the benefits of hybrid energy. National Renewable Energy Laboratory (NREL)’s, Hybrid Optimization Model for Electric Renewable (HOMER v2.68 beta) has been used as the sizing and optimization software tool.

The action plan has been formed on the basis of cost effective modelling, that is minimization of energy production cost in the long run along with minimizing the pollution. Also a comparative study has been carried out in order to study feasibility of various combinations of sources of energy generation that include wind, solar and conventional fuel.

Keywords : *Micro grid; Hybrid; Renewable energy; Port; Sustainable*

Introduction – Case and Scope

Tolani Maritime Institute (TMI) is located 19.1336° N, 72.9154° E. The infrastructure at the campus includes the network of wide tree-lined roads, architectural design with the landscape and waterscape of cooling ponds and a lake. The engineering systems of the campus are a 0.8 MW coal fired power plant, modern vapor absorption chiller, water treatment plant and effluent treatment plant. The academic facilities includes air conditioned classrooms (50), workshops (2), laboratories (20), a library (7,000 sq. ft.), an auditorium (300 seated), a functional ship-in-campus, simulators and faculty offices for over 100 faculties. The residential facilities include 3 hostels accommodating over 1500 students, town styled apartments over 125 for families of faculty and an executive residence for the persons enrolled in advanced courses. In addition to these, different sports facilities, 24 × 7 medical facilities, canteens, shopping complex and a laundry. The pattern of load consumption of campus are studied and suitably modelled for optimization of the hybrid energy system using Homer Software.

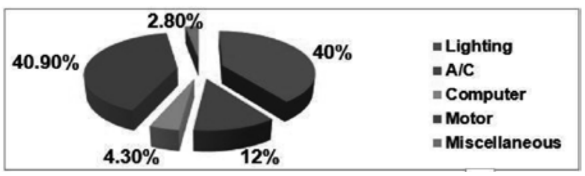


Figure 1 : Load distribution

In order to derive the load profile **(Figure 1)** of the drinking water treatment plant, two key questions need to be addressed: 1) What is the total electricity demand over the course of the year, and 2) How is the demand distributed over a year, week, day, and on an hourly level. The load variation of the campus on a 24 hour basis was measured using a Power Analyzer YOKOGAWA CW240. We have considered the load variation of a day with maximum average load in order to show the feasibility of the micro grid. The monthly average load variation of college campus is shown in **Figure 2** and subsequent campus load variation over a year is shown in **Figure 3**.

Supply Grid Characteristics

The TMI campus is a High Tension (HT) Consumer and is fed by a 22 kV line from Maharashtra State Electricity Distribution Company Limited (MAHADISCOM). It has connected and sanctioned load of 1193 kW, the contract and the sanctioned demand of 750 kVA, and the average of monthly units consumption is 172000. The details of the sub-station are number of incoming feeder/s 1, the outdoor plinth mounted type, 1000 kVA, 22 / 0.415 kV, Delta/ Star connected. The campus has a backup supply of two diesel generator sets of 500 kVA each.

The daily load profile of the Institute during weekday and weekend are shown through the bar diagrams in **Figure 4** and **Figure 5**. The units consumed and subsequent cost/kWh of MSEDCL are shown in **Figure 6**.

Hybrid Model

A variety of terms are used to describe advanced power networks that incorporate traditional and renewable energy: smart grid, VPP, micro grid, and hybrid energy systems.

A micro grid, on the other hand, focuses on the internal structure of the energy system from the consumer-perspective to be autonomous from the main grid by matching supply and demand internally. Self-sufficient energy systems already have been set up in a number of developing countries in order to help with the implementation of rural off-grid electrification in countries such as China, Mexico, Kenya and Bangladesh. The energy systems often consist of PV with battery packs or even backup diesel generators. It is normally grid-connected to help deal with the intermittency of its renewable energy generation. Hybrid systems are usually built for design of systems with lowest possible cost and also with maximum reliability. Once all chosen technical and economic parameters are input, HOMER simulates one year of system production for all combinations of input technology sizes to supply the input electricity demand based on the indicated control/dispatch strategy and by cost optimization using a minimum time-step of 1 minute. This means that at each time step, HOMER chooses to use the cheapest power supply option within the system dispatch and control constraints based on the input fuel costs ($/kWh) to supply the electricity demand. The annual costs for the one year simulation of each feasible system are then extrapolated over the project lifetime and discounted, based on the input discount rate, in order to calculate the net present costs for each system for the project lifetime. The proposed hybrid model is shown in **Figure 7**.

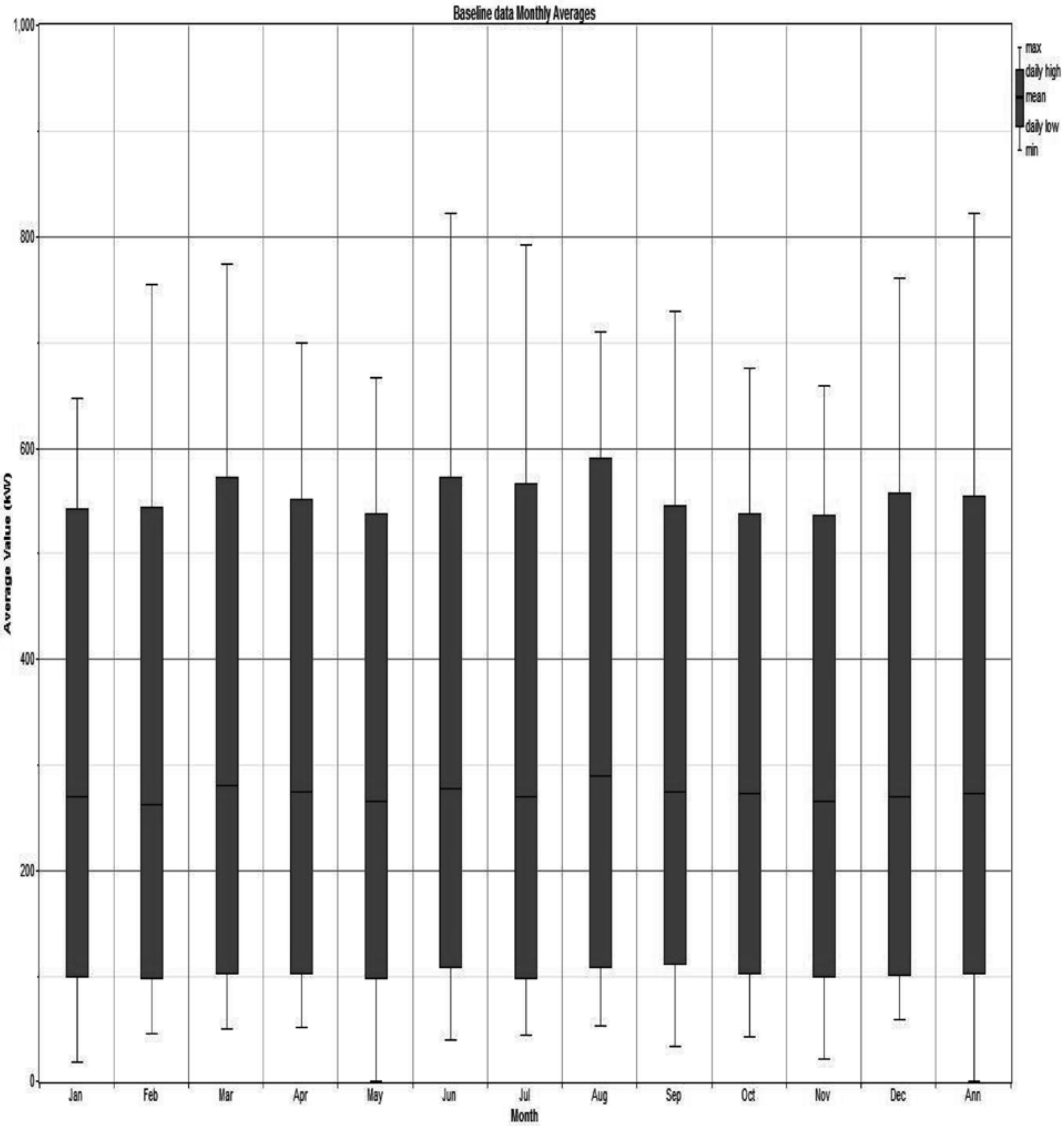


Figure 2 : Baseline data monthly average load variation of TMI campus

The resulting feasible micro grid configurations are then listed based on the lowest net present cost for the project lifetime. The main optimization output results list the size and combination of components simulated (kW or number of wind turbines), grid-connection capacity (kW), initial capital ($), operating cost ($/yr), total net present cost ($), COE ($/kWh), renewable fraction of load (%), capacity shortage (%), diesel fuel used (L), and generator hours. However, more in depth technical production and economic are also produced and analyzed. The final goal is to maximize energy output and reduce COE from distributed energy resources (DERs) by Optimization using HOMER.

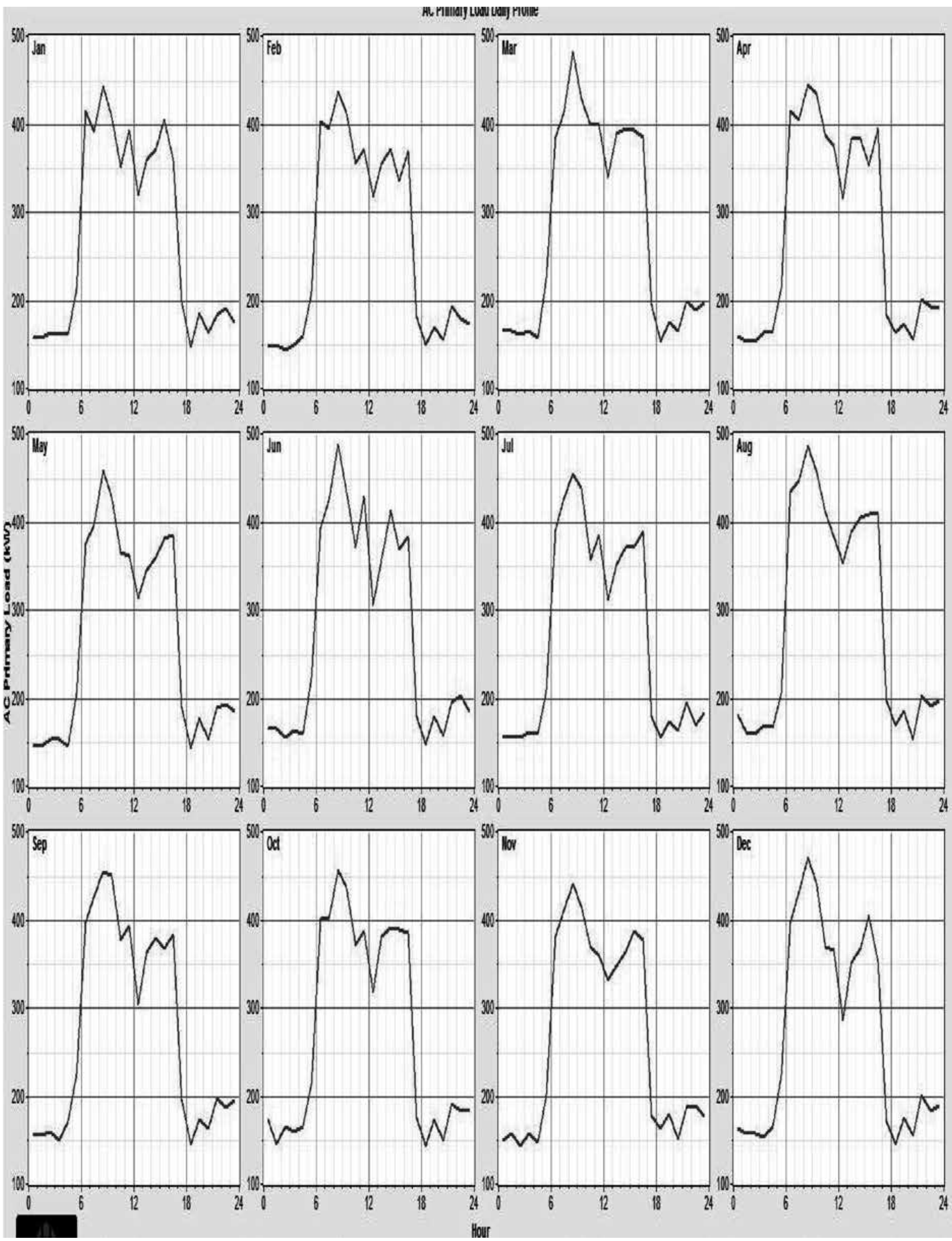


Figure 3 : Campus load variation over a year

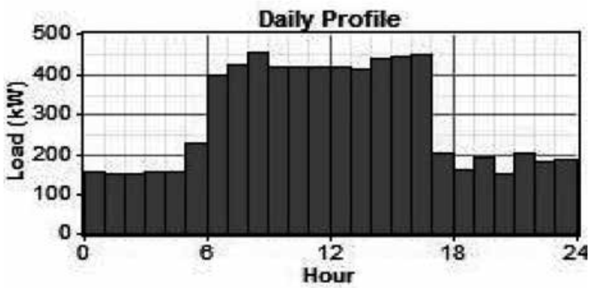


Figure 4 : Daily load profile for weekday

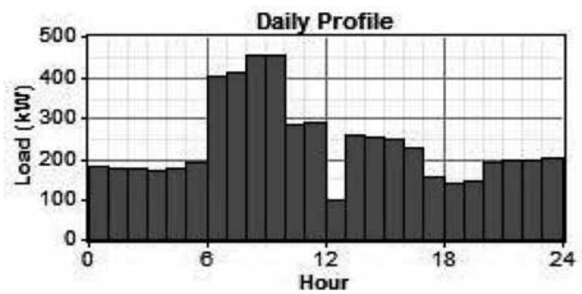
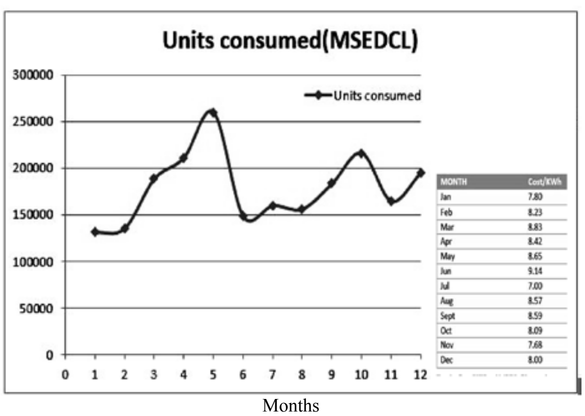


Figure 5 : Daily load profile for weekend



MONTH	Cost/KWh
Jan	7.80
Feb	8.23
Mar	8.83
Apr	8.42
May	8.65
Jun	9.14
Jul	7.00
Aug	8.57
Sept	8.59
Oct	8.09
Nov	7.68
Dec	8.00

Figure 6 : Cost/kWh of MSEDCL supply

Clean Electricity

If the campus produces green electricity onsite and consumes it directly, it can avoid paying these high electricity costs. In this case, solar and wind technologies are chosen due to the aforementioned reasons in the case description.

Wind Power

The total wind power potential of the country is about 49130 MW. The site-specific potential for wind energy depends on the wind speeds at

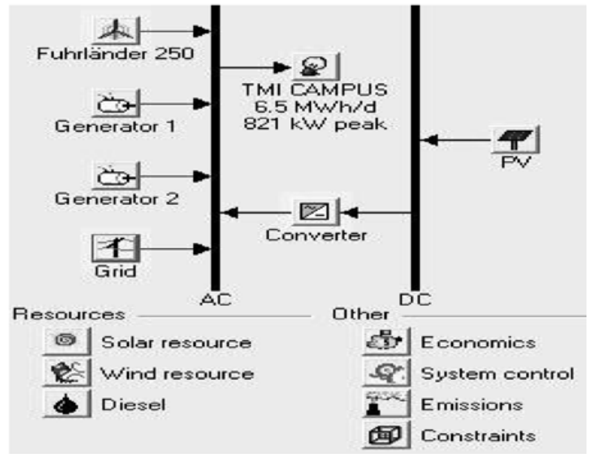


Figure 7 : Proposed hybrid model

the location. **Figure 8** illustrates the measured average wind speeds at the site location over the year.

The wind generator units convert wind power into electrical power. The wind passes through the propeller and producing the circumferential force and axial thrust. This circumferential force is also known as torque, which drives the generator to produce the electrical power. The wind velocity is a variable quantity, both in magnitude and in direction. This variable feature of wind turbine power generation is different from conventional fossil fuel, nuclear or hydroelectric power systems. Wind energy has become the least expensive renewable energy technology in existence. The greatest advantages of electricity generation from wind are that, it is renewable, eco-friendly and needs less maintenance. The most commonly used type of wind turbine is a horizontal axis turbine with a three blade rotor spinning in a vertical plane attached to a nacelle. The Fehrlander 250 wind turbine is considered and is specially designed for low to medium wind speeds **(Figure 9)**.

The capital and replacement cost of the turbine is approximately 308 lakhs. The total onsite potential for wind depends on the space requirement per turbine and space available onsite. The amount of space required for a wind turbine depends primarily on the height and diameter of the turbine both in relation to other turbines and the built environment. Normally a spacing of about 5 to 10 rotor diameters between turbines is necessary in order to maintain optimal wind speeds and production for each turbine. Taking into account the distance to nearby houses, shadow cast by the turbines, and noise effects on the surrounding environment. Other parameters included in the analysis are weibull k, diurnal pattern strength, hours of peak wind speed, etc.

Solar Power

Solar photovoltaic (PV) technology converts the sun's radiating energy into electricity. However, the sun's energy that reaches the earth varies over time. Since the Earth has an elliptical orbit and changes its axis relative to the sun, the amount of radiating energy that reaches a specific latitude varies within a year and from year to year. The solar irradiance is also affected by the "clearness index" which is based on the cloud cover and atmospheric haze since these scatter, absorb, and reflect the sun's radiation. These factors result in varying solar irradiance at a specific latitude, which is one of the main factors in electricity production from the sun.

Besides the solar irradiance, the total amount of electricity produced by solar PV also heavily depends on the specific characteristics of the PV cells, like the conversion efficiency, the placement of the PV panels in relation to the sun, and de-rating factors which cause the PV cells to perform below the rated efficiency. The yearly solar radiation of the campus is shown in **Figure 10**.

PV Panel Characteristics

At current levels, PV technology used for commercial purposes ranges from 12-16% in conversion efficiency, which differs depending on cell type and manufacturer. The PV model chosen for this research is the monocrystalline silicon cell 40A 24V PWM CC model from BlazePower, whose specifications are shown in the **Table 1**.

Power output of the PV panels is also highly dependent on how and where the PV modules are placed, since the following variables influence electricity yield:

- " Tilt angle of the array (slope depending on the location latitude).
- " Azimuth (the direction towards which the panels face).
- " Ground Reflectance (aka albedo, which is the fraction solar radiation incident on the ground that is reflected).
- "De-rating factors (internal & external) that hinder maximum power production.

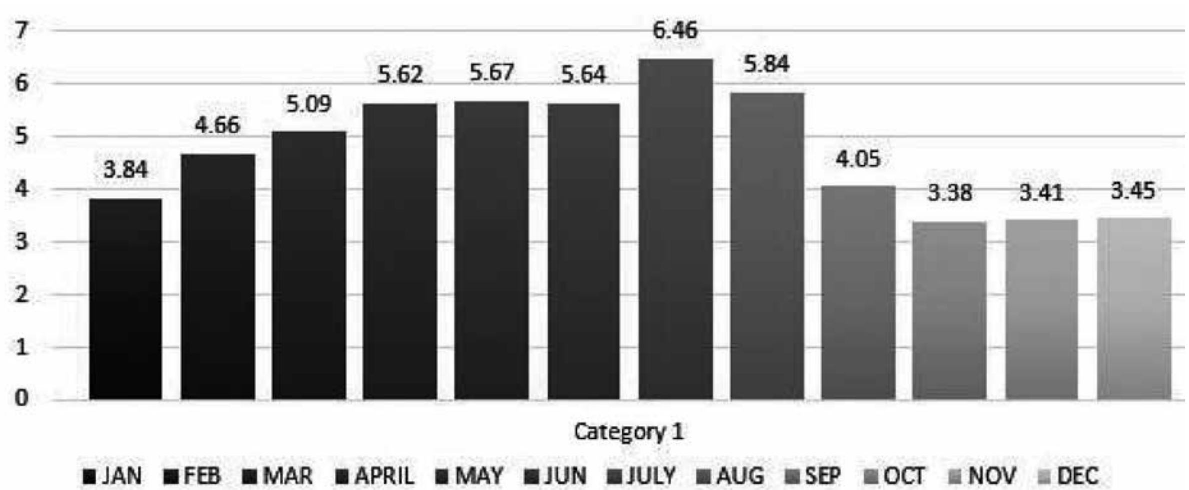


Figure 8 : Yearly wind speed profile at the campus site

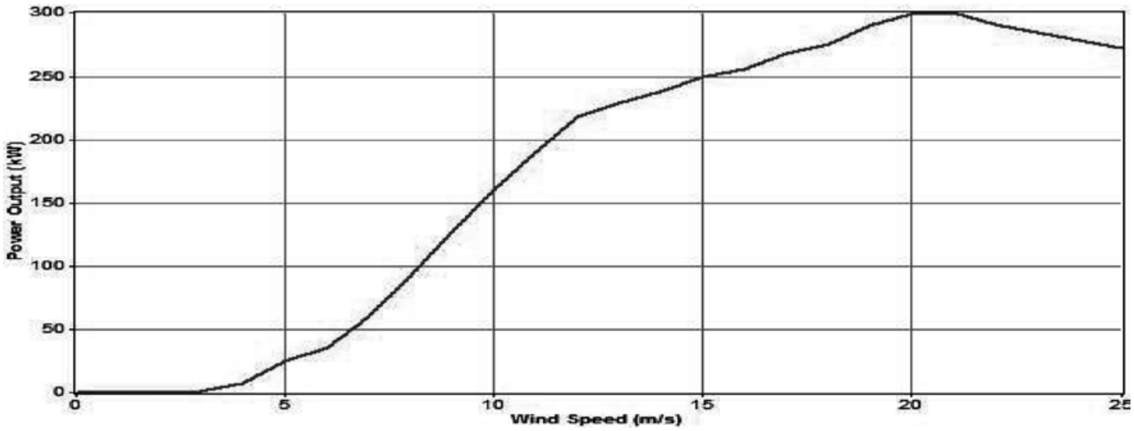


Figure 9 : FL250 wind turbine power curve

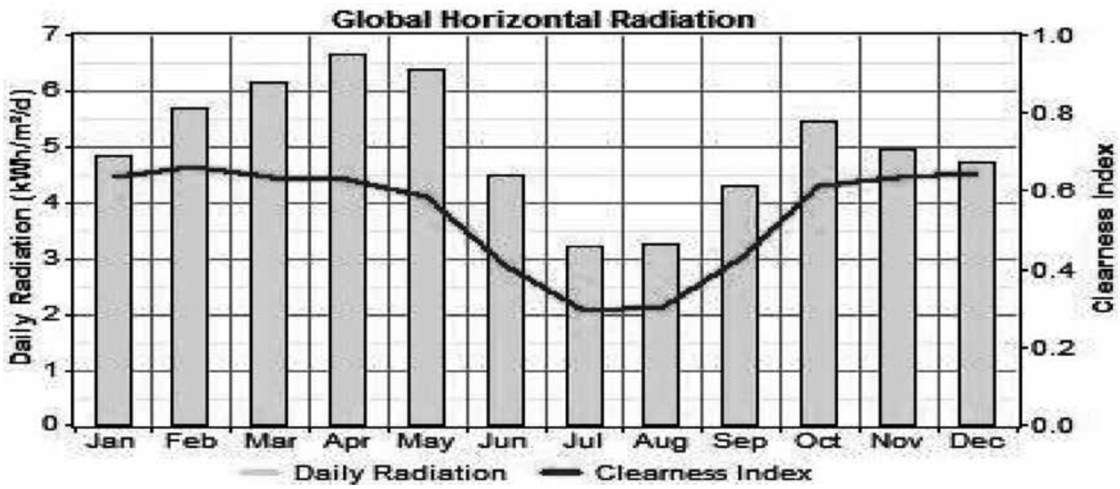


Figure 10 : Yearly solar radiation at the campus site

Table 1 : PV model specification

1 Kilo Watt
250*4 poly PV panels
40A 24V PWM CC
Mounting structure
10m of 4 & 16 sqmm wire
Combiner box
DC fuse protection
Inverter : no
Battery : no
MRP : 69500

Inverter

Since PV technology produces DC electricity, inverters are required to convert the DC power to AC power in order to be used by the system and injected into the grid. Since it has proven compatibility with the chosen PV modules, the modelled inverter is the ABB central PVS800 inverter. The installation and replacement cost per kilowatt capacity of inverter is Rs. 18550.

The maximum AC power output is 98.7% and inverter efficiency is 98.5% at full load, which is well above the required 95%. It has a wide DC input range with a maximum of 1100 V and offers a 20 year replacement and repair warranty on these inverters. However, normal inverter lifetimes are 15 years, so this will be assumed in this analysis.

Diesel Generators

Two Cummins 500 KVA silent diesel generators are used as backup/standby at the campus. Taking into consideration the present cost of diesel, the average cost of diesel generated electric power is 17.8 Rs/KWh. The rated specification of the generator is shown in **Figure 11**.

Figure 11 : Specification tag of diesel generator

Results: Micro-Grid Techno-Economic Potential

CASE 1

In the first case having the lowest cost of energy as optimized by HOMER is 8.1 Rs/KWh.

The total renewable energy fraction stands at 45% of the total energy requirement. Energy produced by PV array is 1,247,820 KWh/yr, whereas the grid purchase is of 1,502,133KWh/yr. Total capital cost of installation of PV array is 504 lakhs, giving a total payback period of 4.55 years. Excess electricity produced contributes 9.71% of total power generation which can be sold back to the grid or the grid consumption can be reduced **(Table 2)**. The system results a cost saving of Rs 138,000 per year on the grid purchase. The monthly average electricity production and subsequent PV output are shown in **Figure 12** and **Figure 13**, respectively. The optimised hybrid model for campus is shown in **Figure 14**.

Table 2 : Excess electricity for case I

Quantity	KWh/yr	%
Excess electricity	266,948	9.71
Unmet electric load	0.00	0.00
Capacity shortage	0.00	0.00

CASE 2

When a sensitivity analysis is carried out with the same system applied to a port(in this case Mumbai port) with an annual average wind speed of 5.6m/s, cost of energy is reduced to 7.8 Rs/yr. With grid purchases contributing to about 49% of the total energy generation and excess electricity production of 6.51%, thus making the system more feasible.

This change in wind speed also reduces the operating cost by Rs 13,90,500 lakhs. The system includes one FL250 wind turbine, 500 KW PV array and 1000 KW grid supply which is capable of giving a 14.66% reduction in cost of energy over a period of a month. With these high RE potentials onsite, grid-connected micro grid system can sell excess electricity beyond the demand, which are very profitable. The sensitivity optimization for a port is shown in **Table 3**. The monthly average electricity production and optimized port hybrid model are shown in **Figure 15** and **Figure 16**, respectively.

Table 3 : Sensitivity optimization for a port for Case II

Production	KWh/yr	%
PV array	779,887	30
Wind turbine	566,296	22
Generator 1	0	0
Generator 2	0	0
Grid purchase	1,273,147	49
Total	2,619,331	100

Government Policies

Even the government has taken certain measures which promote the use of renewable energy. Accelerated Depreciation is one such policy. This tax benefit allows projects to deduct up to 80% of value of wind power equipment during first year of project operation. Investors are given a tax benefit of up to 10 years. Moreover, the government offers indirect tax benefits, which includes concession on excise duty and reduction in customs duty for wind power equipment. In addition to the above the government also offers Central-level Generation–based incentives. Under

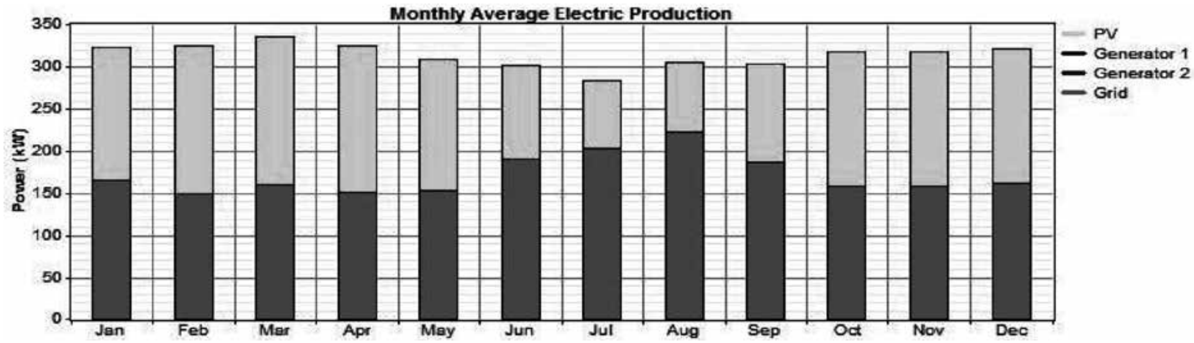


Figure 12 : Case I monthly average electricity production

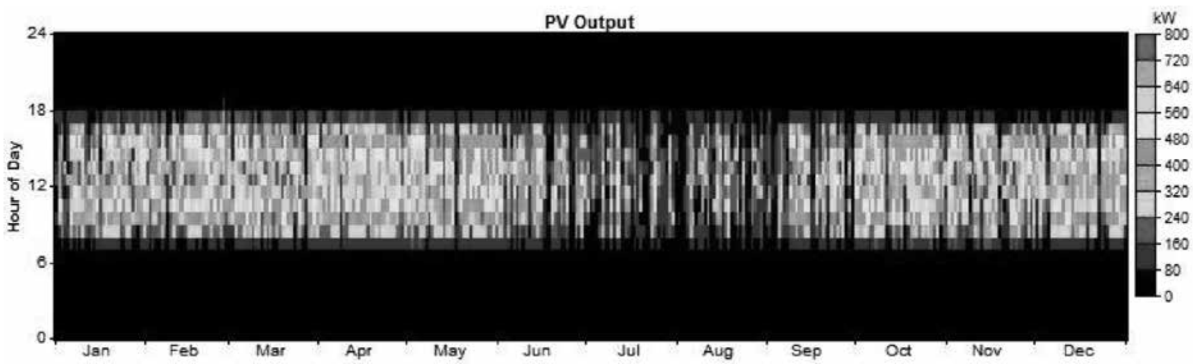


Figure 13 : Case I PV output

Sensitivity Results | Optimization Results

Double click on a system below for simulation results. Categorized / Overall | Export... | Details...

PV (kW)	FL250	Label (kW)	Label (kW)	Conv. (kW)	Grid (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Diesel (L)	Label (hrs)	Label (hrs)
800		400	400	400	1000	$ 1,106,400	229,995	$ 4,046,510	0.133	0.45		0	0
800	1	400	400	400	1000	$ 1,611,695	199,768	$ 4,165,399	0.137	0.58		0	0
	1	400	400		1000	$ 653,295	311,512	$ 4,635,463	0.152	0.16		0	0
		400	400		1000	$ 148,000	355,107	$ 4,687,463	0.154	0.00		0	0

Figure 14 : Case I Optimized hybrid model for campus

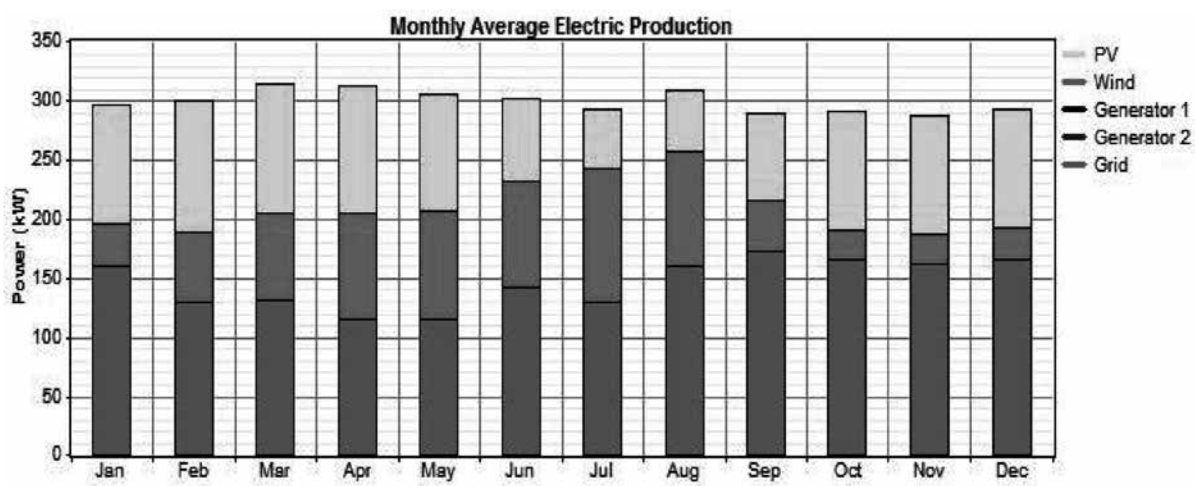


Figure 15 : Case II Monthly average electricity production

PV (kW)	FL250	Label (kW)	Label (kW)	Conv. (kW)	Grid (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Diesel (L)	Label (hrs)	Label (hrs)
500	1	400	400	400	1000	$ 1,296,695	207,511	$ 3,949,379	0.130	0.51		0	0
800		400	400	400	1000	$ 1,106,400	229,995	$ 4,046,510	0.133	0.45		0	0
	2	400	400		1000	$ 1,158,590	247,300	$ 4,319,917	0.142	0.43		0	0
		400	400		1000	$ 148,000	355,107	$ 4,687,463	0.154	0.00		0	0

Figure 16 : Case II Optimized hybrid model for port

this the GBI for wind is available for independent power producers with a minimum installed capacity of 5 MW for projects commissioned on or before 31/03/2012.

Future of Renewable Energy

Human beings are consuming their non-renewable resources at such a rapid rate that it has been predicted that within the next hundred years all the energy provided by Mother Nature in this form will be over. Thus, there is an ever increasing need for mankind to research upon other alternate sources of energy. Renewable energy becomes an important aspect of study on which one must concentrate so that the future generations of this planet will not have to suffer and will have something to bank upon, to live their lives as comfortably if not more than the present generation. Sustainable development is the need of the hour and this can be only be attained through further research in renewable energy. Hybrid energy systems holds the key to the future of renewable energy. Some ideas that have been proposed include the “Night and Day” concept. In this concept it seen that the wind blows more strongly at night in some regions and solar energy can be tapped only during the day. By making more sophisticated use of this basic concept in a connected grid, and combining it with a more advanced form of energy storage, the door could be opened for a much wider use of renewable energy systems. Another concept that is being looked at is the concept of Advanced Energy Storage. In this concept, Electricity is being produced by efficient wind farms. This is then transmitted to a different place where it is being stored via compressed air in certain rock formations; and ultimately used to help power a completely different third location.

Wind energy may be one of the more sustainable sources of power available, but the spinning blades of conventional wind turbines require regular maintenance and have attracted criticism from bird lovers. Researchers in the Netherlands set out to eliminate the need for a mechanical component entirely and created the EWICON, a bladeless wind turbine with no moving parts that produces electricity using charged water droplets.

When most of the wind turbines generate electricity through mechanical energy, the EWICON (Electrostatic WInd energy CONvertor) creates potential energy with charged particles – in this case, water droplets. The current design consists of a steel frame holding a series of insulated tubes arranged horizontally. Each tube contains several electrodes and nozzles, which continually release positively-charged water particles into the air. As the particles are blown away, the voltage of the device changes and creates an electric field, which can be transferred to the grid for everyday use.

Energy output would be dependent not only on the wind speed, but also the number of droplets, the amount of charge placed on the droplets, and the strength of the electric field. Taking the concept of windmills one step further, or higher, scientists want to create power stations in the sky by floating windmills 15,000-feet in the air. The strange crafts will be kept afloat by four propellers that double as turbines, and feed electricity back to earth through a cable.

Conclusion

The result from simulation of distributed energy resources by HOMER shows that

- Solar PV modules, wind turbine, diesel generator and inverter connected to the supply grid is the most economical solution to design integrated system with minimum total net present cost and cost of electricity for a port. Though the different distributed energy resources are technically suitable and available in market, but not necessarily be financially viable.
- Economic viability should be in top priority over the technical feasibility exclusively for port load electrification in the country.
- Utilizing measured wind speed and solar irradiation data for the campus, real time manufacturer data for technology components and a bottom-up approach to model a flexible demand from demand response, the modelled results prove that there is a very high potential for renewable electricity at the campus site which improves further when transferred to a port location, which can make the electricity consumption more than 50% self-sufficient with renewable electricity from solar PV and wind power production.
- The results show that wind production potential is very high at a port location and can meet 22% of onsite demand with solar PV.

However, the results indicate that PV production potential is also substantial and provides a more balanced supply which can supply electricity at times when wind production is insufficient. Due to the supplemental supply over different parts of the day, adding solar PV also increases the benefits gained from the demand response strategy. Therefore, a solar-wind system combination is recommended over a wind or solar only system for installation at port sites.

Acknowledgment

The authors are thankful to the Faculty Members of Tolani Maritime Institute, Pune for providing necessary guidance encouragement and motivation to complete the project.

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Concept Study of Savonius Keel & Wind Turbine Darrieus (SKWID) Coupled with Carbon Capture Storage (CCS) to Produce Fuel in On-Board Ships

Arpit Jajoo, SK Rakibuddin

Indian Maritime University, Chennai

✉ *arpit.jajoo001@gmail.com*

✉ *skrakibuddin07@gmail.com*

Abstract

This paper deals with the coupled study of Savonius Keel & Wind Turbine Darrieus (SKWID) and Carbon Capture Storage (CCS) to produce fuel in on-board ships. CCS aims to utilize CO_2 and H_2 present in water to produce fuel by electrochemical acidification that can be used to run ships. It reduces the consumption of gallons of fuel, global warming, is highly cost- effective and eco-friendly. SKWID aims to provide renewable and cost- effective energy. This energy will be required as an input to drive CCS system. The system has the potential to be very sustainable in the long-term.

Keywords : *CCS; SKWID; Electrochemical Acidification Cell; Alternative Fuel; Coupled of CCS and SKWID*

Introduction

The seas and the oceans cover two thirds of the earth's surface and contain different amount of energy, and its possible resources are far beyond the energy needed by the humanity. The energy resources came from two types of phenomenon: solar energy and gravity variations due to changes in positions of earth, moon and sun. The planetary ocean contains numerous forms of renewable energies, who, in absolute, deliver enough energy to meet the needs of the entire planet.

Carbon capture and storage (CCS) is the process of capturing carbon dioxide (CO_2) from large-point sources (such as power stations, seawater and industrial facilities). In addition to H_20 and salt, ocean water is rich in carbon dioxide (CO_2 concentration is 140 times that of air). So a hybrid system of CCS with a catalytic converter should be built that extracts hydrogen and carbon dioxide from the water with approx. 92 percent efficiency and then -- via a reaction with a metal catalyst - transforms those gases into a liquid hydrocarbon fuel that the ship's existing engines can burn.

SKWID is a floating wind and current hybrid power generation system capable of converting two inexhaustible ocean energy sources into abundant power. By harvesting the renewable energy from never-ending currents and strong and continuous ocean winds, the pioneering technology of the SKWID provides cost-effective power generation with minimal environmental impact.

In this study, it is shown, how to produce fuel in on-board ships from CO_2 and H_2 present in seawater. To run CCS technology in ships a large amount of electrical energy is needed which is produced using SKWID technology.

Working Principle

CCS Technology

This technology is used to remove CO_2 from seawater with a concomitant production of hydrogen (H_2), which are the building blocks of hydrocarbons. They achieved this through the use of Electrochemical Acidification Cells.

SKWID

This technology works on the principle of Vertical-axis wind turbines (VAWTs). In VAWTS type wind turbine, the main rotor shaft is set vertically and the main components are located at the base of the turbine. This arrangement allows the generator and gearbox to be located close to the ground, facilitating service and repair. VAWTs do not need to be pointed into the wind, which removes the need for wind-sensing and orientation mechanisms. The flow chart showing application of SKWID and CCS technology is shown in **Figure 1** and the working principle of SKWD is shown in **Figure 2**.

Production of Electrical Energy using SKWID to Drive CCS

Darrieus Wind Turbine

The Darrieus wind turbine efficiently harnesses the ocean wind **(Figure 3)**. The unidirectional Darrieus turbine rotates regardless of the wind direction. Due to the location of the generator, the system has excellent stability with a low centre of gravity, as well as excellent maintainability with easy access. The Darrieus rectangular swept area catches twice as much wind when compared to the circular swept area of typical onshore wind turbines of the same diameter and is therefore capable of delivering twice as much power from a single installation - far more power from the same wind farm area **(Figure 4)**.

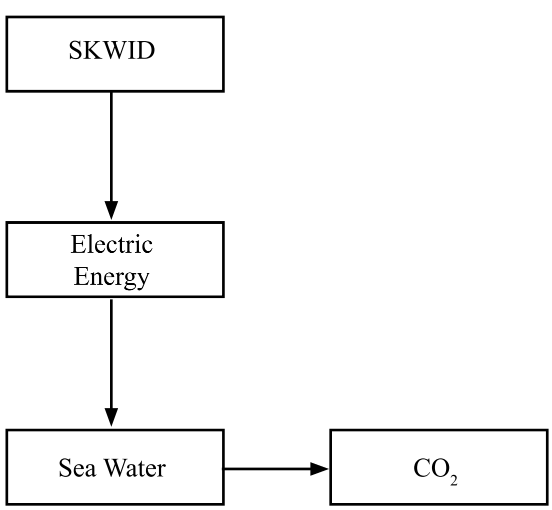

Figure 1 : Flow chart representing production of fuel using SKWID & CCS

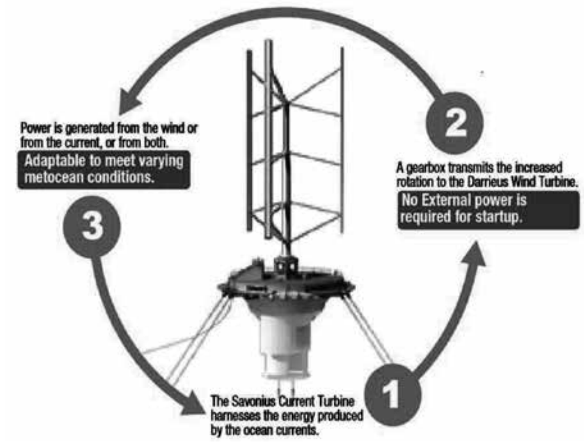

Figure 2 : Working principle of SKWID

Figure 3 : Savonius Keel & Wind Turbine Darrieus

Figure 4 : Darrieus Wind Turbine-Converting Wind Energy to Electrical Energy

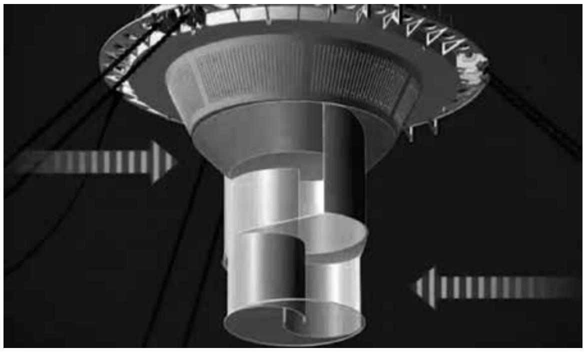

Figure 5 : Savonius current turbine-converting tidal energy to electrical energy

Savonius Current Turbine

The Savonius current turbine harnesses the current **(Figure 5)**. The split-cylinder-shaped buckets of the Savonius current turbine can harness any weak current and will rotate in one direction regardless of current direction. This turbine is insensitive to marine growth on the buckets and is harmless to the marine ecosystem, as it rotates slowly at the speed of the current.

Obtaining CO_2 and H_2 from Seawater using Electrochemical Acidification Cell in CCS

Cell Reaction

The amount of H^+ generated by the anode is proportional to the applied electrical current, which follows Faraday's constant. Faraday's constant is defined as the amount of electricity associated with one mole of unit charge or electron, having the value 96,487 ampere-second/equivalent. For the anode reaction, 96,487 A-sec will produce ¼

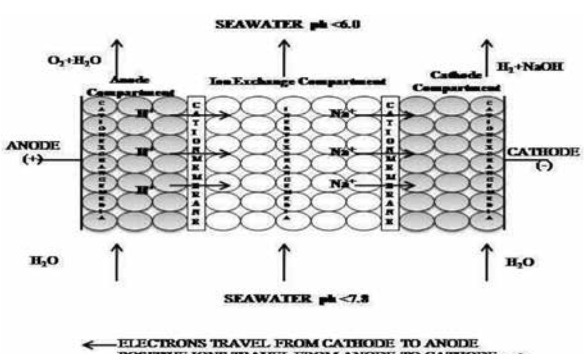

Figure 6 : Electrochemical acidification cell-schematic diagram

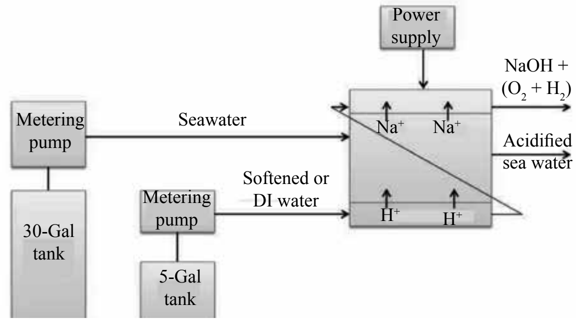

Figure 7 : Schematic showing the acidification cell experiment layout

mole O_2 gas and 1 mole H+ and for the cathode reaction, 96,487 A-sec will produce ½ mole H2 gas and 1 mole OH-. This allows the theoretical amount of H^+, OH-, H_2, and O_2 produced per amp-second of current passed through the electrodes to be determined. The electrochemical acidification cell is shown in **Figure 6**.

Anode and Cathode Reaction

Therefore, seawater with a HCO_{3-} concentration of 142 ppm (0.0023 M) and a flow rate of 1 liter per minute, will require a theoretically applied current of 3.70 A to lower the pH to less than 6.0 and convert HCO_{3-} to H_2CO_3.

The theoretical amount of CO_2 that can be removed from the acidified seawater is 0.0023 moles per liter. Removal efficiency can be defined as the ratio of the theoretical amount of CO_2 removed to the actual amount of CO_2 removed in the acidified seawater. The theoretical amount of H_2 gas generated at 3.7 A. The acidification cell experiment is shown in **Figure 7**.

Production of Hydrocarbon Fuel

The production of hydrocarbons, which are compounds solely made up of hydrogen and carbon, from the recovered gases is a three-step process.

- Firstly, CO_2 and H_2 is collected from seawater by the process of electrochemical acidification cell in CCS.
- Secondly, the CO_2 and H_2 obtained are converted into unsaturated hydrocarbon

Figure 8 : Carbon capture storage

starter molecules called olefins using an iron-based catalyst.

- Thirdly, these olefins are converted into a liquid containing larger hydrocarbon molecules with a carbon range suitable for use in ship engines by polymerization.
- C9-C16 range hydrocarbons are obtained.

Benefits

- CCS technology (**Figure 8**) removes CO_2 at 92% efficiency. Obviously energy will be required as an input to drive the system, and this energy is going to come from energy generated by SKWID, thus preserving eco-system.
- The energy produced by SKWID is large enough to light 100000 houses, this huge amount of energy is sufficient to meet the electrical .
- Independency on fossil fuels make this fuel eco-friendly.
- Highly cost-effective.
- Ships need not stop for refuelling during voyages, as a continuous production of fuel takes place.
- It is estimated that CCS would bring a 15 per cent reduction in the wholesale price of electricity by 2030.
- 15,000_30,000 jobs would be created per year in the CCS industry by 2030 (range based on the installed capacity of 10 or 20 GW).

Conclusion

This paper presents a concept study for the coupled use of SKWID technology with CCS technology to produce sustainable fuel. The paper puts forward the reasons why such a study is welcomed at this moment. With the vast growth in shipping industry, the fuel consumption has increased manifold. Thus Alternate Fuel resource is the need of the hour and as the proverb goes "Necessity is the Mother of Invention", a new coupled technology can be developed in which renewable and perennial Tidal & Wind Energy resource is converted into Electrical Energy by SKWID technology. The Electrical Energy thus produced can be used in two ways-

- Firstly, to supply energy to the Electrochemical Acidification Cell in CCS.
- Secondly, to meet ships electricity requirements. Thus captured CO_2 and H_2 is converted to Hydrocarbon by Catalytic Reaction. These hydrocarbons after polymerisation produce long carbon-chain which can be used as fuel to drive ships.

Acknowledgement

The authors are thankful to the Faculty Members of the Indian Maritime University, Chennai, for putting their precious time and effort for the successful completion of this paper.

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Development of Coastal & Inland Shipping – Emerging Technologies and Challenges Ahead for Shipbuilding & Repair

Rear Admrial N K Mishra[1], Capt. S V Subhedar[2]
S C Misra[3], S Ranganathan[4],
Amit Bhatnagar[5]

[1]Chairman & Managing Director, Hindustan Shipyard Limited

[2]Past President, ICCSA

[3]IMU, Visakhapatnam Campus

[4]Vice President, IRCLASS

[5]Principal Surveyor & Area Manager, IRCLASS, Chairman, Institute of Marine Engineers (I), Visakhapatnam Branch

✉ *amitbhattu@yahoo.com*

Abstract

The shipping consists of 90% of the merchandise trade by volume and yet accounts for less than 5% of the total emissions into the atmosphere. India has more than 7500 km of Coast line and many rivers, which have regular supply of water throughout the year. The Coastal and Inland shipping in the country has remained more or less dormant since independence. The transport system in the country is skewed with road transport accounting for about 55% per cent unlike most developed economies, where Inland transport has better share than any other mode. There is an urgent need to not only develop Coastal and Inland shipping activities but also develop hinterland connectivity to all such terminals for smooth cargo movement through multimodal transport system.

Keywords: *Inland, Coastal, economy, maritime, training, certification, infrastructure, shipping, technologies, challenges, multimodal, transport, shipbuilding, ship repairs*

Introduction

Our country has distinct advantage over the rest of the world due to almost double the GDP growth rate of 6.5% in comparison to world GDP rate of 3.8%. However, 17th in the list maritime nations. Sagarmala project was the dream of former Prime Minister Mr. Atal Bihari Bajpai, which was planned on similar lines of golden quadrilateral road network. The plan was to reduce inevitable land water interface to the minimum possible by development of Port facilities every 200 kms around the coast. It imperative that the development of coastal communities, more water borne traffic of all kinds can lead to more concentric population growth, which will bring light around the coast and prevent 26/11 kind of security breach.

Coastal Economy

At present in India only 0.2% of the total cargo is transported through inland waterways whereas in Germany it is 20 % and in Bangladesh, 32 %. In India the Inland water transport is mainly limited to Goa, which caters for about 80% of total cargo movement through Inland Waterways. It is imperative that inland waters offer less resistance comparing to sea, therefore the fuel cost is even lower in comparison to seagoing ships.

There is an urgent need to enhance ship-building, repair refit overhaul marine equipment manufacturing facilities within the concept of Sagarmala / Smart Cities / Maritime Economic Regions (MER). The government has to build infrastructure for inland and coastal shipping, and offer incentives to encourage investment in the sector. To ensure a fleet of ships offering consistent service, there is a need to encourage shipbuilding and ship repair facilities.

Development of Coastal economy is possible with the ports through development of Coastal Economic Region & projects with synergies to Coastal Corridors. The development of port based smart cities and other urban infrastructure will improve the standards of living. These ambitions can be achieved through skill development and livelihood generation projects for the coastal community in the form of coastal tourism development projects covering Coastal and river sea cruise encompassing Pleasure Coastal Cruise, Eco tourism & Heritage tourism. Fishing in EEZ, in coastal waters, river mouths and rivers are equally important elements of Coastal and inland economy. A well-developed Coastal & inland economy can provide substantial growth to Passenger movement by use of multi hull, high performance vessels, RORO vessels etc. Tourism in all such areas can flourish with the presence of house boats and flotels. The transportation of cargo in India is shown by **Figure 1**.

Benefits for Maritime States

There is an urgent need for modernisation of existing ports and creation of Greenfield ports to reduce bottlenecks for future growth of the sector. Shipping cannot be the sole means for transportation in all cases & need support from other modes of transport in multimodal transportation. The supply chain mechanism need to be established by development of port evacuation system by rail and road network and connection of Inland waterways. This logistics infrastructure shall reduce overall logistics cost and increase cargo movement to and from the hinterland. The states can also encourage new economic activity in the form of ship building and ship repair cluster in their region. Establishment of Maritime boards in Coastal States and states with navigable rivers would help in exercising good control and encouraging serious players. The industry will look for integrated approach to project identification and implementation through proper coordination between ministries, states and private agencies. The industry is encouraged when policy and institutional bottlenecks are removed for obtaining project approvals, access to project funding and implementation partners and project implantation and monitoring.

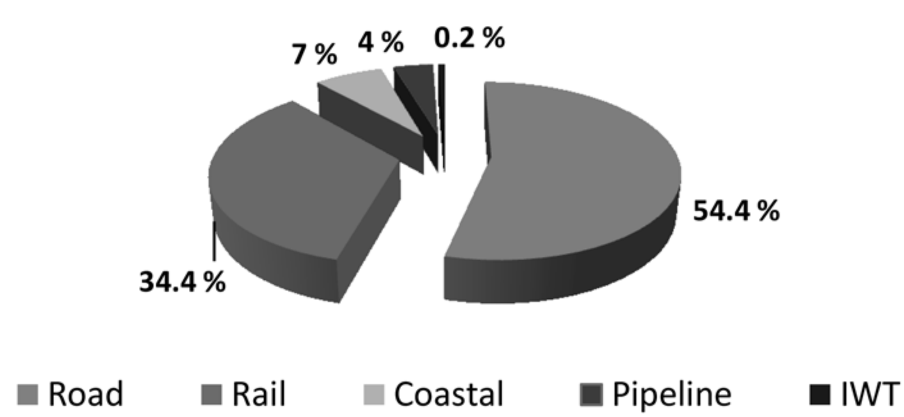

Figure 1 : Transportation of cargo in India

Setting up Maritime Boards

There is an immediate requirement to set up Maritime Boards in all Coastal States. State of Andhra Pradesh and Orissa may be considered on priority due to high investment stake envisaged in both the state. Own rules for plying of Inland vessels and vessels operating on the Coast shall provide clarity to the operators and encourage more players to participate in the maritime growth in these states. The Governments should be able to allocate resources and expertise for domestic shipping, which is readily available in abundance in the country.

Structural & Safety Standards in Accordance with Global Standards for Operation in Similar Areas

The proposed Coastal Vessel Act and Inland Water Act, which is under revision. The structural and safety standards have been defined similar to SOLAS. It is extremely important to understand that applicability of SOLAS is for the ships, which operate in unrestricted waters and most challenging sea conditions across the globe. The industry feels those to be too stringent and difficult to comply both in terms of logistics and costing. The global standards being followed in other parts of the world for both Coastal and Inland shipping need to be taken into account and same can be adopted for implementation.

Dedicated Port Facilities for Coastal Operations

There is an urgent need for development of dedicated port facilities for Coastal ships. The ships operating on Coastal/ IV routes does not require Custom intervention. However, as the port facilities are commonly shared in Custom notified areas, the Coastal ships are also subjected to Custom regulations and massive paper work followed by delays discourage the operators to venture into the business. The dedicated Coastal ports will provide ease of operations to the vessel owners and the terminals without hurdles and delays.

Standards for Training, Certification & Watch-keeping

The crew operating Inland vessels are generally proven vessel operators through generations and may not possess the skills of answering the exam papers. The proposed Indian STCW, may result in failure of many such efficient crew, which will act as a deterrent in employment generation leading to the failure of the purpose. A pragmatic view from the authorities is required before final decision is taken on those standards.

Review & Replace outdated Custom Act & Shipping Trade Practices

According to present Customs Act there is no difference between Coastal and International trade, as long as the transportation has been undertaken from a notified port. Therefore, complete process of Custom formalities are to be undertaken even for Coastal cargoes. The process is not only time consuming but also cumbersome. The outdated Customs Act need to be replaced to reduce bureaucratic hurdles in facilitation of Coastal shipping.

New Coastal & IV Act to be Made Industry Friendly

The development of Coastal & revision of IV Act is under consideration. The industry inputs to be considered in revision/ development of Coastal / IV Acts, in order to encourage more players in the field.

Development of Infrastructure for Terminals, Shipbuilding & Repairs

No industry can flourish without support infrastructure. There is an urgent need of shipyards in the country not only for seagoing ships but also for the river cargo / passenger ships. The timely construction of ships is only possible when the marine equipment/ components are available at reasonable cost and in the vicinity of the ship construction facility. There is strong need of encouraging the industry to come forward with marine equipment/ component manufacturing industry. The vessels while in operation need to be repaired, therefore repairs yards with reasonable infrastructure need to be developed along the rivers banks and on the Coast line. The inland shipping terminals need to be developed along the rivers to facilitate the passenger & cargo handling.

Scope for Innovation

Presently the coastal trade is limited to transportation of coal, oil products & minerals. There is a need to diversify the cargo spread and by the use of containers Consumer articles from tooth paste to electronics & Apparels, Pharmaceuticals, Automobiles, spares almost everything can be transported through Inland and Coastal shipping. The industry with the use of reefer containers can ship even Perishable food products like fish, meat, fruits, vegetable, juices, etc.

As in Goa, we have Transhipper vessels operating for loading & unloading of cargo from and into the Inland vessels from or into bulk carriers at anchorage. On similar lines container feeder barge can be used for transhipment of containers at anchorages.

The feeder barge is shown in **Figure 2** has been developed in Germany to quickly augment Port capacity and unitization of cargo.

There is no need to run behind the foreign technology for all purposes, we can use simple technology already available in the country can also be used for various purposes, such as make in India solution suitable for dredging in alluvial

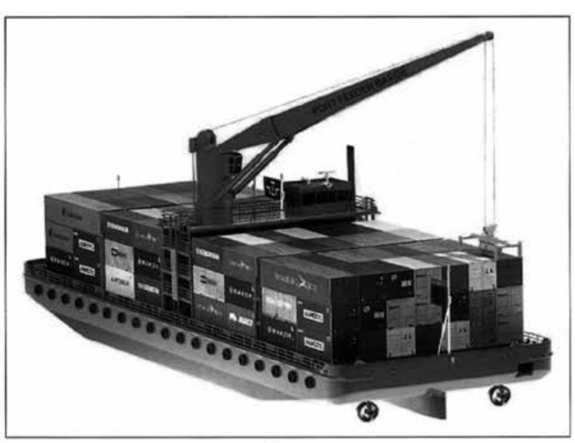

Figure 2 : Container feeder barge

Figure 3 : Suction dredger for alluvial rivers

rivers and free flowing clay and sandy back waters by means of indigenously designed and operated suction dredgers **(Figure 3)**.

Open Hatch Cargo vessels are another concept which is actively in use in Goa. The open hatch barges being operated are either dumb barges (various dumb barge combinations are shown at **Figure 4, 5 & 6**) or self propelled barge (as shown in **Figure 7**). The main challenges for such vessels

Figure 4 : Various combinations of dumb barges

Figure 5 : Various combinations of dumb barges

Figure 6 : Various combinations of dumb barges

in Inland operations are draft, as the vessels operate in shallow waters, optimum breadth for the area of operation, double bottom in cargo hold, as the grab operation can easily damage the hold bottom plate. The vessels also need to be well analysed for hatch coaming design again torsional loads (shown in **Figure 8**). Stability is another issue which needs to be addressed for such vessels, if engaged in Coastal trade.

Figure 7 : Self propelled barge

The concept for open hatch container vessels (**shown in Figure 9**) for coastal and inland operations has also been envisaged, however, the present regulatory requirements seems to be a deterrence for the project to take off. The requirements include Models Test of hourly rate of ingress of green water, Strength in the intact flooded condition, Model Test with significant wave height of approximately 8.5 m, which may be reduced by the RO/Administration (though consensus on same is still not available). In

Figure 8 : Open Hatch vessels showing torsional loads

addition, damage stability in accordance with SOLAS and hold bilge dewatering system and freeing ports are required for such vessels.

The present regulation to promote Inland & Coastal vessels under River Sea Vessel (RSV) Act

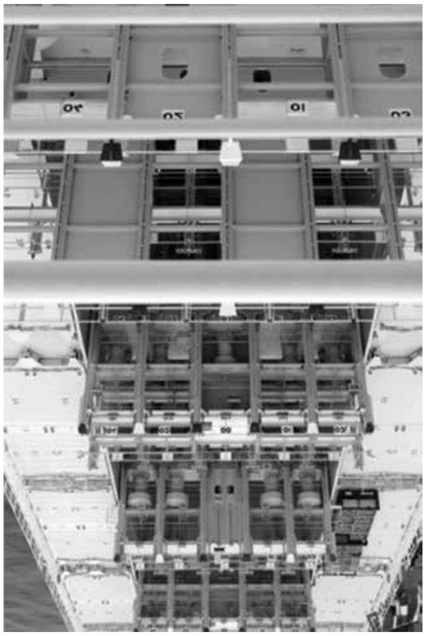

Figure 9 : Open Hatch container ship

allows certain relaxations to the RSV vessels, such as reduced height of machinery space ventilators, acceptance of weighted flaps as closing appliances for air pipes in lieu of approved automatic type closing appliances except in case of air pipes for tanks used for carriage of Fuel oil, Lube oil, Diesel oil or Cargo oil, acceptance of chains between all stanchions instead of guard rails for vessels engaged in lighterage operations.

Figure 10 : RORO vessel

Roll on & Roll Off vessels **(Figure 10)** have certain challenges to be taken care of such as, additional Strengthening of deck for wheel loading, design of Hydraulic Rams for ramp operation, navigability & visibility with lifted ram, securing arrangement for vehicles, protection of deck from operational damages etc.

Other simple solutions with reduced power and high carrying capacity are use of single dumb barge pushed or pulled by tug or a flotilla of dumb barges being pushes by a tug through various combinations based on the area of operation and type of cargo. This can be achieved by the means of minimisation of fuel consumption, which requires optimum hull form design and utilisation of river current. The hull form design can also contribute for better manoeuvrability in winding and shallow waters. While the system proposed to be more self-regulatory, the safety aspect cannot be undermined. The involvement of regulatory bodies to have firm but smooth regulatory regime, is equally essential.

The development as envisaged should not be at the cost of Sustainability. Proper survey and research need to be conducted to ensure that the development of Coastal & Inland shipping does not interfere with the existing ecosystem. The main purpose of development of Inland and Coastal shipping is to reduce pollution and non-interference with existing water activities. The water in canal system in the country is mainly for irrigation purpose, any oil or garbage pollution in canal will reflect into polluted agricultural products. Therefore, the pollution enforcement especially for oil and garbage need to be firmly imposed. Given an opportunity, the Indian designers are capable of developing optimum engine configuration and sustainable power generation utilising LPG/ LNG as fuel, solar and wind power. The easier option can be drawing up a set of standard technical specifications for different needs and developing optimum designs for those standards in the country. It is then possible to develop materials packages which can be handed over to small/medium entrepreneurs for vessel construction. This policy can trigger production of large number of vessels in a short time.

Conclusion

Smooth multimodal cargo operation is need of the hour, which essential to ensure timely low cost transportation of the cargo. The stake holders may ensure active deliberations in order to facilitate positive amendments to maritime laws, now underway clearly distinguishes Coastal Shipping, Inland Vessel operations for by and of India making domestic shipping simple, safe and efficient. This shall save on India's huge fuel bill and carbon emission, which is being incurred due to usage more expensive modes of road and rail. The Government can play major role in increasing capacity of Indian shipping, which has been earlier neglected for more than five decades.

Effectiveness of Engine Waste Heat for Heat Treatment of Ballast Water

Rajoo Balaji
Malaysian Maritime Academy
Melaka, Malaysia.
✉ *rajoobalaji@alam.edu.my*

Abstract

Heat treatment of ballast water using engine waste heat has been investigated earlier but quantum of heat and time availability were issues. From the operational data of a crude carrier, it was found that the available waste heat could raise the temperatures by 25°C but time requirements will be more than 7 days. Heat recoveries were also verified at laboratory levels to be at 14% to 33% of input energies. Effectiveness of these recoveries was tested on a mini-scale system representing a ship system. Species mortalities at temperature range of 40°C to 75°C were recorded. The realized mortalities of tested phytoplankton, zooplankton and bacteria were >95% with heat from jacket fresh water and exhaust gases alone. The viability of the system and the method were validated.

Keywords: *Ballast water, waste heat, species mortalities*

Notations

A_o	Total outside area, tube (approx), m^2
C_{Ao}	Installed cost of heat exchanger, US\$/m^2
C_T	Total annual variable costs including operational costs, US$ (Lagrangean Objective function)
C_{fluid}	Specific heat capacity (sea water/exhaust gases), kJ/kg K
C_i	Cost to pump fluid inside the tubes (exhaust gas), US$/kWh
C_o	Cost to pump fluid on the shell side (seawater), US$/kWh
C_u	Cost of utility fluid, US$/kg
E_i	Power loss inside tubes/m^2
E_o	Power loss outside tubes/m^2
H_y	Hours of heat exchanger operation/year
K_F	Fixed charges including maintenance/year as a fraction of installed cost (%), US$
$Q_{cooling\ water}$	Heat energy lost to cooling water, kW
$Q_{exhaust}$	Heat energy lost to exhaust gases, kW
Q_{in}	Heat energy input, kW
$Q_{odd\ losses}$	Heat energy lost due to other factors, kW
Q_{avail}	Heat available for recovery, kW
$W_{engine\ power}$	Useful energy output, kW
h_i	Heat transfer coefficient, W/m^{2}K
h_o	Heat transfer coefficient, W/m^{2}K
m_{fluid}	Mass flow of fluid (sea water/ exhaust gas)

m_u	Mass flow of utility fluid, kg/s	$\Delta T_{in\sim out}$	Temperature difference (sea water/ exhaust gas), ^oC
Δt_2	Temperature difference at tube entry/ shell exit, ^oC	λ	Lagrange multiplier

Introduction

The Ballast Water Management Convention was ratified only recently and will be enforced in 12 months from now. Treatment systems on various technologies are in commercial readiness and the available systems are mostly in combination as single methods do not assure efficiencies [1-4]. There have been reviews on the efficacies of systems and many alternate solutions including shore based treatment options have been suggested [5-7]. Heat treatment of ballast water has been proposed as a candidate method [8] but issues remain. While heat availability for treating large volumes is the major issue, storage of heated waters, effect on coatings, discharge of heated waters and resistance to mortality of some bacteria strains are other issues.

Heat treatment has been researched upon earlier [9-15]. Heat treatment using heat from the engine jacket water was pegged at US$0.56/tonne [5]. Heat treatment has been demonstrated to be effective in combination with UV, deoxygenation and electro-chlorination [5]. The low to medium range of temperatures are realisable in propulsion engine systems where heat is discarded in the jacket fresh water. If the engine exhaust gases and the other systems such as LT (Low Temperature), steam rejections etc., are considered, higher heat quanta can be realised.

If the sea waters from other systems are directed to the ballast tanks after further heat addition from a high temperature source (exhaust gases), it would result in considerable levels of sterilisation. The realised heat could complement a proven system and the shortcomings of heat treatment being a stand-alone method can be overcome. On this premise, a treatment system was envisaged and tested at laboratory levels. **Figure 1** shows the schematic of the envisaged system. This paper highlights the study which demonstrated that heat treatment using engine waste heat is viable.

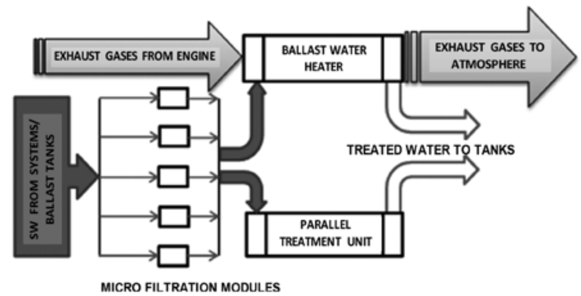

Figure 1 : Ballast water treatment system

Methodology

Figure 2 shows the methodology identifying the significant steps of the study. The study broadly involved three steps. The development of the treatment system extended from the shipboard system [16] and the analyses of heat availability based on the operational and design data from the

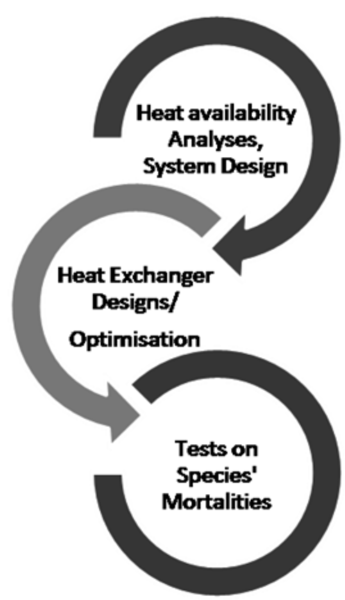

Figure 2 : Methodology steps

ship and verification of the heat recoveries [17] constituted the first step.

The heat availability was verified using a diesel engine test bed arranged with a system with components similar to shipboard auxiliaries (Fresh water generator, fresh water cooler etc.). Additionally a calorifier fitted on the path of the exhaust gases was used to compute the heat energy harvested from exhaust gases.

The heat availability on board as assessed based on the heat balance of the engine at Continuous Service Output (CSO) and the heat rejections into high temperature (HT), low temperature (LT) and steam systems.

The engine heat balance was based on

$$Q_{in} = Q_{exhaust} + Q_{coolingwater} + Q_{oddlosses} + W_{enginepower} \quad (1)$$

The basic equation used for heat was

$$Q_{avail} = m_{fluid} \cdot C_{fluid} \cdot \Delta T_{in \sim out} \quad (2)$$

Development of heat exchanger designs and optimisation for heat harvesting from the exhaust gases[18,19] was the second step. The optimisation of the designs was done keeping annual cost as the objective function from the following equation[20, 21].

$$C_T = A_o K_F C_{Ao} + m_u H_y C_u + A_o E_i H_y C_i + A_o E_o H_y C_o \quad (1)$$

Equation (1) was further expanded with appropriate equations for heat exchanger designs. From this, a system of five equations were derived and solved for five unknowns, i.e., the four variables (h_i,h_o A_o and Δt_2) and the Lagrangean multiplier λ. The equations were then expressed as unconstrained problems for optimisation. The iterations and solutions of resulting equations are not elaborated herein. The objective function costs were then derived from the solutions[18]. The heat exchanger designs were developed for the vessel as well for the test rigs used for the study.

The third step involved assessment of species mortalities at laboratory level and on the mini-scale system. Further, effect of pump impellers on the species was also studied. The test rig arrangement was similar to the envisaged system. While the heat exchanger designs were being developed, species' mortalities were assessed at laboratory level. Temperature and time exposure in heat phase for mortalities were assessed to finalise the heat exchanger designs. Time for 100% mortalities were also assessed.

The last step in the study included the second test rig arrangement fitted with another heat exchanger. Here, the species' mortalities were assessed while maintaining flows similar to the shipboard scenario. This concluded the study. The steps of methodology included elaborate reviews, heat exchanger design computations, cost derivations and protocols for culturing and testing of the species. These are not included in the current deliberations.

Discussions

Ballast Water Treatment System Design

In the Ballast Water Treatment (BWT) system envisaged from the shipboard system [16], the initial ballasting can be done using the auxiliary pumps and the ballast pump. The treatment protocol was during the uptake with the treatment system based on proven technology (additional/ parallel treatment system). Heat Treatment protocol will be during sailing to get the benefits of waste heat from engine and other systems. During these periods, the ballast waters can be circulated with the aid of auxiliary cooling water pumps. Suction from tanks can be changed over as the temperatures rise. The addition of heat causing the temperature rise would amount to heat treatment at low to medium temperature range [16].

Species' elimination and moralities are identified at six stages. The components contributing to the mortalities are the coarse filters, pumps (impeller effects), microfiltration packs (50µm), heat exchangers (fitted coolers and the purpose-built ballast water heater) and the parallel BWT unit based on proven technology.

In the first stage, some species are warded off by the coarse filters placed at the suction of the sea water pumps. In the second stage, as the waters are pumped by the centrifugal pumps, the impeller effect will cause mortalities. As the system is reliant on sea waters from the auxiliary pumps, additional power requirements are negligible [16]. At this stage, certain amount of heat absorption is expected as the sea waters removing heat from the systems (from fresh water and other coolers) are directed to the ballast tanks. The microfiltration packs were the next stage for species' elimination. Microfiltration efficiencies were assumed to be good based on available research [22-25, 5]and the high usage of the method in other treatment systems.

Major heat addition occurs in the heat exchanger where the high temperature exhaust gases are passed through. All these stages form part of the envisaged treatment mode complementing the parallel treatment unit based on a proven technology. The results presented in this paper are focussed on the elimination effects at the pump impellers and the exhaust gas heat exchanger.

Heat availability Analyses

Table 1 shows the heat balance projections of the ship's engine and the test bed engine[17]. Referring to the heat balance on ship's engine, the HT system heat (from fresh water) was not considered as this will not be available if the fresh water generator is in operation.

The main engine (ship's engine) recoveries from exhaust gases accounted for is 15.25% of input energies. Even if the heat lost to exhaust gases is pegged at 25%, a residual 9.75% heat is available. If the losses are pegged at 30%, then around 14.75% is available. At least 10% of this can be recovered but only 6.62% was assumed for the design of the ballast water heater which would harvest the heat from the engine exhaust gases. However, the optimised heat exchanger design had scope for these extra recoveries[18]. The possibility of such a recovery by placing a heat exchanger on the path was demonstrated by tests on the test bed. A minimum 14.87% to maximum of 33.36% of input energies was recovered from the exhaust gases in the test bed exercises. Heat losses from pipelines, tank stratification and hull (will be increased as the ship moves) were accounted for and the heat requirement to raise about 90000m^3 ballast water by 25^{o}C was found to be 12.01 to 15.36 days [17]. For normal voyage considerations, a voyage longer than two weeks is termed as a long voyage [26]and longer voyages would be better suited to sustain the medium temperature ranges.

From the analyses based on ship's operational data and test bed exercises, it was apparent that heat treatment could not be employed as a single method to sterilize large volumes. Yet the economic benefits of waste heat harvesting and the simplicity of system warrants further investigations [6, 7]. The heat exchanger design assures effective recoveries.

Heat exchanger designs and optimisation

The heat exchanger designs for shipboard use were finalized from almost eight designs. All the designs were optimized using Lagrangean equations, Bell-Delaware approaches and

Table 1 Heat balance: ship's engine and test bed engine

Component	% of Input Energy	
	Ship's Engine	Test Bed Engine
HT System (FWG not in operation)	7.39	4.33
Turbochargers + Exhaust Gas Boiler +Ballast Water Heater	21.87	14.87*
Output	48.98	30.63
Radiation, LO	10	10
Input	100	100

* Exhaust recovery in calorifier

geometric parameters verified by TEMA standards [27]. The final choice was made considering the maximum temperature rise and with scope for maximum flow rates[18].

The geometric values were worked for the chosen design and based on this, heat exchangers for test rigs were developed[28]. The physical similarities were ensured and the other parameters were verified for commercially available designs[19]. Computer programmes and SolidWorks® were used to TEMA[27] standards.

Tests for Species' Mortalities

The three widely prevalent genres of phytoplankton, zooplankton and bacteria were used for the tests. They were representative of sea water and fresh water species and the numbers (culturing) were maintained to suit test volumes as per recommended densities in IMO Guidelines G8 [29].All the species were tested at temperature range of 40°C to 70°C. At laboratory levels the effect of pump impellers were also tested and 62 to 100% mortalities were realised. This substantiates earlier studies on impeller effects by Hillman et al., [30] and Veldhuis et al., [24].

The next level of tests involved the mini-scale test rig arrangement. The tests were conducted with engine running and the cooling sea water was made to harvest the heat from the fresh water coolers and the exhaust gas heat exchanger. **Table 2** shows the summary of the species' tests done on the mini-scale arrangement.

Table 2 Average species' mortalities: Summary of tests

Test Condition	% Mortalities		
	Artemia sp.	**Chlorella sp.**	**E coli**
Engine heat + Impeller	98.1	98.3	>95
Impeller only	100	100	>95

Conclusions

The viability of harnessing the heat in a ballast system with minimum modification and additions has been demonstrated. Treatment by heat alone would not suffice for the large volumes in available time period but the studies assure that heat treatment with shipboard waste heat can complement any proven technology. The results of the study warrant further investigation, especially for increasing the sea water flow rates, assessment with other heat exchanger designs and particularly in combination with proven technologies such as UV and electro-chlorination.

Acknowledgements

The Author wishes to thank MISC Berhad for the vessel data. The heat availability tests were conducted in Marine Engineering Workshop of Malaysia Maritime Academy. The laboratory level tests were conducted in Universiti Malaysia Terengganu and the species' mortality tests on heat exchanger-engine arrangement were carried out in Universiti Teknologi Malaysia. The tests on species' mortalities were supported by the Science and Technology Fund (Ref: 04-01-06-SF1031) of Ministry of Science, Technology and Innovation (MOSTI), Malaysia. The contribution of the Ballast Water Project Team (Prof Omar Yaakob, Kho King Koh, Faizul Amri bin Adnan, Nasrudin bin Ismail, Badruzzaman bin Ahmad, Mohd Arif bin Ismail of Universiti Teknologi Malaysia) and of Dr. Hing Lee Siang of Universiti Malaysia Terengganu for tests on species is duly acknowledged.

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Exergy Analysis of a Medium Size LNG Tanker Steam Power Plant

Rajendra Prasad Sinha, Rajoo Balaji

Malayasian Maritime Academy, Melaka, Malyasia

✉ *rajendra@alam.edu.my*

Abstract

Exergy is the maximum work which can be obtained from a quantity of heat Q at temperature T1 received by a system interfacing with a surrounding environment at temperature T0. In other words from the received heat energy 'Q' a small portion fails to convert into useful mechanical work and is thus lost which we call exergy destroyed. The loss of exergy in this heat work exchange process lowers overall thermal efficiency of the plant. Exergy destruction is actually the result of irreversibility in various processes of the plant and can be estimated from the second law of thermodynamics as the product of ambient temperature T0 and the positive entropy change Δsi.e. (T0Δs). The common irreversibility which cause entropy rise are mechanical or hydraulic friction, heat transfer with a finite temperature difference and diffusion with a high gradient of concentration etc., as most of these are present in a physical plant. Exergy analysis gives an insight into the way energy flows in the system and helps to locate components of the plant with high irreversibility to effect design improvements.

In this paper the authors conduct energy and exergy analysis of 30 MW dual fuel fired marine steam power plant of a typical medium capacity LNG tanker and identify components responsible for major exergy destruction. Effects of steam reheating to reduce irreversibility and potential utilization of the cold energy of boil off gas in the thermodynamic cycle has been studied with the result showing 2-4 % improvement in the overall exergy efficiency of the plant.

Keywords: *Liquefied Natural Gas, Exergy, Exergy destruction, Boil off Gas, Heat balance, Cold Energy, Combined Cycle*

Notations

BOG	Boil-off Gas
G	Mass, kg/h
h	Enthalpy, kJ/kg
H	Enthalpy, kcal/kg
LNG	Liquefied Natural Gas
m	Mass, kg/s
T	Temperature ^{0}C
S	Entropy kJ/kg-K

Introduction

First law of thermodynamics which is the basis for design of ship power plants only accounts for energy conservation and does not consider the quality aspect of heat during conversion to work. Therefore first law assessment of plant performance is not expected to give correct result. To get accurate result of the plant performance and distinctly identify non performing subsystems the first law analysis alone is inadequate and must be supplemented by the second law. In this synopsis, performance analysis of a 26 MW steam power plant of a medium capacity LNG tanker using the first and second laws of thermodynamics is reported.

Irreversibility and Exergy Destruction

It is well known that while mechanical work can be fully converted into heat whereas the reverse is not possible. When heat is supplied to an engine to produce mechanical work, only some portion of this heat is converted into useful mechanical work,the remaining is lost to the environment. The portion of heat which is converted into useful mechanical work is known as availability or exergy while the fraction lost is the exergy destroyed [1]. This directional constrain in heat and work exchange process is an outcome of the second law of thermodynamics and has influence on the performance of thermal plants. Mathematically it is expressed as,

Work, $W = Q(1 - \frac{T_2}{T_1})$ Exergy or availability (1)

The heat which is not converted into useful work can be expressed as

Exergy destroyed = $W = Q(\frac{T_2}{T_1})$ (2)

Where Q = Heat supplied to engine; T_1 = Temperature of heat source

T_1 = Temperature of rejecting environment

It is observed from equations (1) and (2) that if heat supplied from high temperature source and rejected into a low temperature sink then exergy rises and destruction of exergy reduces. This means the same amount of heat will provide different work output depending on the temperature of heat supplying and rejecting sources. This introduces a concept of quality of heat. Thus, heat flow from high temperature source is good quality because it produces greater amount of work. On the other hand same amount of heat received from low temperature source will produce less work, hence it is termed as bad quality heat. This is an outcome of the second law of thermodynamics and is related to the change in entropy of the system caused due to heat and work transfer.

Exergy destruction is actually the result of irreversibility in various processes of the plant and determined from the second law of thermodynamics as the product of ambient temperature T_0 and the entropy change Δs i.e., $T_0 \Delta s$. The common irreversible phenomena which generate entropy are mechanical or hydraulic friction, heat transfer with a finite temperature difference and diffusion with a high gradient of concentration as most of these are present in a physical plant. Exergy analysis provides insight into the way energy flows in the system and helps to locate plant components with high irreversibility.

Heat balance is essentially an energy accounting procedure based on the first law while exergy analysis is the outcome of the second law of thermodynamics and addresses loss of real usable work due to irreversibility in the system. Both analyses methods are complementary and should be used to help identifying the components which are responsible for low performance of the power plant. The power plant under investigation comprises of cross-compounded high pressure and low pressure turbines with two water tube boilers operating in parallel at 60 bar pressure and 515^0C temperature. Operating parameters of the plant at 90% load are shown in **Table 1**.

The energy flow diagram in **Figure 1** prepared from operating data in **Table 1** shows heat balance of energy flow into and out of each component of the power plant indicating mass, enthalpy, pressure and temperature parameters. The exergy destruction in individual units of the power plant has been estimated using thermodynamic parameters in the heat energy flow diagram. The dead state of the power plant for exergy analysis has been assumed to be the ambient condition of 1 atmosphere at 25^0C temperature.

Table 1: Plant Operating Parameters

			Loading Condition	
S.No	Description	Unit	90% Value	50% Value
1	Turbine Power Output	kW	21728.57	12071
2	Main Steam Pressure	bar	60	60
3	Main Steam Temperature	0C	515	510
4	Main Steam Flow Rate	kg/s	24.51	17.28
5	Fuel Oil Consumption	kg/s	1.80	1.253
6	Lower Calorific Value	kJ/kg	38737.80	38737.80
7	Reheat Steam Pressure	bar	---	---
8	Reheat Steam Temperature	^{0}C	---	---
9	Reheat Steam Flow	kg/s	---	---
10	Condenser Pressure	bar	0.05	0.08
11	Number of LP Heaters	---	1	1
12	Number of HP Heaters	---	1	1
13	Boiler Efficiency	%	88.50	88
14	Sea Water Temperature	^{0}C	24	24
15	Turbo Generator Load	kW	1210	1230
16	Turbo Feed Pump Load			
16	Ambient Air temperature	^{0}C	38	38
17	Air heater exit temperature	^{0}C	130	130
18	Mass of combustion air	kg/s	32.922	31920
19	Mass of combustion products	kg/s	35.105	33873
20	Evaporator Load	t/day	30.00	0.00
21	Main circulator power	kW	300	300

Exergy of Steady Flow Thermal System

Exergy equation of a thermal system [2, 3] with multi point heat input and work flow is expressed

as follows, $\overset{0}{X} = \sum_{k=1}^{n} (1 - \frac{T_0}{T_1}) \overset{0}{Q}$ (3)

And specific exergy of control volume is expressed as

$$\chi = (h - h_0) - T_0(s - s_0) \quad (4)$$

Then the total exergy associated with the flow stream is the product of specific exergy and mass flow rate.

$$X = m[(h - h_0) - T_0(s - s_0)] \quad (5)$$

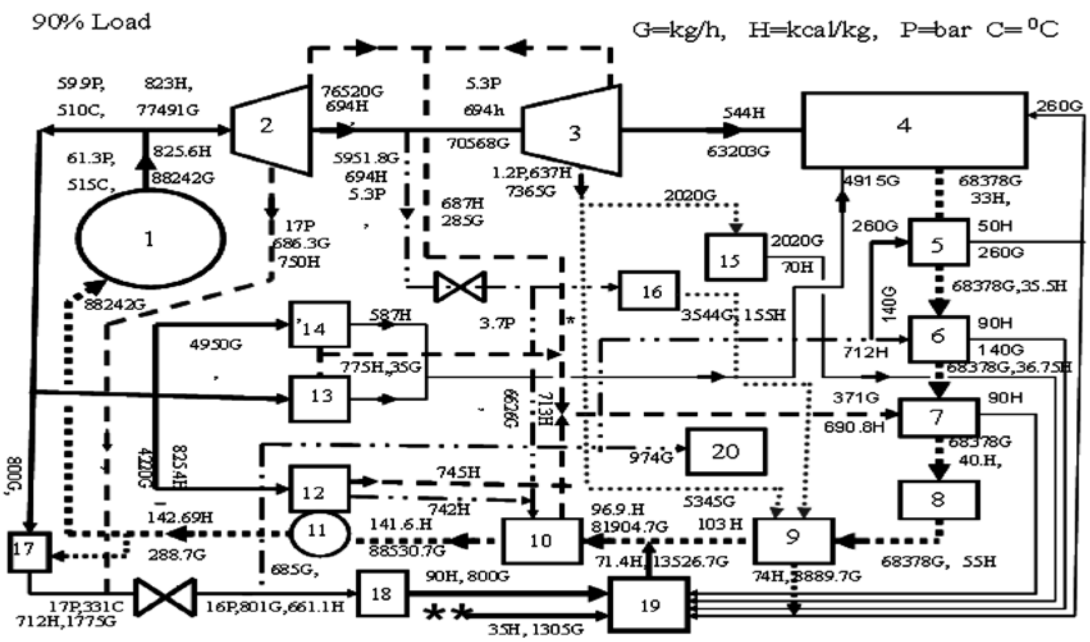
The net exergy destruction, which is the real loss in available work due to irreversibility in the system is the difference of exergy in and exergy out from the control volume and equals to -

$$X_{destruction} = X_{in} - X_{out} = \sum_{k=1}^{n} T_0 S_{gen} \quad (6)$$

From these equations, the exergy destruction and exergy efficiency of the major plant [4, 5] components is tabulated in **Table 2**.

Results and Discussion

Major Exergy destruction and heat energy loss in the power plant main equipment has been estimated and shown in **Figure 2**. The boiler, turbines, condenser, feed heaters and air pre-heaters account for maximum exergy destruction and heat loss in the power plant. The exergy loss in remaining equipment of the plant was found



Legend

1 Boiler; 2 HPT; 3 LPT; 4 Condenser; 5 Air ejector; 6 After condenser; 7 Gland Condenser; 8 Fresh Water Generator; 9 LP heater; 10 Deaerator; 11 Feed pump; 12 Feed pump turbine; 13 TG1; 14 TG2; 15 Evaporator; 16 Air heater; 17 Desuper heater 18 Auxiliary desuper heater; 19 Auxiliary Tank; 20 Drain tank; 21 Soot blower

Figure 1: Energy Flow Diagram of Plant

Table 2: Power Plant Exergy Destruction

Component	Exergy Destroyed	Exergy Efficiency
Boiler	$I_D = \sum_{k=1}^{n}(1-\frac{T_0}{T_1})\dot{Q} - X_{out}$	$1-\frac{I_D}{\sum_{k=1}^{n}(1-\frac{T_0}{T_I})\dot{Q}}$
Turbine	$I_D = X_{in} - X_{out} - W_t$	$1-\frac{I_D}{X_{in}-X_{out}}$
Pump	$I_D = X_{in} - X_{out} + W_p$	$1-\frac{I_D}{W_p}$
Condenser	$I_D = X_{in} - X_{out} + W_f$	$\frac{X_{out}}{X_{in}+W_f}$
Heat exchangers	$I_D = X_{in} - X_{out}$	$1-\frac{I_D}{X_{in}}$

to be relatively small and can be ignored. As expected the exergy loss in boiler is high at 37 %. The main cause of excessive exergy loss in boiler is the presence of high degree of irreversibility from large temperature difference between the hot furnace gases and water in the steam drum.

These findings are in the similar studies in land based power plants where steam boiler has been a source of high exergy loss. Similarly steam turbines, both HP and LP are also subjected to high irreversibility due to pressure and temperature gradient between inlet and exit ends and account for about 14.5-27.7 % exergy loss. Condenser on the other hand is relatively a lesser victim of the exergy casualty mainly because it receives low quality heat of much reduced exergy potential from the turbine. Similarly most other equipment

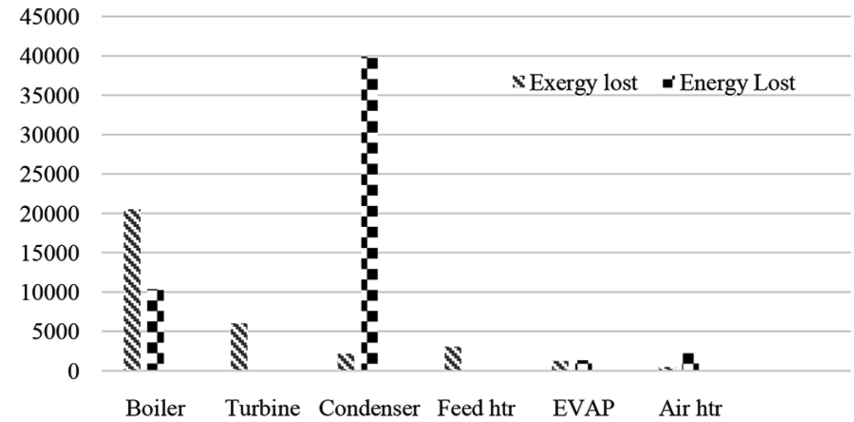
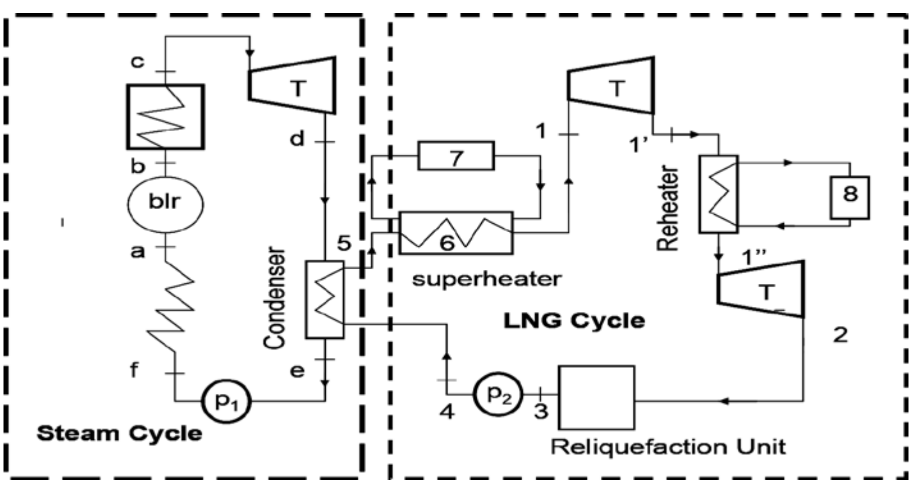


Figure 2 : Exergy/Energy Destruction at 90% Load [kJ]

except feed water heater also receive low grade heat and consequently their exergy destruction remains relatively small and thus can be ignored.

The comparison of exergy and energy loss of individual components of the plant gives a very different picture. For instance, though boiler due to use of excellent insulation material has very small heat loss but its exergy loss is as high as 37%. On the other hand condenser which rejects about 62% of the total heat input to the plant, has comparatively small exergy loss of only 6%. Therefore it is the heat exchange process in the boiler and not condenser which requires careful assessment in terms of irreversibility. The irreversibility in steam boilers is addressed in shore based power plants through use of air pre-heaters and implementation of steam reheat cycle. Feasibility of implementing reheat cycle in marine steam plants is under investigation by MHI heavy industry for marine version of their UST plants.

In LNG tanker context the quality of heat available can be enhanced to improve exergy of the plant by utilizing the cold energy from Boil-Off Gas



Process Cycle

Legend

(1) Economizer (e-f); (2) Boiler (a-b); (3) Super heater (b-c) (Steam turbine (c-d); (4) Condenser (d-e); (5) Feed pump (e-f); (6) LNG heat exchanger (4-5); (7) LNG boiler (5-6); (8) LNG super heater; (6-1) LNG turbine (1-1'); (9) LNG Reheater (1'-1"); (10) LNG turbine (1"-2); (11) Reliquefaction unit (2-3); (12) LNG feed pump (3-4); Condenser (LNG temp -90^{0}C); Superheater (LNG temperature -40^{0}C); Reheater (LNG temperature -112^{0}C)

Figure 3 : Schematic diagram of LNG combined cycle plant

(BOG)to lower the condenser temperature. Use of BOG to enhance exergy was investigated. Result shows that plant overall efficiency can be raised by 2.5% by incorporating cold energy of the BOG in a combined power cycle. Combined cycle plant layout [6,7] is shown in **Figure 3**.

The operating parameters of the proposed LNG combined cycle plant is shown in **Table 3**. The extra power derivable from the natural BOG of this plant has been estimated to 500 kW which is equivalent to 2.5% of the ship's total propulsive power. Since, price of LNG is now comparable to bunker fuel the combined cycle power output can be raised through forced BOG to further improve plant efficiency. This would also help in meeting regulations pertaining to emissions [8].

Table 3: Combined Cycle Operating Parameters

Steam Cycle		**LNG Cycle**	
Inlet steam pressure (Mpa)	6.0	NG superheat pressure (Mpa)	3.64
Inlet steam temperature (^{0}C)	510	NG sat temperature (^{0}C)	-90
Condenser pressure (kpa)	5.0	NG Superheat temperature (^{0}C)	-40
Exhaust steam temp. (^{0}C)	45	NG Exhaust pressure (kpa)	101
Maximum steaming rate (kg/h)	60,000	NG Exhaust temperature (^{0}C)	-161
CW flow rate (kg/h)	12×10^5	LNG BOG rate (kg/h)	6500
CW temperature (^{0}C)	24	Coolant flow rate (kg/h)	850
Reheat pressure (Mpa)	--	NG reheat pressure (Mpa)	0.5819

Conclusion

Results and findings of exergy and energy analysis of a medium sized marine steam power plant has been reported. As expected the plant equipment with higher irreversibility are susceptible to greater exergy destruction which is the cause of real low plant efficiency. The losses in boiler, turbine and condenser, which inherit higher irreversibility, are more significant and require additional measures to improve performance. The air and feed water heating are the means available to minimize exergy loss in boilers. For steam turbines and condenser using cold energy of BOG in combined cycle can improve performance and reduce exergy loss marginally. It may be thus concluded that for new ships to comply with new energy efficiency regulations, future ship designs should include 2nd law analysis as supplementary tool to the first law of thermodynamics.

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How Efficient are Malaysian Shipping Companies: A Stochastic Frontier Approach with Malmquist Productivity Indices

Saravanan Venkadasalam, Rajoo Balaji
Malayasian Maritime Academy, Melaka, Malyasia
✉ *v.saravanan@alam.edu.my*

Abstract

The purpose of this paper is to analyse the performance of the Malaysian Shipping Companies. The company's performance indicators such as technical efficiency and total factor productivity (TFP)have been measured using the stochastic frontier approach and subsequent Malmquist index. A secondary data for selected shipping and transportation service provider's annual reports for the past five years were analysed using Frontier 4.1 and Data Envelopment Analysis Program (DEAP)software. It was found that 80% of the shipping companies were operating below the frontier line (<1.0). The findings are expected to contribute significantly to the business progress and performance metrics of Malaysian companies and also help to benchmark the shipping industry's best practices.

Keywords: *Stochastic Frontier Approach, Total Factor Productivity, Malmquist Index, Data Envelopment Analysis, Shipping companies.*

Introduction

Sea transportation is still the preferred mode for transporting billions of tonnes of goods. United Nation Conference on Trade and Development (UNCTAD) reports a steady increase in global trades by sea transportation every year. In the year 2014, about 40% of the world total goods loaded were from the Asian nations[1]. Similarly, 60% of the world total goods unloaded were in Asia region. Its shows a dynamic, strong economic development in the Asia region.

In Malaysia, international trades significantly contributed to the economy to make it the third largest nation in South East Asia controlling the trades through the Straits of Malacca. On an average, MYR 100 million monthly traded externally in Malaysia[2]. With its strategical central location between East and West Asia trade routes, shipping companies in Malaysia were presumed to perform better within this region. But, a recent study on Malaysian Shipping Companies shows most of the shipping companies were facing a financial distress condition[3]. If this condition continues, bankruptcy of the companies would become unavoidable.

Monitoring and evaluating the company's performance is important to identify the best practices in the industry [4].It not only helps to understand their competitive position, but also would help to strategize the long term policies [5]. In the literature review, the efficiency analysis of shipping companies were insufficient or can be considered as absent. The current literature mainly focuses either on the port management or a component of the international trades such as container liner, container terminal, etc. This study will further enrich the existing literature by evaluating the Malaysian shipping companies' efficiencies and measure their total factor productivities. Based on the outcome, a benchmarking was also carried out for the companies.

Methodology

In the year 2015, a total of 14 shipping companies were listed on the Kuala Lumpur Stock Exchange. Only five companies were trading in international trade zone. Others were providing services to oil and gas sector locally and internationally. To obtain a balance panel data, all these 14 companies' data, such as equity values, total current assets and total current liabilities of past three years were extracted from the company's annual reports and the profitability, liquidity and leverage ratios were computed. The analysis of performance was conducted in two stages.

Firstly, the Bayesian stochastic production frontier model was used to analyze the technical and cost efficiencies. This is a proven parametric analytical method for evaluating company's efficiency. The approach is feasible, even in complex problems and with small samples [6].Since the number of shipping companies in Malaysia were not many, the stochastic production frontier analysis model was adopted as a best tool to evaluate the performance. The data were analysed using the Frontier 4.1 software.

Secondly, the Malmquist total factor productivity analysis was conducted to measure the technical efficiency change, pure technical efficiency change, scale efficiency change and total factor productivity change. The means of three year efficiency scores were computed to rank the companies.

The initial study shows many companies were operating far from the frontier line. Total about 80% of the companies were inefficient and only 50 % were significantly positive total factor productivity change. The study also shows that many companies were operating far from the frontier line. Total about 80% of the companies were inefficient.

Table 1 shows the outcome of the non-parametric output oriented model's efficiency analysis using Data Envelopment Analysis Program (DEAP) version 2.1 developed by Tim Coelli for selected shipping companies in Malaysia. On average, shipping industry in Malaysia operates inefficiently.

Table 1 : Technical efficiency scores for selected shipping companies in Malaysia

	2008	2009	2010	2011	2012	2013
Global Carrier	1.000	1.000	1.000	1.000	1.000	1.000
MISC Bhd	0.013	0.005	0.004	0.004	0.005	0.005
PDZ	1.000	1.000	1.000	1.000	1.000	1.000
Maybulk	0.279	0.067	0.136	0.166	0.269	0.338
Habour link	0.600	0.538	0.435	0.394	0.446	0.469
Hubline	0.294	0.229	0.174	0.201	0.173	0.220
Perisai	0.509	0.474	0.423	0.250	0.191	0.134
Tanjong	0.440	0.324	0.250	0.309	0.602	0.770
Alam Maritime	0.306	0.228	0.205	0.223	0.173	0.164
Sealink	1.000	0.266	0.226	0.242	0.242	0.224
Overall	0.367	0.228	0.214	0.216	0.234	0.241

Conclusion

Two hypotheses can be tested in this study. Firstly, there was no efficiency variation between the shipping companies operated in Malaysia. Thus, all shipping companies were operating at the same production frontier. Secondly, there was no productivity change variation between the shipping companies in Malaysia. The null hypothesis was that the shipping companies have the same total factor productivity change. This research may be used to benchmark all shipping companies in Malaysia.

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Hybrid Renewable Power Generation and their Applications

Shalabh Agarwal, Ankit Parasar, Maninder Singh

Tolani Maritime Institute, Pune

✉ *kushagarwal1234567@gmail.com*

✉ *ankitparasar@gmail.com*

✉ *msingh03@y7mail.com*

Abstract

The technical paper lays emphasis on generating more eco-friendly forms of electricity with the help of limitless and abundant renewable sources of energies (wind and wave). This innovative idea reveals the method to utilize these two substantial forms of renewable energies combined together in one unit and harnessing energy at the same place and time. The paper also presents a wide range of analysis done on various parameters (tension, length and angle of belt relative to wind) of the belts which in presence of wind experiences aeroelastic flutters which ultimately result in generation of electricity. This analysis is done using ANSYS software where we optimize the angle with wind must strike the belt for maximum power generation using complex flow simulations by Computational Fluid Dynamics using Fluent software. Additionally a sample model is being prepared to optimize some of the other parameters like length. The other part stresses on harnessing blue (wave) energy at shore as well as at offshore platforms. This paper aims at combining these two renewable forms to obtain a supply of electrical energy. A combined model designed on Pro Engineer Software has also been shown in the paper.

Keywords : Hybrid Electric System; Wind Energy; Ware Energy

Introduction

A hybrid renewable energy system is a combination of two or more renewable energy sources used together to provide increased energy supply to the same unit. It can be made into operation by proper utilization of these resources in a completely controlled manner. The sources can be solar, wind, wave, biomass, fuel cell etc. Any combination between the two or more among these can be used as hybrid power generation unit.

All these generating systems have some or the other drawbacks, like Solar panels are too costly and the production cost of power by using them is generally higher than the conventional process, it is not available in the night or cloudy days. Similarly Wind turbines can't operate in high or low wind speeds and Biomass plant collapses at low temperatures. But their combination can serve our purpose.

A small hybrid electric system may consist of wind electric and solar electric technology to offer several advantages over either single system. The wind speed is low in the summer and the sun shines brightest and longest. The wind is strong in the winter when less sunlight is available. Because the peak operating times for wind and solar systems occur at different times of the day and year, hybrid systems are more likely to produce power when you need it.

To obtain constant power supply, the output of the renewables may be connected to the rechargeable battery bank and then to the load. If the load is alternating current (AC), then an inverter is used to convert the direct current (DC) supply from the battery to the AC load.

Wind Energy Generation

Wind energy is the energy extracted from wind using various methods like wind turbines, wind belt, vibro-wind oscillator and others. Wind power, as an alternative to fossil fuels, is plentiful, renewable, widely distributed, clean, produces no greenhouse gas emissions during operation.

Wind Farms

Wind power is capital intensive, but has no fuel costs. Wind farms consist of hundreds of individual wind turbines which are connected to the electric power transmission network. Wind turbines can be used as stand-alone applications, or combined with a photovoltaic (solar cell) system to make it hybrid. It may also be located offshore due to more frequent and powerful winds that are available in these locations and have less aesthetic impact on the landscape than land based projects. However, the construction and the maintenance costs are considerably higher. Due to higher installation and maintenance cost, we need to look for an alternative method of harnessing the wind power.

Vibro Wind Oscillator

A vibro wind oscillator can be used to capture the wind energy and convert this energy to electrical. This oscillator has a frame which mounts 25 pads made of foam. Each pad is coupled with piezoelectric transducer. These pads vibrate when wind flows over them and each individual pad will produce electricity which can be stored in batteries.

Another design for the vibro wind oscillator can be in the shape of a tree where the 'trunk' makes use of the piezoceramic material PZT (Pb(Zr-Ti) O3) and the 'leaves' are made from a relatively soft, flexible polymer poly(vinylidene fluoride) (PVDF). The idea is that the more rigid trunk can harvest energy more effectively in stronger winds and the leaves work best at lower wind speeds, and both send a trickle of electricity down to a rechargeable battery at the base of the system. Also flexible film of a solar cell onto the leaves for electricity production on windless days can be included to make it a hybrid renewable energy system.

Windbelt

Instead of using conventional geared, rotating airfoils to pull energy from the wind, the Windbelt relies on an aerodynamic phenomenon known as aeroelastic flutter ('flutter'). Unlike conventional wind turbines, windbelts are effective at producing electricity at low wind speeds. Regions that typically have lower average wind speed are best suited for windbelt installation.

At its heart, the windbelt uses a tensioned membrane (taut string or ribbon) undergoing a flutter oscillation to pull energy from the wind. A pair of magnets is fastened to the belt, so as the belt moves up and down the magnets follow the same motion. This motion of the magnets takes place directly next to the stator (coil). A magnetic field moving next to a coil of wire induces a current to flow. As generated, the electricity is alternating current (AC). This AC may be converted to direct current (DC) with the enclosed rectifier.

Unlike conventional wind turbines, which require expensive bearings and gears to be efficient, windbelts are relatively easy to construct at a low cost. This makes it more feasible for areas with relatively lower wind speed. Windbelt design is relatively new and experimental. New materials, several parameters like wind speed, belt tension to achieve resonating frequency, angle of incidence of wind with the belt for maximum flutter, magnet placement, length of belt etc. and new designs can be tested to advance this potential source of clean energy.

The aim of this paper is to predict some of the parameters for maximum power generation by windbelt. Also, comments have been made regarding constructional details, material of the windbelt, their properties and the cost.

Windbelt

Constructional Details

The Windbelt consists of a very simple design that can be self modified and enhanced to suit the needs of the user. The main components are a containing bracket, two copper coils, two strong button magnets, a ribbon and some bolts and nuts to piece together the entire system. The major components of the system are:

Frame

The frame holds together the entire unit. It can be fabricated from any available material such as treated timber, aluminum or plastic. It is exposed to the weather conditions so the frame must be durable. Also it must be able to withstand the high winds as the high winds can create a lot of torque upon the windbelt's mount and can damage the windbelt or the structure it is attached to.

Ribbon or Belt

The ribbon is the platform for the entire functionality of the Windbelt. When exposed to wind above 4m/s the ribbon in our Windbelt will experience aeroelastic flutter. Wind will cause the ribbon to move up and down with high frequency oscillating motion.

The material for the ribbon can be anything durable enough to withstand the weather and high wind forces. It is key for the ribbon to be as lightweight and thin so that it acts as an airfoil and the cut in wind speed for flutter is minimized. The ribbon will bw taut and subjected to potentially high wind speeds, so the material must have high tensile strength. The ribbon also needs to be torsionally strong so that the oscillation is as linear as possible, with little twist during the motion. There are only few materials those prosess these characteristics for windbelt construction. The one suited for it is mylar-coated taffeta. Similar materials, such as Kevlar, tape, or camera film can be used alternately. Kevlar is a strong material with similar mechanical properties that of taffeta. Some of the properties are:

R.D: 1.44, UTS:3620 Mpa, Poisson_s Ratio:0.36, E:131 Gpa

Magnets

Permanent magnets, two in number are used to induce current in the coils when vibrating in and out of the coil. The magnets must be light weight so that it does not disrupt the aeroelastic flutter of the ribbon. Neodymium magnets are most commonly used. The stronger the magnetic field greater, the greater the magnetic flux and thus the larger current induced.

Coils

The copper coils provide the medium for electromagnetic induction. According to Faraday's law of induction, the induced Electromotive Force (EMF) is directly influenced by 'N', the number of turns in a coil, hence the number of turns is one of the factor deciding the output emf. There are copper coils in almost all appliances such as televisions and speakers. Any of these coils will potentially work in the windbelt.

Optimizing Angle of Incidence of Wind on the Belt

The belt chosen for analysis is of following dimensions:

Length- 600mm

Width-30mm

Thickness-1mm

In this CFD analysis, air was used as a medium which was made to incident on the belt at different angles and corresponding drag and lift forces were observed **(Table 1)** on the upper and lower surfaces of the belt. The wind speed was taken as 6 m/s. The software image of belt mesh is shown in **Figure 1**.

The aim of the analysis is to obtain an optimized angle at which the drag and lift forces are nearly equal so as to obtain maximum aeroelastic flutter of the belt. This condition is satisfied where the pressure force on both the upper and lower zone

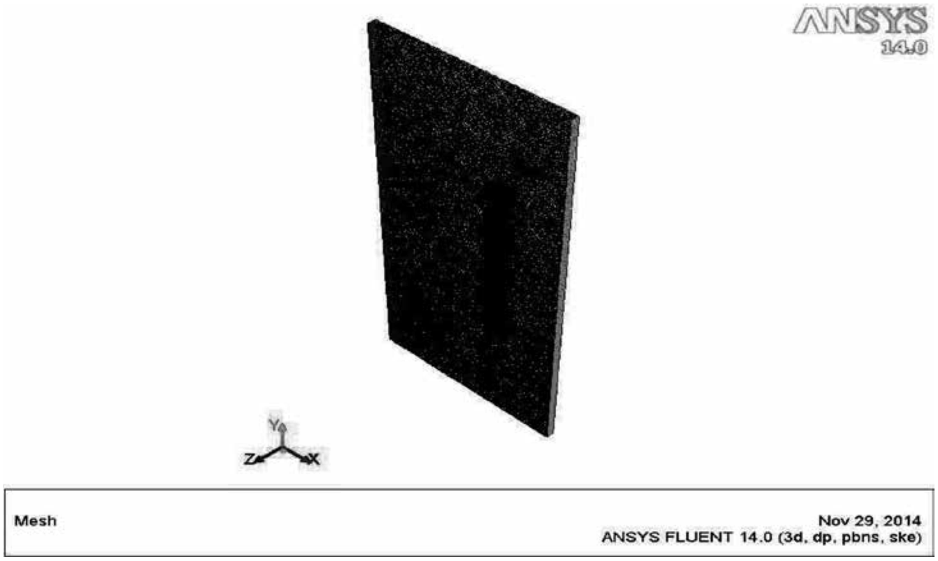


Figure 1 : The software image of belt mesh

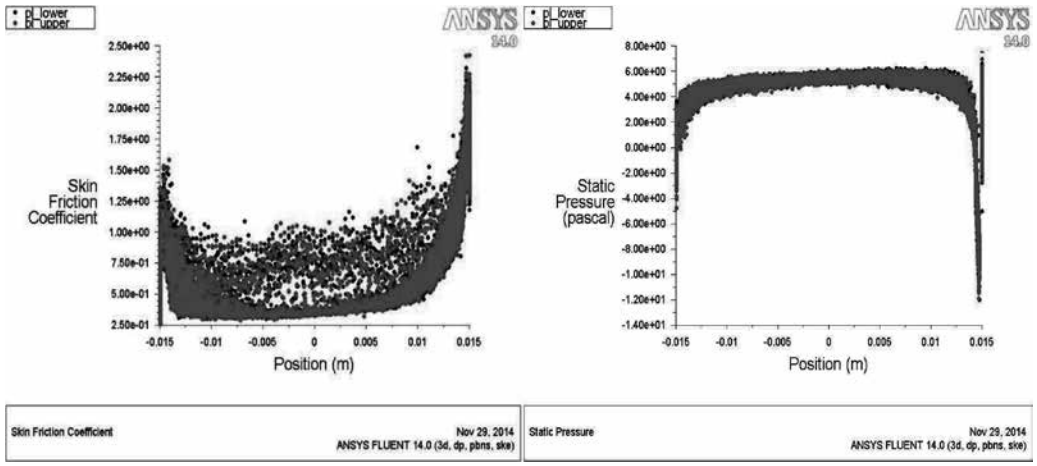
Table 1 : Forces on lower and upper zones at different angles

Angle, Degrees	Zones	Pressure	Viscosity	Total
0	P1_lower	0	-0.0054284733	-0.0054284733
	P1_upper	0	-0.0054102234	-0.0054102234
10	P1_lower	-0.039341715	-0.0058889758	-0.045230691
	P1_upper	-0.044080873	-0.0010172996	-0.045098173
20	P1_lower	-0.098131149	-0.0057998375	-0.10393099
	P1_upper	-0.17388427	0.0017561001	-0.17212817
30	P1_lower	-0.31364420	-0.0024096375	-0.31605384
	P1_upper	-0.29069931	0.00079630912	-0.289903
40	P1_lower	-0.44527532	-0.0037481141	-0.44902344
	P1_upper	0.50162226	0.0011796816	0.50044258
50	P1_lower	-0.70972979	-0.0027836939	-0.71251348
	P1_upper	-0.64470047	0.00082209671	-0.64387837
60	P1_lower	-0.99646966	-0.0016658001	-0.99813546
	P1_upper	-0.75648045	0.00050760404	-0.75597284

of belt are equal (as far as possible). As per the results in the table, the pressure forces are nearly equal at an angle between 30 and 40 degrees. On interpolation, the angle is found to be 33 degrees approximately. Hence the optimized angle is 33 degrees. Also looking at trend of viscous force, it has been found out that it is minimum at an angle of 30 degrees in the table. So the optimum angle is predicted as 33 degrees.

Plot of Skin Friction Coefficient and Static Pressure (in Pascals) versus Position of Belt (in Metres) at Various Angles are shown in **Figures 2(a to d)**.

Most important and essential part of the wind belt arrangement is the ‘belt’. There are many factors associated with a belt that largely influences the amount of power that the wind belt arrangement generates. These factors include length of the belt,



(a) Belt position for different static pressure and skin friction coefficient at 0°

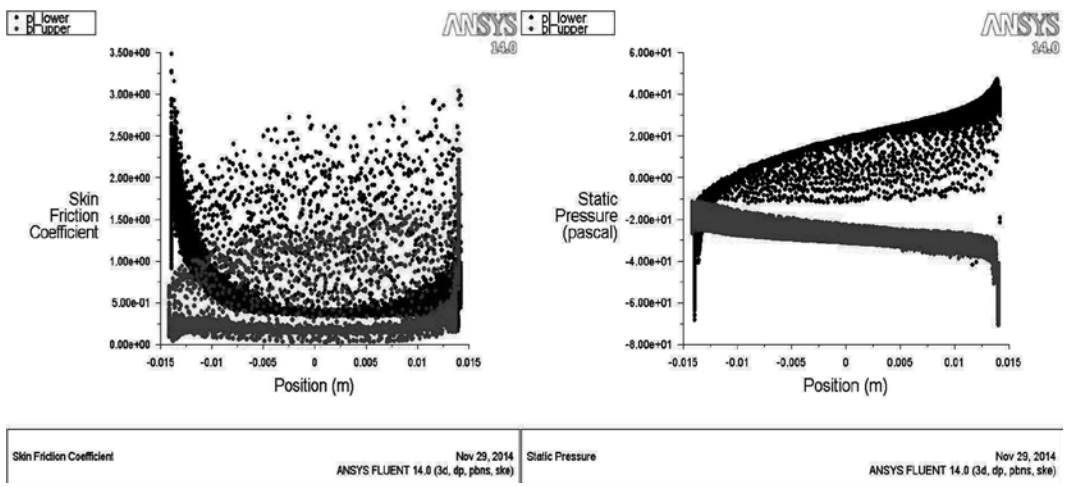


Figure 2(b) : Belt position for different static pressure and skin friction coefficient at 20°

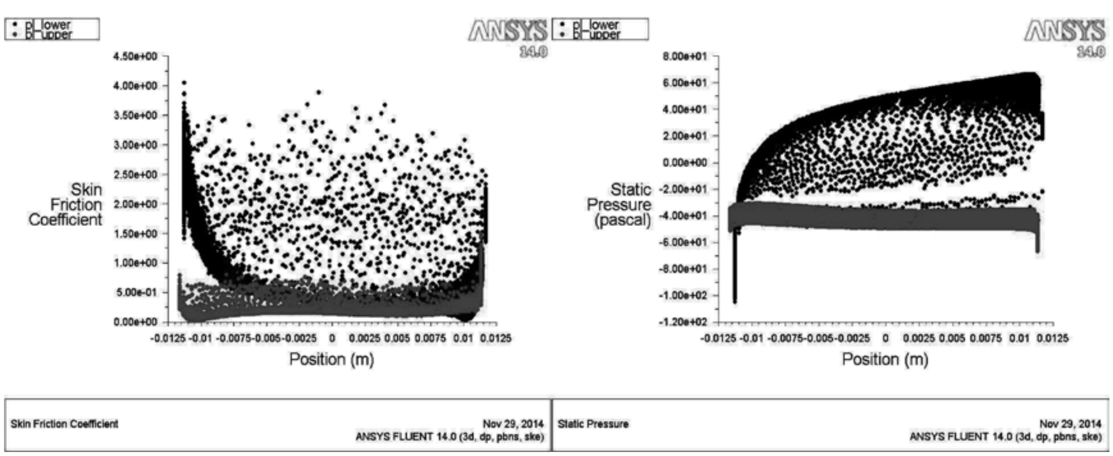
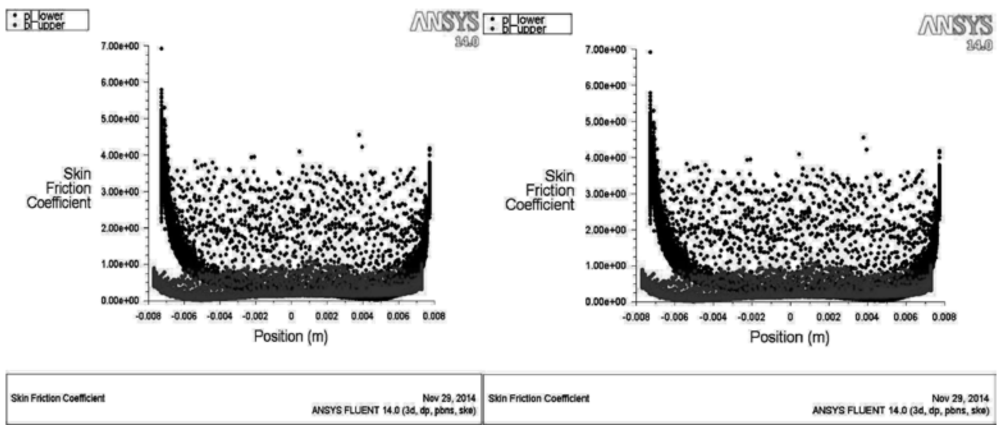


Figure 2(c) : Belt position for different static pressure and skin friction coefficient at 40°



(d) : Belt position for different static pressure and skin friction coefficient at 60°

Figure 2 : Skin friction coefficient vs static pressure

width of the belt, tension in the belt and angle at which wind strikes the belt. We have to somehow optimize these factors and try to bring out maximum amplitude flutter from the belt. Hence this is an important task of optimizing the above stated parameters in order to achieve best possible power generation.

Optimizing the Tension Required on the Belt

Resonance is a state achieved by an object or material when its natural frequency becomes equal to the applied frequency. Under this case the object tends to vibrate with a larger amplitude. This property can be made useful in this wind belt project. Here we have initially determined the initial natural frequency of the wind belt by fixing both of its ends.

The dimensions of wind belt choosen for analysis are: 600 mm length, 30 mm width, 1 mm thickness.

The properties are :

Material choosen is KEVLAR with the properties stated earlier in the paper.

Initially both ends of the belt were fixed and subsequently its natural frequency based on material properties was determined.

The time based frequencies with the natural frequency of 62.037 Hertz and also at different tensile loads are shown in **Table 2**. The corresponding images of the belt is shown in **Figure 3**.

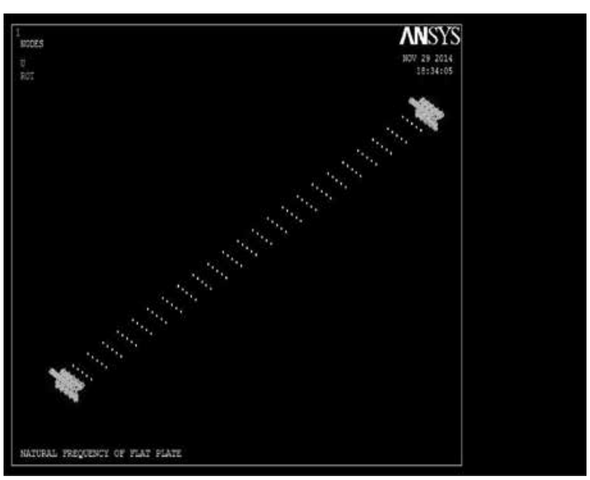


Figure 3(a) : Belt image with natural frequency 62.037 Hertz

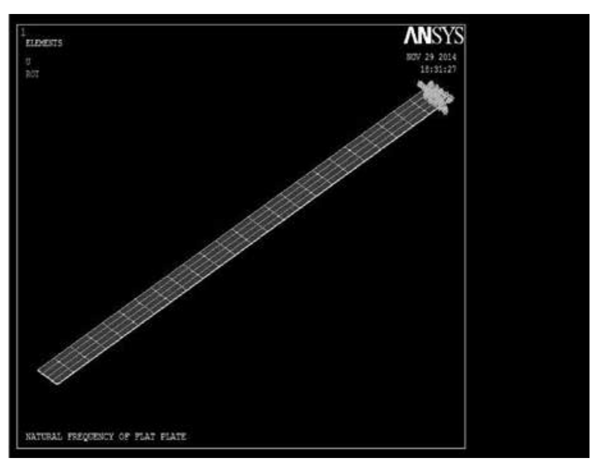


Figure 3(b) : Belt image with wind velocity 6m/sec

Table 2 : Effect of time based frequency at different tensile load (up to 250 N)

Set	Load setp	Time/frequency								
		At natural Frequency 62.037 Hz	At 10 N Tensile load	At 20 N Tensile load	At 30 N Tensile load	At 50 N Tensile load	At 100 N Tensile load	At 150 N Tensile load	At 200 N Tensile load	At 250 N Tensile load
1	1	62.037	17.547	22.114	22.114	31.168	41.413	49.330	56.035	61.959
2	1	170.55	73.227	83.438	83.438	106.98	135.46	145.37	149.36	153.22
3	1	333.49	133.32	134.23	134.23	136.90	141.22	157.91	177.10	194.17
4	1	549.69	181.46	192.21	192.21	220.92	260.56	293.85	323.09	349.50
5	1	714.81	343.62	353.65	353.65	354.20	355.11	356.02	356.92	357.82
6	1	818.31	353.46	354.31	354.31	384.45	429.42	469.42	505.73	539.19
7	1	837.07	559.51	570.06	570.06	600.54	647.92	691.70	732.51	770.86
8	1	1138.0	823.85	824.87	824.87	827.93	833.00	838.03	843.02	847.98
9	1	1427.9	828.17	838.61	838.61	869.15	917.69	963.61	1007.2	1048.9
10	1	1506.9	1059.5	1060.1	1060.1	1061.7	1064.5	1067.2	1070.0	1072.7

Now one end of the belt was fixed and then apply tensile load at the other end and then we obtain the frequencies at different loading (tensions) conditions, shown in **Table 2**.

Since the natural frequency value have been approached very closely the tensile slightly, from 250 N to 251 N.

By increasing the tensile load marginally from 250 N to 251 N, the results have indexed in **Table 3**.

The results obtained in Table 3 shows that at 251 N tension load trends to approach the natural frequency of the belt and this is the optimized level of tension at which the belt taken for experimentation would fit. The experimental setup is shown in **Figure 4**. in the wind belt frame.

Table 3 : Index of data sets on results file

Set	Time/Freq.	Load step
1	62.071	1
2	153.29	1
3	194.49	1
4	350.01	1
5	357.84	1
6	539.83	1
7	771.61	1
8	848.08	1
9	1049.7	1
10	1072.8	1

Wave Energy Potential

The numbers on the map express the wave energy potential at the specific site- the higher the number the greater the potential (kW/m wave front).

The waves are generated by wind blowing across the sea surface. Further, during wave generation energy is transferred from wind to wave. The power of the seas depend upon the length and strength of the wind blowing over the surface. The energy within a wave is proportional to the square of the wave height, so a two-metre high wave has four times the power of a one-metre high wave. Generating power from wave energy is not a widely employed commercial technology although there have been attempts of making use of it since 1890's. It is a genuinely renewable energy source and distinct from tidal energy. Wave energy is generally considered to be the most concentrated and least variable form of renewable energy. It is the high power density of wave energy that suggests it has the capacity to become the lowest cost renewable energy source

The World Energy Council has estimated that approximately 2 terawatts (2 million megawatts), about double current world electricity production, could be produced from the oceans via wave power. It is estimated that 1 million gigawatt hours of wave energy hits Australian shores annually and that 25% of the UK's current power usage could be supplied by harvesting its wave resource. Wave energy has significant global potential with the USA, North & South America, Western Europe, Japan, South Africa, Australia and New Zealand among some of the best wave energy sites around the world. Wave energy is measured as an amount of power (in kW) and it flows in the direction of wave propagation.

Wave Generation and Propagation

Waves are generated by wind passing over the surface of the sea. As long as the waves propagate slower than the wind speed just above the waves, there is an energy transfer from the wind to the waves. Both air pressure differences between the upwind and the lee side of a wave crest, as well as friction on the water surface by the wind, making the water to go into the shear stress causes the growth of the waves. Oscillatory motion is highest at the surface and diminishes exponentially with depth. However, for standing waves (clapotis) near a reflecting coast, wave energy is also present as pressure oscillations at great depth, producing microseisms. These pressure fluctuations at greater depth are too small to be interesting from the point of view of wave power. The waves propagate on the ocean surface, and the wave energy is also transported horizontally with the group velocity. The mean transport rate of the wave energy through a vertical plane of unit width, parallel to a wave crest, is called the wave energy flux (or wave power).

Figure 4 : Experimental setup

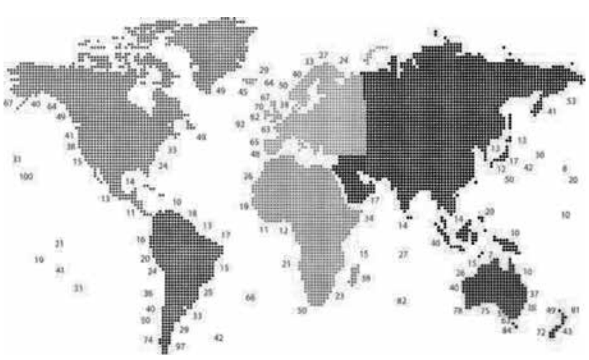


Figure 5 : Representation of wave energy potential in the world map

Methods of Obtaining Energy from Waves

There are several methods of getting energy from waves. One of them works like a swimming pool wave machine in reverse. At a swimming pool, air is blown in and out of a chamber beside the pool, which makes the water outside bob up and down, causing waves. At a wave power station, the waves arriving cause the water in the chamber to rise and fall, which means that air is forced in and out of the hole in the top of the chamber. A turbine was placed in this hole, which is turned by the air rushing in and out. The turbine has transformed to a generator. A problem with this design is that the rushing air can be very noisy, unless a silencer is fitted to the turbine.

Advantages of Wave Energy

Potential: According to estimations there is a lot of potential from the use of wave energy **(Figure 5)**. Based on current estimates and efficiency levels of the wave energy converters we can exploit the waves to get about 2TW of energy power so that we can turn it into useful energy like electricity. This means that exploitation of wave energy is still at its infancy.

Green: Wave energy is green, meaning that it does not emit any hazardous for the environment polluting gases thus contributing to the reduction of CO_2 emissions and towards the goal for a cleaner environment.

Renewable Source: Wave energy is a Renewable Energy Source, RES, with all the benefits such a source would have. It is renewable and as long as we have waves we can capture their energy. Of course waves will exist for as long as we have winds.

Consistent Wave Power: Waves are consistent throughout the day and thus electricity production is predictable and overall it can be planed and properly managed. This makes wave energy more consistent than Wind and Solar Energy.

Low Operational Costs: Once the Wave Energy Converters, WECs, are installed the wave energy plant has low operational costs which makes such an investment attractive.

Minimal aesthetic pollution: Wave energy converters are installed either on the surface of the water or are submerged in the water thus affecting the surrounding as little as possible. Many plants are built offshore thus affecting the aesthetics even less.

No pollution danger: There is no danger of polluting the surrounding area in case of a disaster like there is with fossil fuel plants. Quite frequently accidents at oil rigs pollute the surrounding areas this can never be the case with wave energy plants.

Harnessing Wave Energy using Floating Buoys and Mechanical Arm Arrangement

Each arm is formed by a floating buoy of diameter depending upon the size of the floating platform, investment cost , and amount of power required to be generated. When the waves reach the floating buoy, due to crest and trough formation the buoy experiences an elliptical oscillatory motion. There is a mechanical arm fixed on top of the floating buoy to which the motion is transferred by the buoy. Mechanical arm and buoy are connected by a suitable arrangement. There is a pump connected to close circuit of fresh water. The up and down movement of the mechanical arm activates the hydraulic pump which through a closed circuit injects fresh water kept on high pressure system formed by a hydro pneumatic accumulator and a hyper baric chamber. The system releases a stream with a pressure equivalent to around 300 metres water column (number similar to large hydroelectric plants). This pressurized stream of water is used to spin the turbine which in turn activates the generator and produce electric energy. These projects can be modified and expanded to generate even higher power output. This concept has been used in electricity project on south of brazil. The system can be optimized to have minimum weight so that the movement of the mechanical arm is maximum.

Combining Wind and Wave Energy

The most promising energy solution today is to harness the kinetic power of the ocean wave and the wind. Many projects are underway around the world and they claim to generate enough energy for billions of homes without burning fossil fuel. These forces of nature are free, steady and predictable.

On combining the energy of both wind and wave and at locations of its maximum effectiveness the energy produced would be sufficient in comparison to its cost. As its only one time installation cost that is required and then the energy is for free. The objective is to combine the wave and wind power by preparing a common platform to support both the structure that is the wind belt and the floating buoy. The best available option is to design an offshore platform that can be placed at some distance from the shore or near breakwater. The offshore platform can be similar to the drilling platforms.

The sides of the platform will contain a number of floating buoys **(Figure 6)** (diameter depending on the amount of energy) with mechanical arms attached to it. A pump is connected to a closed circuit of fresh water on the platform which gets activated by alternate movement of the mechanical arm. The energy is produced by the rotating turbine due the injection of pressurized stream of water similar to hydroelectric plant. The turbine activates the generator and produces electricity.

For harnessing wind energy, certain number of decks can be made on the platform for installing a large number of windbelts. Windbelts will be arranged between successive decks **(Figure 7)**. All the windbelts can be connected to a single supply unit. During installation, the probable direction of wind in the region though out the year must be kept in mind as the optimum angle of windbelt is important for maximum power production. Also there can be an arrangement for changing the position (angle) of frame and hence the belt as per the direction of the wind.

Results and Discussion

There are many variables that may or may not be controlled in such a design. Some of them are discussed below:

- The length of belt is kept constant to 600 mm. Although the length can vary up to 1000mm
- The width should be such that it should be able to withstand torsion. The width of the camera film is best suited and it is 35mm.
- The material used for making the belt is camera film which is similar material to mylar-coated taffeta. It has low creep, is relatively strong, is not elastic, and does not deform plastically.
- Minute alteration of tension with the help of spool will have large effects on the motion of the ribbon. Also the tension should be such that the belt is able to achieve its resonating frequency.
- The windbelt works best at a wind speed of 6m/s or higher.
- The coils must be iron core and not air core. Also the magnets should be placed such that it does not stick to the coil (stator).
- The 500mm windbelts will vibrate at around 70-100 Hz. The 1000mm windbelt vibrates at a lower frequency: 20-50 Hz range ideally. As shown previously, the belt of 600mm will vibrate at 62.037 Hz. Frequency varies, depending on belt thickness, belt tension, wind speed, etc.

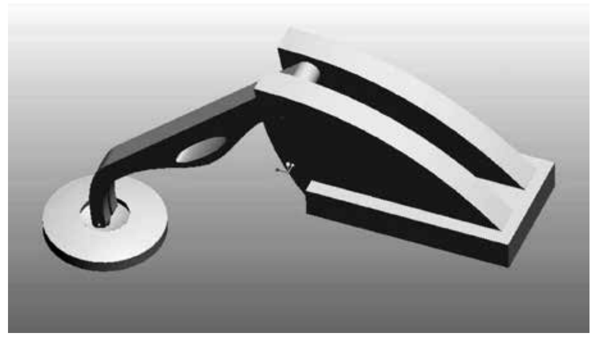


Figure 6 : Floating buoy and mechanical arm arrangement in pro-engineer software

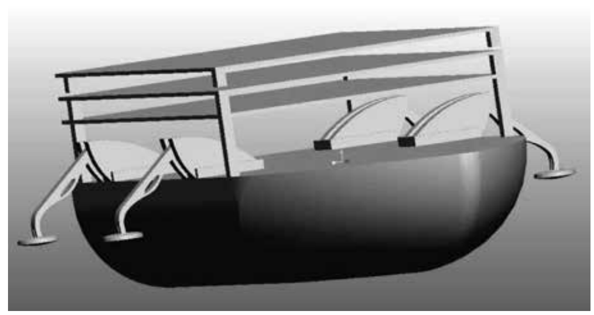


Figure 7 : Floating platform structure with buoys and wind belt arrangement made on pro engineer software

- At 6m/s wind speed, around 50mW delivered to a load. Voltage, unloaded, will be around 1.8 to 2.5 Volts AC before rectification.

Acknowledgement

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Impact of Emerging Technologies and Curriculum Development :-

Enriching the Marine Curriculum in the Under Graduate Program

Puja Awachat, Capt. Indranath Banerji

Tolani Maritime Institute, Pune

✉ *pujja@tmi.tolani.edu*

✉ *indranathb@tmi.tolani.edu*

Abstract

Before delivering the curriculum, the trainer needs to write down the objectives. There are three domains of learning objectives – Cognitive, Psychomotor and Affective. In the Marine Curriculum of the Undergraduate program, large emphasis is laid on Cognitive, a lesser amount on Psychomotor; but in the Affective domain, generally there are no objectives. On board ships, most accidents are attributed to human error. The single largest contributing factor towards human error is 'Improper Communication'. The aim of this paper is twofold. One, to highlight, with the help of case studies, factors that contribute to marine accidents due to 'human error'. A close analysis of the case studies reveals that accidents occur despite the presence of seafarers with great degree of experience. The factors contributing to these accidents usually are Complacency, Ego, the feeling that 'It cannot happen to me' etc. In other words, the mariner is either not Receiving or Responding or Valuing. These words are the first three levels of objectives of the Bloom's affective domain taxonomy. IMO has recognized this and in the year 2010, Manila Amendments to the STCW code, new competence requirements related to leadership, teamwork and managerial skills have been introduced in the management and operational levels. The same needs to be done for the Under Graduate program also. The purpose behind doing so is to prepare the trainees for acquiring at this level itself the right attitude, emotion and feeling – the target areas of the affective domain – so as to carry out duty at sea without any error. In view of this, the second aim of the paper is to make suggestions towards ways to incorporate in the Undergraduate Program the 2010 amendments to the STCW code with regards to teamwork and trainer training. Also, the paper deals with the challenges that an Under Graduate institute may face while striving to subsume in its program these amendments.

Keywords : *Affective domain, STCW Code, Teamwork, Trainer Training*

Introduction

In recent era, the teaching-learning process has been challenging for both the teacher and the taught. The teacher / instructor must put in effort to make his / her teaching engrossing. The learner, in turn, must focus despite all odds to correctly comprehend and analyze the instruction.

Today, however, with the explosion of knowledge, the task of the teacher has become doubly challenging. Technology seems to be the way out. The teaching-learning process must be so designed that the learner is engaged, without any dwindling attention. It is time the teacher moves beyond the use of paper and computer screens. The learner must be provided with opportunities for activities that will help him / her to learn the new ideas and further assimilate them with ease. The curriculum should be developed to incorporate in it the technology-based tasks so as to enhance the methodology for the transfer of knowledge.

Before delivering the curriculum, the trainer must identify and clearly write the learning objectives in his / her lesson plan. By definition, an objective is – "A statement in specific and measurable terms that describes what the learner will know or be able to do as a result of engaging in a learning activity". The purpose of objectives is twofold –

1. By knowing where you intend to go, you increase the chances of you and the learner ending up there
2. Guides the teacher relative to the planning of instruction, delivery of instruction and evaluation of student achievement.

Bloom's Taxonomy

In the early and mid-90's, just remembering facts (rote learning) was the prime focus of education – the single point objective that most educators aimed to achieve. However, in the year 1956, educational psychologist, Dr Benjamin Bloom, along with his team, created the Bloom's Taxonomy in order to give a boost to higher forms of thinking – Analyzing and Evaluating – when one is involved in the process of learning. The taxonomy is most often used while designing educational curricula.

Three domains of educational activities were identified by Bloom and his team. They were–

1. Cognitive (intellectual abilities).
2. Psycho-motor (muscular action, dexterity).
3. Affective (attitudes, values, interest).

The diagrammatic representation of Bloom's Taxonomy **(Figure 1)** shows the ascending levels of thinking involved in a learning process for each of the three domains. These domains today form the basis of formulating the learning objectives which, in turn, help the teacher to design and assess students' learning. Skills in the cognitive domain revolve around knowledge, comprehension, and critical thinking on a particular topic. Skills in the psychomotor domain describe the ability to physically manipulate a tool or instrument, thereby bringing about change / development in behavior and/or skills. Skills in the affective domain typically target the awareness and growth in attitudes, emotion, and feelings [2]. Bloom believed that all three domains be equally incorporated in the teaching-learning process to have a more holistic approach to education.

In the Marine Curriculum of the Undergraduate Program, however, large emphasis is laid on Cognitive and Psychomotor, but we do not see any objectives in the Affective domain. Curriculum developers and educators must bear in mind that not only is the intellectual and physical ability of learners necessary to be developed, but the learners

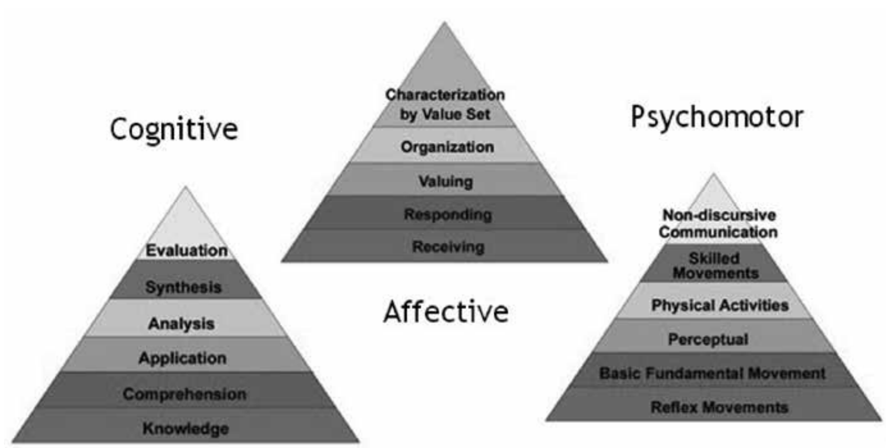

Figure 1 : The three domains of Bloom's Taxonomy of educational objectives [1]

must also acquire the right attitudes, values and interests towards their job. For this, the Affective domain must equally be taken into consideration while writing the learning objectives. Time and again it has been proven at sea that the crew's attitude and interest towards their job is not in place; thus indicating that the affective domain is not accounted for in the educational curriculum.

On board ships, most accidents are attributed to Human Error. The single largest contributing factor towards human error is 'Improper Communication'.

Certain aspects of Human failings have constantly cropped up after every accident investigations:

- Way back in 1966, the Torrey Canyon ran aground off the Isles of Scilly in clear visibility leading to huge oil pollution.
- In 1984, the MV Balduin ran aground in the Oslo fjord. The Pilot and the Duty Officer did not even once communicate for almost two hours.
- On the Arahura in 2004, senior engineers along with experienced shore workshop while repairing a faulty sensor, inadvertently disconnected the wrong wires which caused a loss of propulsion, that too when the vessel was in a narrow channel while departing port.
- In the year 2008, the Maersk Kithira encountered heavy weather off Hong Kong and while investigating water ingress in the forward store, the Chief Engineer lost his life.
- In the same year 2008, the Ro-Ro vessel Moondance when shifting berths within Warren point Harbour in North Ireland, suffered a blackout and subsequently ran aground. [3]
- Braer, Al Shamal, Sea Empress, Norwegian Dream , Tor Scandinavia, Crown Princess, Royal Majesty…..the list can go on and on.

In all the above cases, accidents have occurred despite the presence of seafarers with great degree of experience. The factors contributing to these accidents usually are Complacency and Ego, the feeling that 'It cannot happen to me' etc. In other words, the mariner is either not Receiving or Responding or Valuing. These words are the first three levels of objectives of Bloom's affective domain taxonomy.

IMO has recognized this and in the year 2010 Manila Amendments to the STCW code, new competence requirements related to leadership, teamwork and managerial skills have been added in the management and operational levels. But it has been felt that this is not enough. A diluted version of the BRM and ERM courses have to be inculcated in the Undergraduate Program also so as to allow assimilating this knowledge at this level only to be rightly exhibited at sea later.

Let the three cases be focused in particular to understand further the vital role of the affective domain in seafaring.

When the QE 2 departed Alesund, Norway on 6th June, 2005, she increased speed without casting off the aft tug. The tug was almost girded with its bridge awash. Luckily the line got loose from the tugs end and the tug became upright [4]. The focus is on the officer at the aft stations. Agreed that under those circumstances he could not cast off the tug, but -

- Did he not see what was happening as he was busy with something else?
- Did he see the tug but did not expect any problem and so did not report?
- Did he think that the tug would take care of itself ?

On 18 September, 2013, the Malta registered chemical tanker, Ovit, ran aground on the Varne Bank in the Dover Strait while on passage from Rotterdam, Netherlands, to Brindisi, Italy. This case has been deeply analyzed on poor passage planning and on the use of the ECDIS. The deck cadet had been on board for 6 months. Before the grounding, on a night of clear visibility he was on lookout duties on the starboard bridge wing. He was aware of flashing white lights of the East Cardinal buoy but he did not report the sighting to the OOW. [5]

Did he

- Not recognize the lights as an East Cardinal buoy
- Not realize that the vessel had to pass East of the buoy
- Or simply did not bother to report as he was left standing out on the bridge wing

In case of the Cosco Busan coming in contact with the Oakland Bridge, lot of literature is available and Company, Master and the Pilot have been penalized. [6] The focus is on the error check function – The second officer. As the navigating officer he was the most familiar with the ECDIS. When the Pilot wanted the Master to indicate the center of the channel, two possibilities occur-

- The Master knew and indicated to the correct symbol but the pilot mistook it for some other point on the chart. The Second officer should have realized that the same when observing the courses being steered. Was he afraid of the response from the Pilot?
- The Master did not know and indicated wrongly. The Second officer could have corrected the same. Was he afraid of the response of the Master?

In the above three cases – Did the junior officers not regard themselves as an important resource in the ECR or the Bridge? The question highlights the fact that the officer has been unable to display any of the affective domain elements, probably for sheer lack of them in him. Hence the need to provide the same in the Under Graduate program.

It is also required to be focused on why a junior engineer or an officer refuses to alert his seniors when they suspect that something is going wrong.

- Is it because he believes that they must be wrong since the seniors are more experienced?
- Is it because the seniors did not take it kindly when he pointed out a mistake the last time?
- Is it because he felt that usually nothing goes wrong?
- Is it because everything went well last time around? [7]

They need to be taught to ask a question right. When it comes to safe vessel operation, if someone don't ask a right question, he won't get the right answer.

The way forward is 'Role Play'. It can be done in class but it required a very good trainer to generate the correct environment considering that the students have not yet seen a ship. It can be done in the laboratory and workshops but there too restrictions exist.

The easiest way out would be to use existing and emerging simulators where the trainees are able to play specific role. Initially the team members could be from the same batch enacting any scenario. For example, the Engineering students preparing the Engines for arrival in Port, while the nautical students doing a similar exercise on the Bridge. After they come back from their internship, a common scenario could be written to expand the exercise as a Bridge – Engine Room Interaction as they prepare the vessel. Similarly, an interaction between the Cargo Control Room and the Engine Control Room could be played out. Objectives from the affective domain should be added to those of the psychomotor domain. After all, it is the affective domain that forms a bridge between the cognitive and psychomotor domains.

Also, the trainers need to be trained with regards to Effective Interpersonal and Communication Skills such as body language and behavioral Actions. Apart from checking the theoretical knowledge and technical expertise in handling the equipment, learning objectives must be written in the affective domain.

The trainee should be assessed on following parameters also -

- Effective communicator
- Team player
- Organizer – use of team
- Responsive to feedback

- Encourage team to feedback
- Prioritize information\
- Effective risk assessor

These are areas not covered in TOTA but are a must if the trainer were to impart training in the affective domain.

The challenges that will be faced in future are –

1. Since there already have a Full Mission Ship Simulator incorporating Bridge and Engine Room Simulations along with Steering Simulators, GMDSS Simulators, Liquid Cargo handling Simulators and Electronic Charts and Information System Simulators, the training in the affective domain could easily be started. Use of New and Emerging Simulators such as Fire Simulators, Crane Simulators would be welcome. Additional simulator units would be beneficial. The financial constraints in obtaining the simulators could be overcome by Academia – Industry Interface. After all, the final product from the academy is the Raw Material for the industry.

2. Obtaining the number of hours without diluting the cognitive domain, else the mariner just becomes an operator and thus defeats the very purpose. This can be achieved by reworking the hours given to the psychomotor domain and adding the affective domain. Also, where possible, topics now redundant could be eliminated. Today 60 -70 hours' training are being imparted to every student on the simulators. Some of the exercises could be re-written with an affective component incorporated in them. An additional 10-12 hours would be required by re-working the curriculum.

3. Training of the trainers for writing objectives in the affective domain is indeed hard. By writing the objectives correctly, the chances of the student to perform better on board ships may increased.

Finally, the under graduate marine institutions must understand that Simulators are the emerging technology in training. These allow the students to become active participants, rather than merely sitting back and listening or observing, passively probably. Their participation in real life situations before actually braving them and asking the questions when in doubt, would inculcate in them the right attitude and feeling towards their job; thereby making them adept to perform to the best of their ability. An amalgamation of simulator-based training and the elements of the Affective domain at the under graduate level would definitely make a better mariner.

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Life on Board of a Marine Engineer – then and now

Ritinkar Sen
60/2 Lake Road, Kolkata 700 029
✉ *ritinkarsen@hotmail.com*

Introduction

Marine Engineers who began their career at sea in the 40's and 50's may recall reading a book entitled "Verbal Notes and Sketches" written by John William Major Sothern (1868-1940). It was - like Gray's Anatomy to medical students – a bible for any marine engineer aspiring for his "ticket'.

The book contained a section on how to take over a watch. It began with the sentence "An engineer's life at sea is not exactly a bed of roses". It went on to describe the various checks that should be made before taking over the watch. Besides reading the thermometers and pressure gauges, feeling of temperature by touch was an important part of assessment of the running condition of the triple (sometimes quadruple) expansion reciprocating steam engine. Thus the engineer was expected to synchronize touching the ahead guide surface with the palm of his hand just as the crosshead began its downward journey while standing on gratings between the adjacent cylinders at the intermediate level. He had to be careful not to foul up his boiler suit with the eccentric linkages. This was relatively a simple task. Feeling the crosshead bearing was also too difficult. One had to put his hand on the bearing body before the crosshead reached the top end and keep feeling the temperature until it descended far enough to make it impossible to hold on any longer.

The most difficult was to feel the bottom end bearings. One way to do this standing on the bottom floor plate level, was bring the edge of the palm down to descend upon the upper edge of the top half of bearing just as it crossed the top dead centre and keep the hand in contact for a fraction of a second to get an idea of the temperature. Another way was to lower the hand in the crank pit and slowly bring it toward the bottom end bearing as it kept rotating so that in one position, the bearing will just rub past the hand giving its owner a feel of its temperature.

It took some time to get used to this method of checking the temperature and a few cuts and bruises were regarded as a part of the learning process. Having mastered it, the proud engineer would then be ready to demonstrate his newly acquired skill to the next junior engineer joining ship much to the awe and admiration of the latter.

For the benefit of those young readers who may have difficulty in understanding the above, let me clarify that in those days ship's main reciprocating steam engines (and also some of the early diesel engines) did not have the moving parts such as crossheads, connecting rods and the crankshaft enclosed in a casing. Lubrication was by means of oil in small containers fixed at cylinder cover level in which wicks were placed and the oil ran down to feed the bearings through small bore pipes by gravity. The piston rods had to be swabbed manually with oil. Crosshead bearings were lubricated periodically by hand held oil can, moving it up and down to synchronize with the crosshead movement, pouring oil into oil into the oil cup all the time. Guides were lubricated at intervals by means of a hand operated syringe squirting oil on the guide surface.

Another area of responsibility of the watch keeping engineer was the boilers - usually, 3 Scotch boilers or, in later days water tube boilers. Early ones were coal fired. There used to be a tindal for watch in charge of the firemen (the names still continue today) whose responsibilities were to feed coal by shovels into the furnaces, rake, remove and dispose off the ashes. Fortunately, ,the engineer did not have to partake in such operations, but his skill and endurance would be put to extreme test in case of a leaky smoke tube or stay to be repaired at the back end of the furnace at sea without even cooling the boiler down.

Operation of the boiler feed pumps and maintaining correct water level in the boilers were the responsibility of the watch keeping engineer. Proper blowing and reading of gauge glass water level was one of the most favourite subjects for the examiner of engineers during oral examination and there have been many casualties amongst candidates failing to give the expected answers.

Coal used to be stored in tween decks abreast the engine room and had to be shovelled down the chute from time to time into the stokehold where it entered through vertically sliding doors on the bulkhead. This was the job of the coal trimmer who also who also had to break the large pieces of coal by hammer to make them easy to handle and feed into the furnaces. Coal bunker was at best dimly lit and was believed to be haunted by ghosts. The sight of the shadowy figure of the lone coal trimmer moving in the middle of the night among piles of coal sent shivers down many a brave engineer's spine. Bunker consumption was calculated by checking the number of ship side frame spaces exposed by the coal taken out, but in those days, nobody seemed to be particularly concerned about the coal consumption. Specific fuel consumption was never talked about.

There used to be animated discussions in the engineer's mess room about lap and lead of valves controlling steam and exhaust from cylinders (why, for example, the steering engine valve did not have any lap or lead?), how to draw a valve diagram, Stephenson's link motion, Andrew & Cameron's poppet valves, working of steam shuttle valve of the Weir's feed pump (which I must confess, I never understood even today) and what should be the diameter of lead wire used for measuring bottom end bearing clearances. Regarded as highly technical work those days was adjustment of piston rod metallic packing which only the Chief Engineer was entitled to dismantle and overhaul.

Electricity was supplied usually by 2 Nos. steam engine driven 110V DC generators (known as "dynamo" those days) of about 20 kW each. Parallel operation was unheard of. After starting the No. 2 dynamo, all the feeder switches had to be changed over from No. 1 to No. 2 dynamo one by one causing black outs for a second or two. The only electrical loads were general and navigation lighting, cabins fans, radio equipment and accommodation blowers. It was possible to run the ship without electricity. In emergency oil lights were used for navigation.

Other engine room auxiliary included main engine driven air pump, main circulating pump, bilge and ballast pump, fire and G. S. pump, forced draught fan for boiler - all steam driven.

Even the early motor ships had all steam auxiliaries and the ship could make sea passage without electricity.

The standard of accommodation was primitive. Not even the Chief Engineer had a separate bed room or attached toilet. Messing used to be separate for deck and engineer officers, often leading to suspicion amongst the latter that the deck officers were being treated with better culinary fare by the Butler.

Looking through the rear view mirror, those days now appear to me us full of adventure and romance. If I close my eyes and let my imagination take over, I can still smell the steam mixed with cylinder oil and water sprinkled over hot ash, hear the groaning of the boiler feed pump, and feel the hot air on face as soon as one entered the engine room.

Like all other branches of engineering, marine engineering has seen considerable progress in the last 6 or 7 decades Scotch boilers and steam reciprocating engines are now a part of history. Even steam turbines are rare these days. Ships are now propelled by highly rated internal combustion engines which demand much closer attention and understanding of their operation. The marine engineer today is required to possess a much higher degree of intelligence, knowledge and skill in the operation of machinery. He has to have a good understanding of thermodynamics; combustion of fuel, hydraulics, pneumatic controls, and electronics besides also being a maintenance engineer. Brawn has been replaced by brain in many areas. Large nuts are no longer tightened by swinging sledge hammers. The required tensile-force is achieved by torque spanners and hydraulic tensioning device. Lead wire is outdated. Clearances are measured by feeler gauges, micrometers and sometimes by electronic means. The machinery on board today are far more complex and numerous compared to what was there in the steam engine days. And of course, more machinery means more work. Routine maintenance takes up much more time in port than before. The amenities on board and wages have vastly improved, but life of the engineer still remains “not exactly a bed of roses”.

In earlier days, nobody seemed unduly perturbed about the length of port stays. On a cargo liner trading between and India and Europe, one could expect a port stay anywhere from 3 to 10 days in such places as Antwerp, Rotterdam, Hamburg, London and Liverpool. Ships used to dock not far away from the city centre – giving plenty of opportunity to the ship’s staff to spend time ashore.

Today, although sizes of ships have increased manyfolds, the port stays have reduced dramatically due to containerisation and efficient bulk handling facilities at the terminals. It is not unusual to discharge a 70,000 dwt Panamax Bulk Carrier in under 36 hours. Loading sometimes takes even less time. For a container ship, port stay can be only a few hours. For most of the part during port stay the engineer would be busy carrying out routine maintenance, repairs, surveys, taking bunkers, stores and spare parts and attending to the port state control inspectors.

The newly created ultra-modern facilities are now located far away from the city often making it impossible for the ship’s staff to go ashore even when they do manage to get some time for this after attending work on board. I have often been told by some masters and chief engineers that in cases they never got a chance to step ashore even once during their tenure on board.

One often hears laments about falling standards and lack of dedication of the present day engineers and remarks about the easier life about they lead on board now a days. My own view is that the engineers on board today are a much more knowledgeable and technically superior breed than their predecessors of yesteryears. And they certainly do not lead an easier life on board than what their ancients did.

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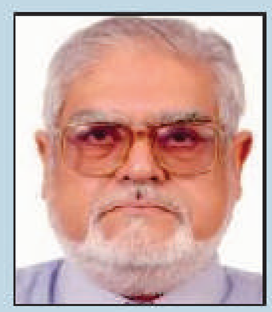

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Member

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The Institution of Engineers (India)
8 Gokhale Road, Kolkata 700 020
Phone : +91 (033) 2223-8311/14/15/16, 2223-8333/34
Fax : +91 (033) 2223-8345
Website : http://www.ieindia.org
e-mail: technical@ieindia.org
iei.technical@gmail.com