SOLAR POWERED PROPULSION

SUBMITTED TO INDIAN MARITIME UNIVERSITY CHENNAI

IN THE PARTIAL FULFILLMENT FOR THE AWARD OF THE DEGREE

OF

BACHELOR OF TECHNOLOGY IN

MARINE ENGINEERING

BY

Sr. No.	NAME OF THE CADETS	ENROLLMENT NUMBER
1	CDT. ABDUL QUADIR AURANGABADI	1749608001
2	CDT. ABHISHEK PANDEY	1749608002
3	CDT.ABHISHEK RAI	1749608003
4	CDT. ADITYA SACHINDRA SINGH	1749608004
5	CDT. AKSHAT RASTOGI	1749608005
6	CDT. ANISH KUMAR	1749608006

UNDER THE GUIDANCE OF

MR. AZARUDDIN MOMIN

DEPARTMENT OF MARINE ENGINEERING

SAMUNDRA INSTITUTE OF MARITIME STUDIES,

VILLAGE TAKWE KHURD, LONAVALA, DIST. PUNE

CERTIFICATE

THIS IS TO CERTIFY THAT THE PROJECT REPORT ENTITLED

SOLAR POWERED PROPULSION

SUBMITTED BY

CDT. _____

IS A BONAFIDE WORK CARRIED OUT UNDER THE SUPERVISION OF MR. AZARUDDIN MOMIN AND IT IS APPROVED FOR THE PARTIAL FULFILLMENT OF THE REQUIREMENT OF INDIAN MARITIME UNIVERSITY, CHENNAI FOR THE AWARD OF THE DEGREE OF BACHELOR OF TECHNOLOGY (MARINE ENGINEERING)

MR. Azaruddin Momin
(Project guide)

Mr. Jims Andrews
(Vice principal)

Mr.Abhiram Wakankar
(Course in charge)

Mr. Biju Baben
(Dean)

External Examiner

DATE:

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In the present world of competition there is a race of existence in which those are having will to come forward succeed. Project is like a bridge between theoretical and practical working.

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ABSTRACT

As the Maritime sector is increasing and growing rapidly, fuels are also consumed at the similar rate. This is leading to continuous carbon emissions which are increasing year by year. Shipping emissions are expected to continue to grow, increasing the importance of addressing barriers to decarbonisation.

Also fuel demand is increasing and consumption of fuel per day in marine industry is growing. This further leads to more greenhouse gas emissions. Researchers in all disciplines have a particular responsibility of development which is environmentally friendly and lead towards sustainable future development.

So, the maritime sector is trying to reduce these emissions and also looking for alternate fuels. The International

Maritime Organization (IMO) has set the ambition of reducing the shipping industry's greenhouse gas emissions.

In 2018, the IMO announced the initial strategy to reduce greenhouse gas (GHG) emissions. The strategy outlines an ambition to at least halve international shipping GHG emissions by 2050, while reducing CO_2 emissions intensity by at least 40% by 2030, and pursuing efforts towards 70% by 2050, relative to a 2008 baseline.

While this is not binding, the IMO is expected to follow up with more specific measures by 2023. The industry currently accounts for around 2.7% of global CO_2 emissions.

To tackle this condition, researchers and various big companies are working on alternate method of propulsion. One of such method is Solar Powered Propulsion. Solar energy is a renewable energy source which has massive energy existing as heat and light and can convert it into electricity. Besides the domestic uses, solar power can be

utilized as the alternative fuel and capable of minimizing the air pollution and fuel cost as well.

The main intent of our project is to clarify the idea about Solar Powered Propulsion and its design considerations. Use of solar panels can help reduce the emissions.

Though solar power is too much expensive for main propulsion of big merchant vessels, it can be used in many small offshore vessels and can also be used as reserve fuels for fishing vessels.

The project deals with the amount of research and applications already available in this area today and which areas could be developed and improved in future research.

In our project we are using solar energy as our reserve fuel for propulsion in case of emergency. We've used batteries that are charged by solar panels that will further run the motor and cause propulsion.

Besides, for any cloudy or emergency condition, a backup power system integrated with the photovoltaic cell will

drive the boat to make the system more secured. Both mechanical and electrical part of the boat has been designed which is found more reliable, efficient and economic.

By this we are trying to take a step towards a world with fewer emissions and promote ideas to keep our environment safe and also to protect it.

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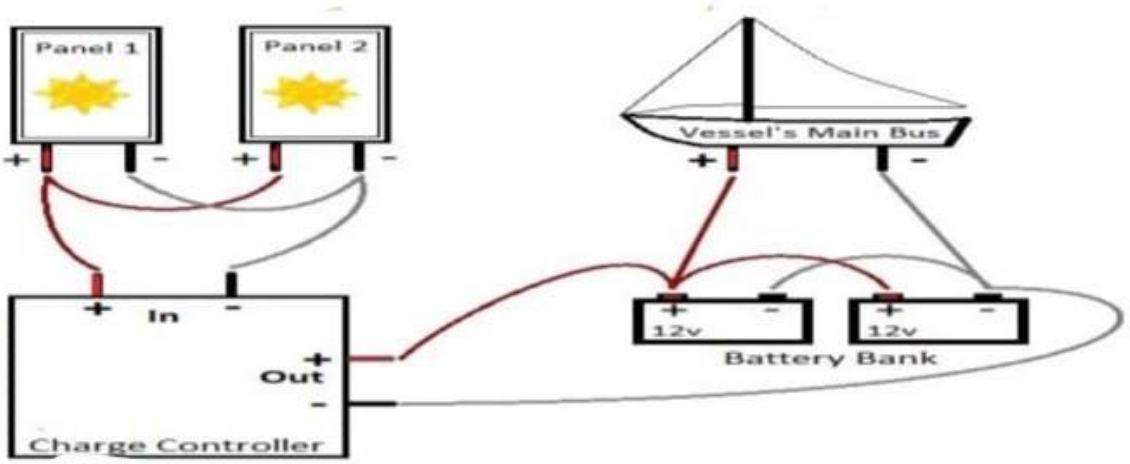
1.INTRODUCTION

We are living in a world where we are exhausting our conventional fuel resources at an exponential rate. Hence the need arose for finding new alternative resources for the industries we have worked so hard to make them bloom.

Using solar energy to generate electricity is not a new concept, research on it began as early as 1839 when Alexander Becquerel observed a photoelectric effect when a electrode in a solution of conductive liquid became charged when in sunlight. Here we are going to make a model which

will enhance the possibility of running a boat using hybrid propulsion system.

Over the past years, new flexible and light in weight solar panels have been invented which have increased the possibility of making a solar power boat. Clearing the general misconception that solar panels generate electric current only when in sunlight contact, they also generate in overcast condition but the amount generated will be less.



Our model uses solar panels that transform thermal energy to electrical, to be stored temporarily in battery pack to drive the motor.



The idea of this project is to contribute to the environmental issues but also use and expand our knowledge.

2. MAJOR COMPONENT

DC motor



- Model No: MY6812
- Operating Voltage: 24V DC
- No Load rated current: 5A
- Shaft: Full Round Type Ø8mm
- Rated power: 120w
- Weight: 1.1 Kg

Solar Panels



- Dimension: 54x 34cm
- Weight: 1.5 Kg
- Output of one cell: 12V/30w

Li-ion Battery



- Dimensions: 17 x 14 x 7 cm
- Weight: 2.2 Kg
- Output: 24V/20Ah

Charger Controller



Dimensions: 15 x 7.7 x 3.7 cm.

Weight: 159 Grams

Max Solar Panel Input:

120W(12V),

Max 240W(24V)

Lighting Control Voltage: 8V (Solar Panel)

Current Rating:10mA

Crocodile clips and wire set



3.DESIGN

2.1 Background Research

2.1.1 Choosing the motor

A DC motor is an electrical machine which converts electrical energy into mechanical energy. The basic working principle of the DC motor is that whenever a current carrying conductor places in the magnetic field, it experiences a mechanical force. Fleming's left-hand rule and its magnitude decide the direction of this force.

A common electric Dc motor requires 9-24v and 3-20Amp supply which helps in the propulsion of a model boat. We chose a DC motor which is a high torque motor

considering the losses, resistance and drag. Eventually, as we want our model to be light in weight, hence we will use a 24v battery input to supply to the 2 motors and charge the battery using suitable solar panels and charger controller.

2.1.2 Choosing the solar panels

Typically, a solar panel consists of 6 layers:

1. The cover glass which protects the rest of the components from damage

2. Anti-reflect coat, this helps the panel absorb as much light as possible

3. Contact grid, this is what holds the modules together

4. Negative and

5. Positive silicon is what transforms the light energy into electrical energy and then finally

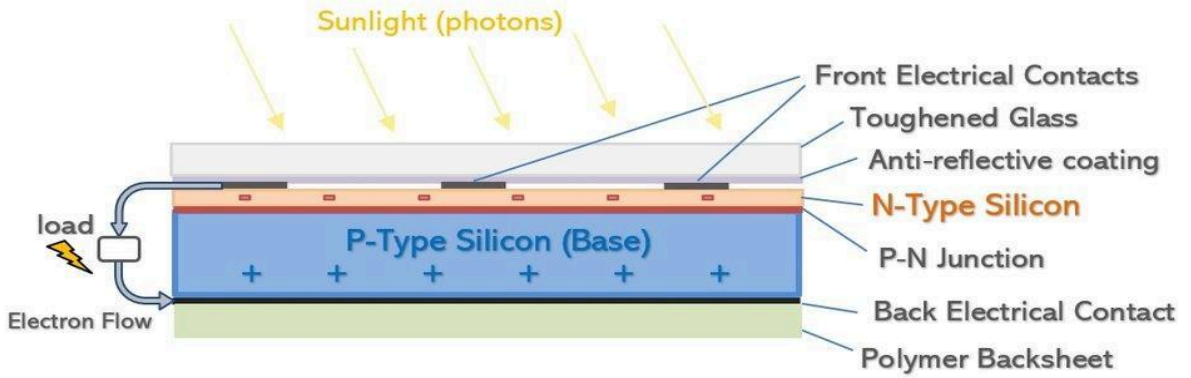
6. The back contact, which is simply the back support of the entire cell.

A solar cell has an efficiency of about 20%. Photovoltaic cells are a group of cells electrically connected and packed in one frame.

These are made up of 'Si' semiconductor. 'Si' absorbs some of the energy. The P-type Si has lots of holes and attract negative electrons towards it and similarly N-type Si has too many electrons to fill up the holes. When the sun shines and emits energy, electrons will be knocked out of their place. Consequently, electrons flow from N-type Si to P-type Si. This makes current and if metal contacts are drawn from the top and bottom of the module electricity can be withdrawn and be used for our own purpose.

To charge our 24v Li-ion battery, we had to consider a solar panel which will supply enough voltage/current but also is light in weight for our model. If we would’ve used solar power directly to supply to the motor, the weight and

cost will go exponentially high, hence a battery power is

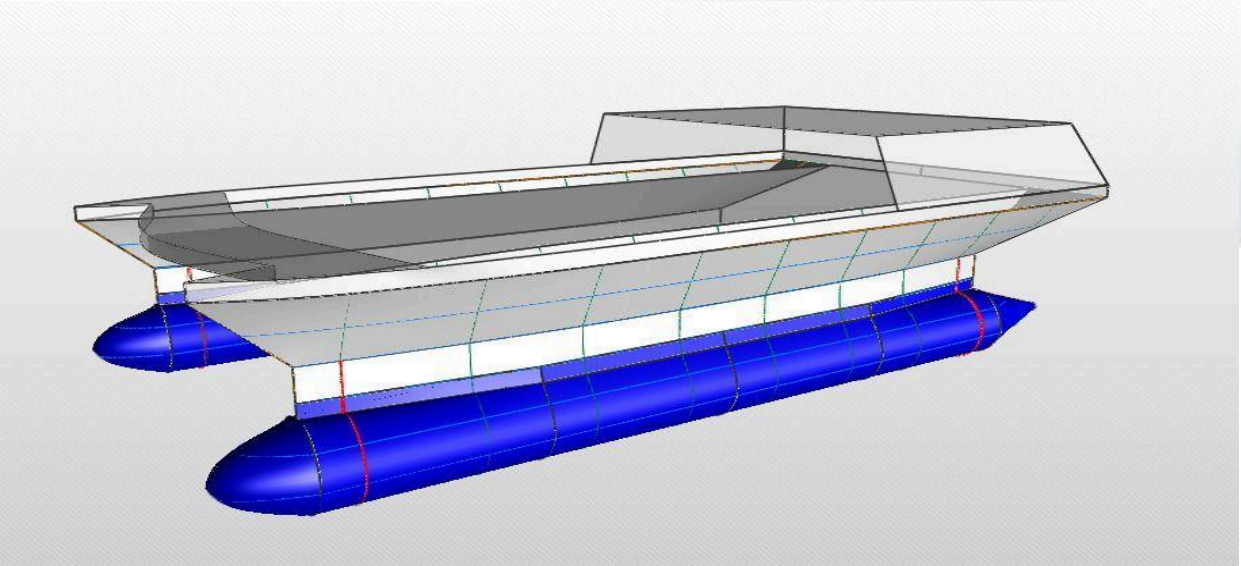


being used

The battery being used is a Li-ion rechargeable 24v battery, which must be charged using solar power using a controller.

2.1.3 Choosing the Hull

Upon researching different types of hull according to our requirement, we needed a type so that the drag is minimum even after the load is increased and the water plane area should be minimum and of higher stability, hence we chose a multi-hull design (E.g.: Catamaran, Trimaran). Here we've decided to choose a Catamaran type SWATH model ship.



Small waterplane area twin hull (SWATH)

● Advantages:

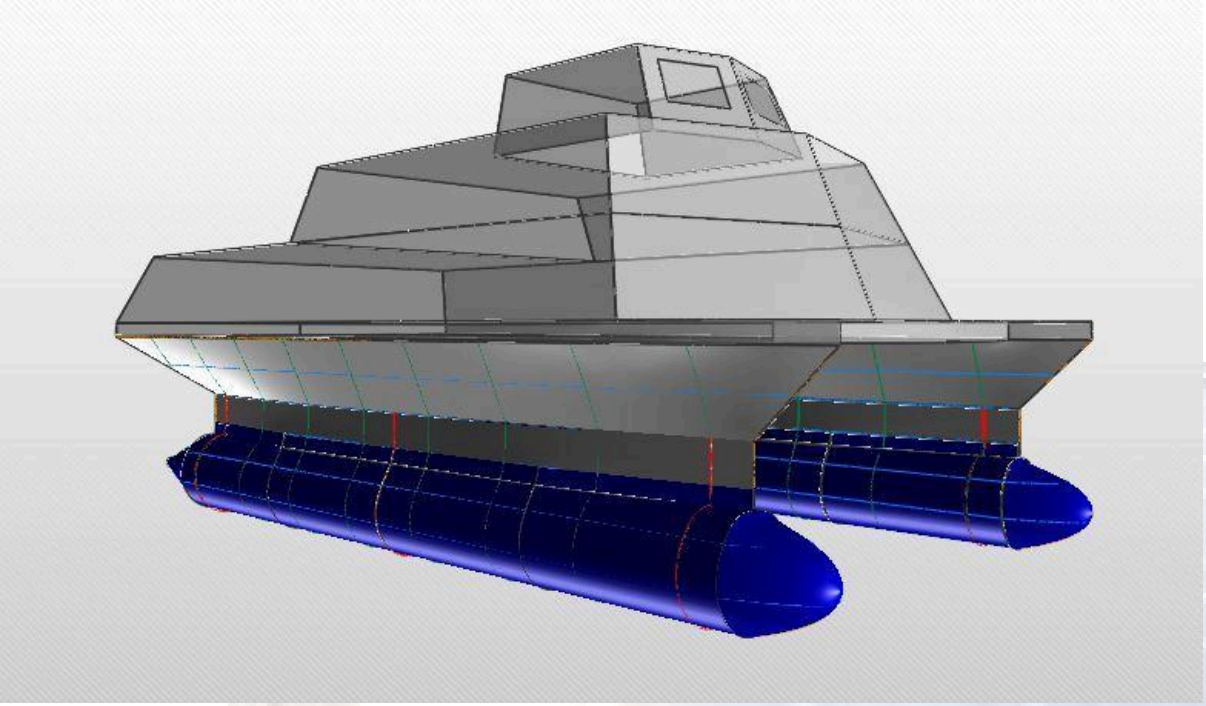
1. Massive deck area of a catamaran than on monohulls
2. More Stability
3. Light in weight
4. High speed

● Dis-Advantages:

1. SWATH may be too insensitive to the waves.

2. SWATHS are also extremely weight sensitive
3. Higher price for charter

3.2 Designing of the model



In order to calculate the minimum propulsion power requirement of or model, a help was taken from a well-known software known as Delft-ship. We used a computer-generated design of SWATH JCM-001.

Which we further modified it to our requirement and scaled it down by a factor of 0.03 which gave us our model boat dimensions:

- Design length: 0.9m
- Design Beam: 0.48m
- Design draft: 0.09m
- Displacement: 0.011t

As we know that solar panel works at its maximum efficiency when kept at perpendicular to the rays of the sun, then we used a manual hand lever to swivel the panels according to the direction of the sun.

3.3 CALCULATION:

Serial No.	Components	Quantity	Weight of One component	Total weight
1.	Motor	2	1.1kg	2.2kg
2.	Battery	1	2.2kg	2.2kg

3.	Solar panel	2	1.5kg	3kg
4.	Charging controller	1	0.16kg	0.16kg
				Total Weight: 7.56kg

As dead-weight is found to be around 8kg, i.e. less than 11kg displacement,

∴ the model will stay afloat.

Formulae used:

$$\frac{L_{model}}{L_{prototype}} = \frac{1}{Scaling\ factor} = 0.03$$

$$\frac{L_{Prototype}}{L_{model}} = 33.33$$

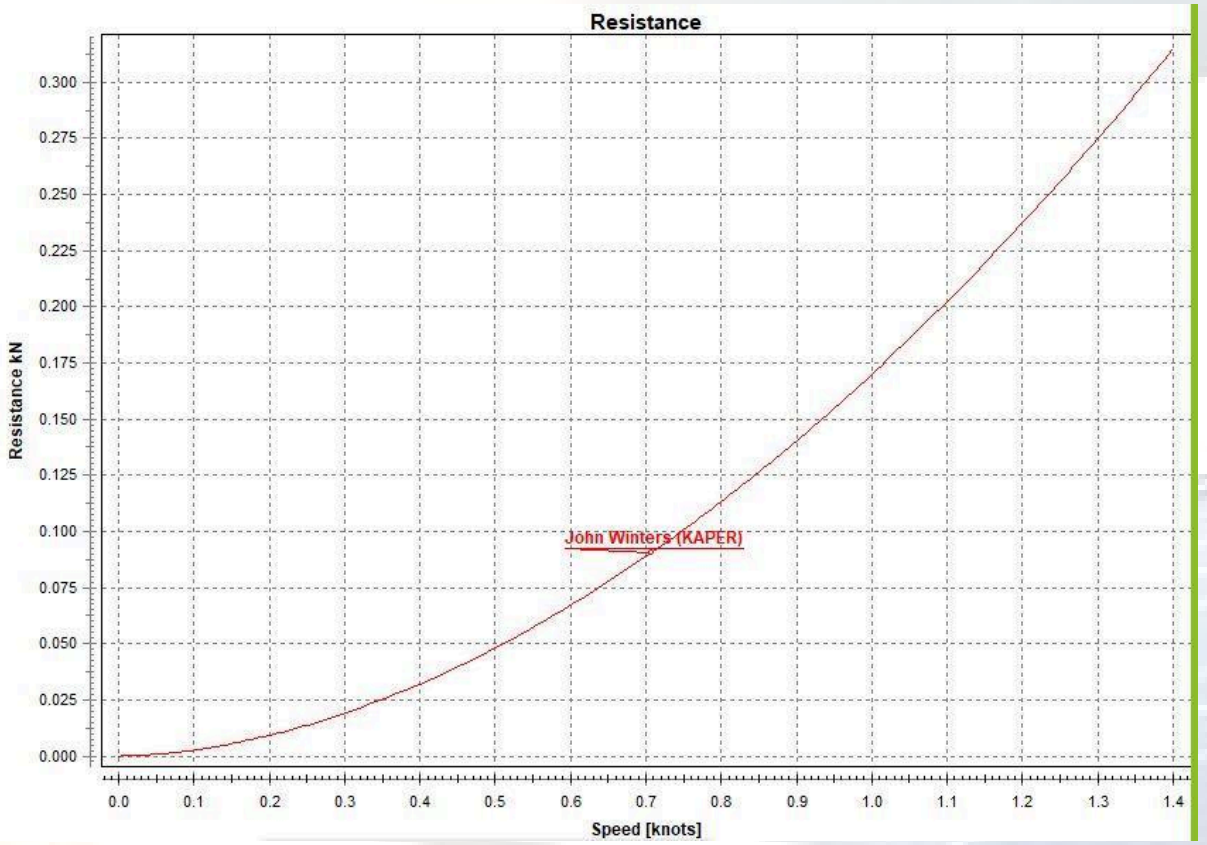
$$\frac{V_p}{V_m} = \sqrt{33.33}$$

- Considering average velocity of prototype (SWATH ship) as 8 knots,

  we get,

$$\frac{8}{V_m} = \sqrt{33.33}$$

$\therefore V_m = 1.38$ Knots i.e. 0.70 m/s



From the above graph plotted using KAPER'S method to find resistance, it is evident that at the designed model velocity, resistance is found out to.

R_{Total} = 0.32KN (neglecting residuary resistance)

Now,

To calculate effective power,

$P_{effective}(model) = V_m . R_{Total}$

$= 0.7 * 0.32 * 10^3$

$= 0.226KW$

This effective power is obtained at the end of the propeller,

But for our design, we need to find the actual power required to turn the propeller i.e. brake power (P_B).

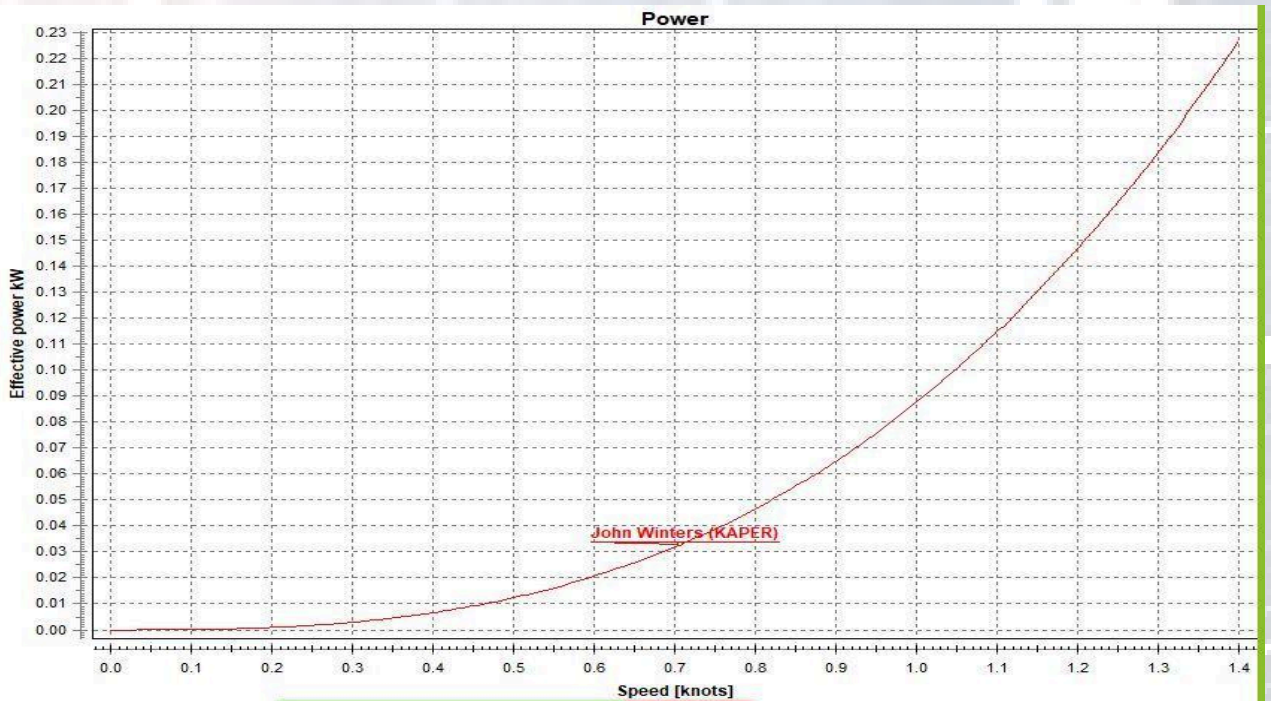
Considering,

Shaft losses, Friction and bearing losses to be 5%,

$P_B * 0.95 = P_{effective}$ (model)

$P_B * 0.95 = 0.226$

Therefore, $P_B = 0.238KW$



To verify our calculation, we used John Winter's KAPER methodology to check the effective power from the graph obtained and hence it was found to be around 0.226KW.

About KAPER method:

KAPER is a mathematical performance prediction program designed by John Winters exclusively for the design and evaluation of small lightweight human powered watercraft. It is based on over 200 ship, boat and model tests of light displacement, shallow draft, low Beam/Length ratios and refined to suit tank test data from both canoes and kayaks.

The first edition of KAPER was created in 1989 and limited to high beam/length ratios common to canoes. It was based upon Admiral David Taylor's formula for ship resistance modified to suit low $\frac{Displacement}{Length}$ ratio hulls and canoe test data. After many permutations the existing program was refined to its current state in 1996

According to KAPER method

Frictional resistance=

0.99525 x coefficient of friction x wetted Surface x speed^2

Since 0.238kw is not feasible (high cost and weight) from solar panel for direct supply to the motor, we use the panels only for charging the battery. The battery will be used to run the motor for propulsion.

Solar Panel Calculation:

As per our decision, we chose a solar panel of 12v and 30W rating, hence we will use 2 solar panels in series to get 24v output supply to charge our battery

Number of Solar panels will depend upon the capacity of battery to be charged, which is:

- Voltage rating of battery=24v
- Current rating of battery=20 Ah
- Power rating of solar panel=30w

∴ Watt-h of battery=24*20 = 480Watt-h

Time required to completely charge the battery=$\frac{480Watt-h}{30Watt}$

= 16 hrs.

This is an ideal time to charge the battery which may increase depending upon the condition of battery and weather.

Now, if we want to decrease the charging time of the battery, we must increase the rating of the solar panels by adding same rating of cells in parallel to the cells which are already connected in series.

According to our design of SWATH ship, it will be a twin-screw ship with two motors and one battery, each connected to respective propellers.

The solar panels will be placed at the topmost area of the model so that it comes in direct contact with the sunlight

connected mechanically to a swivel mechanism using a hand lever

3.4 Why Catamaran Hull Design?

- **If considered a Monohull**
  - Monohulls are less stable than catamarans both under sail and at anchor.
  - Each area of a monohull tends to be smaller than its counterpart on a catamaran, simply due to the shape of the boat and the usable space each design permits.

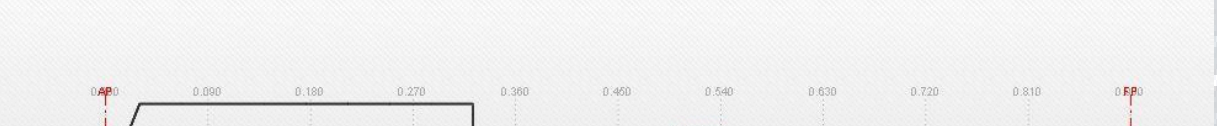
- **If considered a Trimaran**
  - Due to their complexity, they require some extra design effort.
  - Cost undeniably is a factor into trimaran construction.

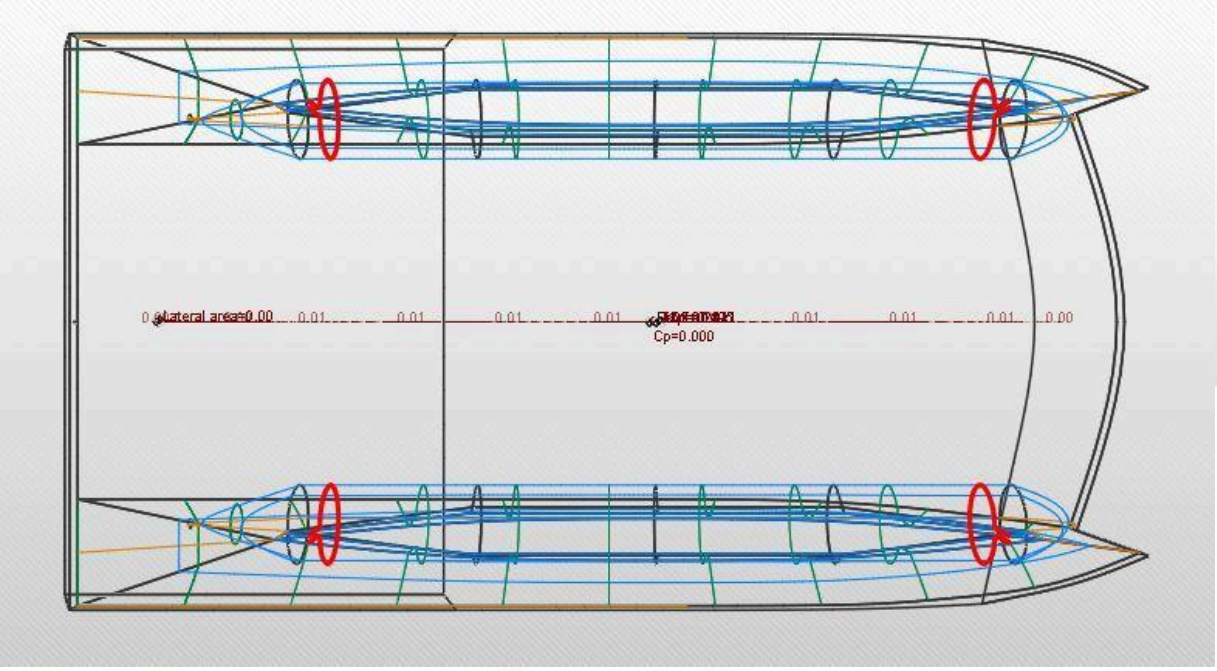
- **If considered a Catamaran**

- **Speed/Sailing Performance**-Cruising catamarans will typically be 25-30% faster than a cruising monohull of the same length.
- **Safety– Unsinkability**
- **Motoring Performance/Maneuverability**-Cruising catamarans and trimarans, with their easily driven hull forms and light weight, enjoy excellent fuel efficiency when compared to monohulls, and track very straight. Cats almost always have twin engines, set many feet apart, which allow for tremendous control in tight situations. In fact, the boat can be spun in place or crabbed sideways without any way on.

- **Shallow Draft/Bleachability** - Multihulls' stability comes from the beam and extra hulls (form stability), there is no need for ballast or a substantial keel. This reduces overall weight and, importantly, draft as well.

- **Lines Plan of model**





Waterplane view

In designing a propulsion system on a solar powered electric boat, there are 3 main sub system that is calculated, resistance of the boat, and propulsion of the boat & hull design of the boat. With results based on this analysis of propulsion on the catamaran, a model will be designed with high maneuverability and stability.

4. CONSTRUCTION

Construction will be divided into two stages of testing. At first, will be the testing of hull as without the right buoyancy the boat will either sink or become unstable. Secondly will be the testing of solar panels and seeing how well they worked as this would be the crucial factor to determine how well the motor would run.

4.1 About the selected model

Our project is based on solar propulsion for which we may require large no of solar panel for large power requirement which may increase the load on the model, hence we would decide such a hull which will give us lesser drag at even higher loads as well as speed.

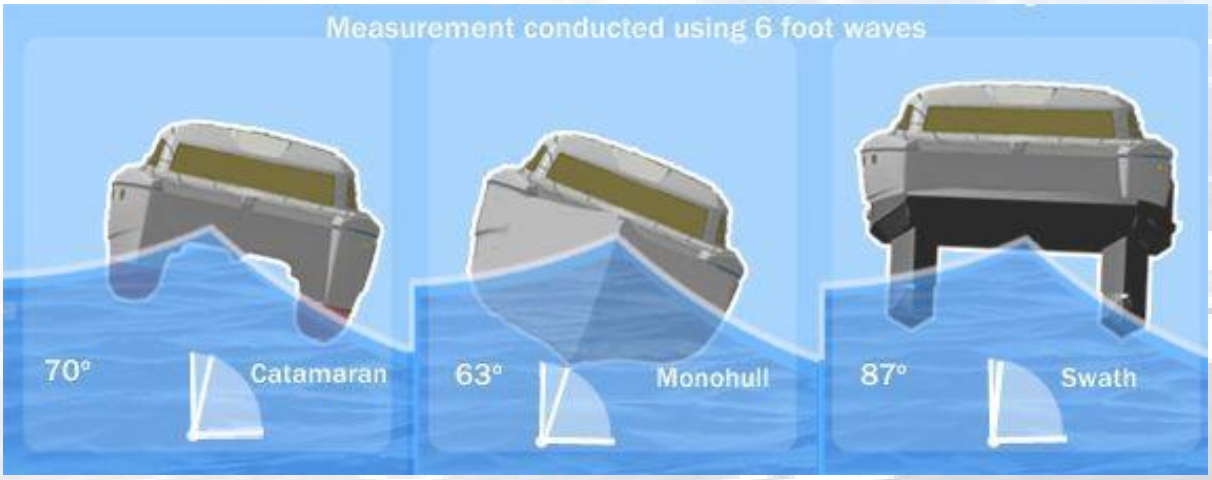
As a result, multi-hull was preferred over monohull as they don't have a heavy keel loaded with lead, also they have large amount of buoyancy that it won't capsize.

SWATH reduces wave-generating resistance by moving displacement volume below the waterline, using a pair of tubulars, submarine-like hulls, connected by pylons to the

bridge deck with a narrow waterline cross-section. The submerged hulls are minimally affected by waves.

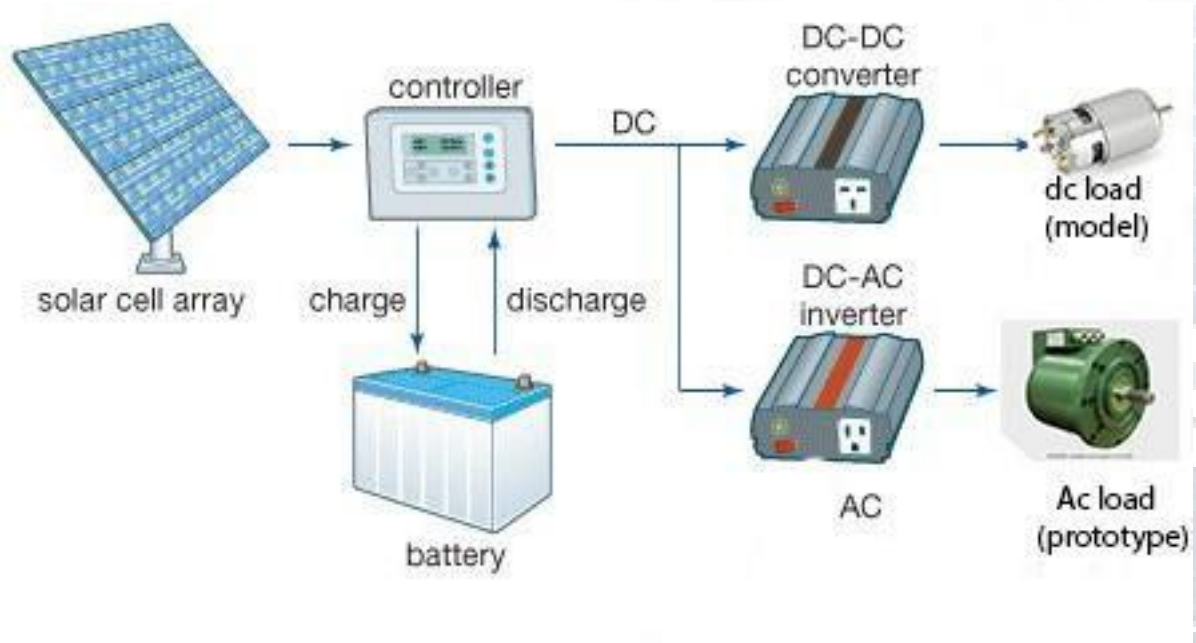
SWATH vessels compare with conventional powered catamarans of equivalent size, as follows:

- Larger wetted surface, which causes higher skin friction to drag
- Significant reduction in wave-induced drag, with the configuration of struts and submerged hull structures
- Lower water plane area significantly reduces pitching and heaving in a seaway.



4.2 Arrangement and Assembly

The solar panel which will be used further, will be placed on the topmost of the deck in direct contact with the sunlight i.e. recommended is that it should be perpendicular to the rays. The rest of the components will be secured beneath the deck.



The electrical circuit connection is as follows:

As solar panel works on the photovoltaic principle, the photovoltaic effect is the generation of voltage and electric current in a material upon exposure to light. It is

a physical and chemical phenomenon. For both phenomenon's, light is absorbed, causing excitation of an electron or other charge carrier to a higher-energy state

As explained previously, solar panel generates electric energy due to the transfer of free electrons and holes, hence this electric current is transferred to the charging controller which is basically a voltage and/or current regulator to keep batteries from overcharging. It regulates the voltage and current coming from the solar panels going to the battery. Most '12 volt' panels put out about 16 to 20 volts, so if there is no regulation the batteries will be damaged from overcharging.

- **For model:**

As our model uses Dc power directly from the battery pack, we can use a DC-DC step up booster circuit to increase the voltage according to our requirement and supply it to both the

motors by connecting it using suitable gauge of wires and securing them beneath the deck with proper arrangement for safeguarding it from the outside water.

The propeller will be connected to the motor shaft using a shaft connector. DC motors, like AC motor, can be configured to turn in either direction. Their direction can be easily controlled by inverting the polarity of the applied armature voltage by reversing the armature leads.

- **For prototype:**

For our actual prototype, Dc power will be converted to Ac using an inverter circuit to power our Ac motor used on-board, basically an induction motor connected to a gear box for controlling the speed.

In the electrical propulsion system, the direction of the rotation of propeller is governed by either the electrical control of the motor itself or by changing the electrical supply.

Normally variable speed electrical motor is used for fixed pitch propeller system and constant or variable can be used for variable pitch propeller or CPP.

Also, to run the motor of consumption much higher than the model, we must increase the no of batteries of high rating as corresponding to the requirement.

5. PROBLEMS FACED

After deciding the topic, our first motto was to find the type of ship upon which the system would be fitted and which would offer lesser drag and would be completely stable even when the load is increased. After researching on web and taking guidance from our project guide, we came to know about the Delftship software which gave us the desired result in a twin hull (SWATH) Ship.

Also, as this software was new to us, it took us a little time to understand its interface to generate our results based on graphs and the lines plan. The result obtained from this software helped us in verifying the calculation done by us manually.

At first, we decided our model dimensions to be 60x32 cm with a displacement of 4kg, but these results were found inaccurate relating to the specification of the motor, panels and the battery available, as the overall weight was exceeding the weight limit. Hence, we finalized our dimensions to be 90x48 cm with an increased displacement of 11kg with proper weight adjustments of the components

Our next challenge was to fit the desired number of solar panels which would give us the same required power that was needed to run the motor, which will result in running of the propeller, so instead we decided to run our motor with the help of a battery.

Our next hurdle was to determine a panel which would be light in weight and allow for the faster rate of charging the battery. As this was not feasible, we decided to go with two solar panels which when

combined would increase the rate of charging and would fulfil our power requirement.

As the design was being little complicated it took a lot of effort in obtaining the final version of our model.

6. CONCLUSION

Our overall goal in this project was to research, plan, & design based on solar power and was achieved by us. Since the idea at start was to research if a ship could be supplying its own power with only solar panels, but later it was found out that we can use this system only as a hybrid propulsion.

We also learned about the concept on how does solar panels work i.e. by using a semi-conductive material like silicon to absorb the energy from the sun and then two metal contacts built into the panel make an electrical circuit to use the power from the solar panel.

A little more knowledge was gained about mechanical system implied for the panels, electrical and electronic data on DC motors and types of batteries.

Currently to manufacture a solar electric boat, there are extra cost due to photovoltaic plant, battery bank & control system. These additional costs are partially compensated by reduction of operation cost as there is no consumption of fuel and the maintenance are relatively lower.

Besides the advantage of the use of renewable energy, it also produces socio-economic advantages, eco-system preservation, reduction of CO_2, SO_X, NO_X, etc.

Along the course of the project the design was continuously changing and being modified to improve it and to accommodate the solar panels and motor I had decided to use.

<u>Points to remember:</u>

- Choose your solar panels and motor carefully according to the weight and cost analysis. Choosing incorrect amount/rating of panels will affect the efficiency of the model.

- You can attach your solar panels in series (to increase voltage) or in parallel (to increase current).
- Also, choose you battery source as required because more the capacity, heavier the battery will become meaning that it will necessarily not run longer.

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