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E-Drive for Dual Powered Eco-Friendly Hybrid Dory Boat in Fishery

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Abstract*: -- Fossil fuels are the stage of extinction. Future generation depends on the renewable energy sources which are available abundant in nature. Renewable energy sources such as solar, wind, fuel cell, biogas sources are fast emerging energy sources used in the application of hybrid vehicles on both land way and waterway transportation. In marine sector, diesel engines are needed to maintained frequently. Dory boats are the means of transportation for rural fishing and passenger carrier in the tourist area. On accounting to the conventional ferry/Ro-Ro/tugboats owner's revenue report, about 45% of their revenue is spent on the purchase of fuel like diesel. In addition, fuel spillage in water bodies can cause a chance of the threat to sub-marine diversity. In order to cut down the fossil fuel cost and to reduce the spillage of fuel in water hybrid eco-friendly dory boats is designed, which are powered by renewable energy like battery and solar cells. In order to overcome the uncertainty caused by solar output, the battery is introduced to act as a backup source during of the adverse condition. With the help of power electronic converter, the output voltage of the battery and solar cells are combined to get the maximum efficiency at all environmental condition. Variable input voltages are processed with the help of multi-input power converters. In this application proposed dual input buck-boost converter which is mainly used to buck-boost the output dc voltage and also to supply power to the load individually or simultaneously according to our requirement. In conventional dory boats, IC Engine's are the major reason for noisy operation and CO2 emission. In order to overcome this strategy, conventional engine's are replaced by excellent performing noiseless BLDC motor drive which is zero percent emission. To put it in nutshell, eco-friendly hybrid dory boats can reduce the expenditure on the area of fuel cost and maintenance cost and water pollution. On the whole hybrid, dory boats can improve the style of social living of boat owner's and users.

***Keywords* — Solar PV panel, lead-acid battery, buck-boost converter, BLDC motor.**

I. INTRODUCTION

India stands 3rd position in fishery and 2nd position in aquaculture. According to survey reported from department of Indian fishery, it reveals that about 1.07 (% in GDP) is contributed from fishery and 5.15(% in GDP) is contributed from aquaculture. By analyzing the annual export earning report, we could conclude that Indian fishery gets a profit of about Rs. 33,441.6 crore /year and also in addition, its clear that fishery sector provides employment for 14.6 million people/year. Dory boats are the means of transportation for rural fishing and passenger carrier in tourist area. In marine sector, diesel engine used in boats requires regular maintenance which costs more for the owners. On accounting to the conventional ferry/ Ro-Ro/tugboats owner's revenue report, about 45% of their revenue is spend on the purchase of fuel like diesel. Moreover the fuel spillage in water bodies may cause pollution in the water bodies. The diesel engines also cause air pollution. Hence it's essential to find a good alternative to diesel engines to safeguard the environment and thereby improving the social life of fisher men.

II. DESIGN CRITERIA TO BE CONSIDERED FOR EDRIVE OF DORY BOAT

A. Mechanical Power required for the boat

Total power required for the boat mainly depends on total weight of the boat and speed of the boat it cruise. Required power can be calculated by total resistive force and velocity of water.

$$P=R*V \quad (1)$$

Where; R= resistive force; V= velocity of water

B. Selection criteria for primary source :

(solar panel) Selection of solar panel is entirely based on the boat sizing, cruiser maximum driven speed and When size of the solar panel is higher it directly affects the stability of the cruiser. Total watt-peak rating needed for PV panel is calculated by

$$\text{Total watt-hour per day} = \frac{Total\ watt-hour}{Panel\ generation\ factor} \quad (2)$$

Panel generation factor = 4.32 in India

$$\text{Solar panel required} = \frac{Total\ watt-hour\ per\ day}{Rated\ output\ watt-peak\ of\ the\ pv\ module} \quad (3)$$

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C. Selection criteria for secondary source: (battery)

When there is insufficient radiation from the sun and during night hours battery source will be at active condition. They act as a backup source when the solar power is insufficient and also on other edge when the solar radiation is high, solar power will be used to run the motor and charge the battery simultaneously to future need. In this proposed E-drive system lead-acid battery is choose as a secondary source.

$$\text{Battery capacity(Ah)} = \frac{Total\ watt-hour\ per\ day}{(0.85*0.6*battery\ nominal\ voltage)} * DOA \quad (4)$$

$$DOA = days\ of\ autonomy$$

$$\text{Energy demand} = (\text{load(Kw)})*(\text{Time(hr)}) \quad (5)$$

D. Selection of charge controller

To control the charging and discharging of battery separate control circuit is adopted. They are selected based on

$$\text{Current of charge controller} = \frac{Total\ watt}{voltage} \quad (6)$$

E. Selection of multiple-input converter

Low output voltage from the renewable energy source is boosted by using proposed dual input buck-boost power converter. Variable input voltages from solar and battery source is processed and conditioned to power the BLDC motor. In this application, we go for dual input source as solar cannot fulfil the user at all environmental condition. To overcome this uncertainty caused by solar, we have battery as a secondary source. With the help of proposed dual input buck-boost converter, input dc voltage can be boosted or reduced and also it can supply power to the load individually or simultaneously according to the environmental condition.

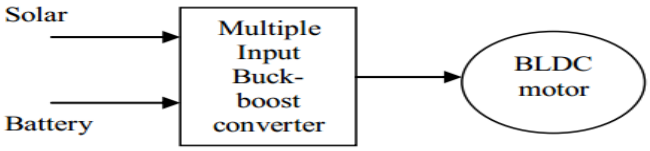


Figure: 1 Block diagram of converter

F. Selection of drive for boat

Output from power converter is used to drive the motor. In order to choose the motor many motor are considered.

Induction motor:

Induction motor is one of the most widely used AC motor in both electrical vehicle and in industries as speed control is difficult in induction motor we go in search of other motor which is in ease of control. Another drawback in induction motor is cost. Both operation and maintenance cost is high in induction motor.

DC motor:

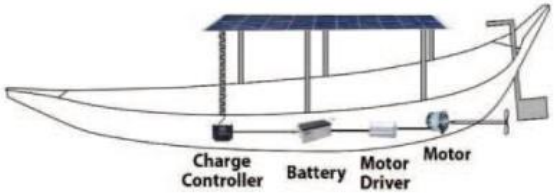
Dc motor is most widely used motor in dc application. Although this mo tor satisfies our requirement they too have many drawbacks. Presence of brushes in field maycreate problem. Regular maintenance is required by this cost factor get worst and also when wear and tear warrens frequent change of parts. On the whole, they will be a cost burden for fisherman in addition.

Brushless dc motor:

Brushless dc motor are kind of synchronous motor. They overcome the drawbacks of conventional dc motors. Need for commutators and brushes which subjects to wear and maintenance is completely eliminated by selection of brushless dc motor.

Advantage of brushless dc motor:

- Longer life
- No maintenance
- No dust residues
- Spark-free
- More efficient and energy saving
- Small and lighter weight more suits for boat
- Produce less heat



III. MODELLING FORMULATION IN MATLAB SIMULINK

Usually, it has been seen that two 100Watts BLDC motor can is sufficient for carrying 2 fisherman weighted approximately 250kg in a PV powered dory boat and also input of the converter is output of the solar panel. Maximum power from the solar is about 250 watts if it's necessary two 250 watts panel can be used according to the requirement. A. Modelling of PV panel In figure 2 model of PV panel is designed based on our requirement for powering BLDC drive. Here in this parameters are listed in table 1

TABLE 1

parameters	value
Rs	0.62Ω
Is	2.54 A
Rsh	250.57Ω
Voc	24V
Ig	1.13A
N	1.3
Tc	298

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As describes the modelling of PV panel and the values of voltage(V), power (P),and current (I) are taken as output

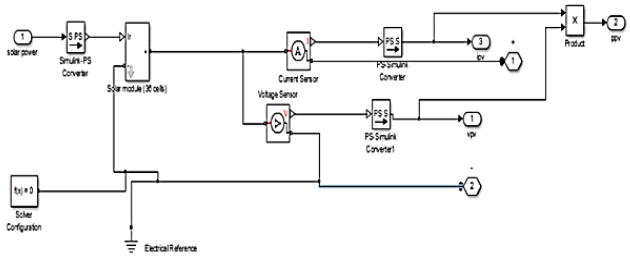

Figure: 2 Subsystem of modelling of solar panel

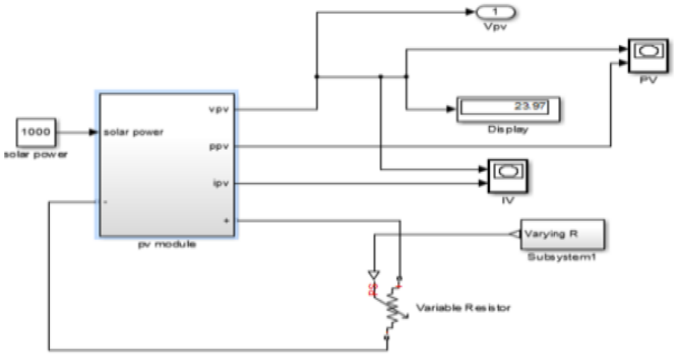

Figure: 3 Complete modelling of solar panel with variable resistor

Due to lower efficiency of solar panel, major challenge is to extract maximum power at all condition, so we go for MPPT technique. In general, PWM technique is employed to control the duty cycle of power converter, which in turn, it controls the transfer of energy from solar panel to load. Electrical characteristics of solar will get vary due to change in solar irradiation. To guarantee an operation under all adverse condition to deliver better power conditions, a common type of control we adapt to it is called as Maximum power point technique. Most commonly used MPPT technique are

- Perturb and observe method
- Incremental conductance method
- Fractional voltage or current sweep method
- Constant voltage or open voltage method

Perturb and observe algorithm:

To obtain maximum power at all condition, we go for maximum power point tracking. Here we used, perturb and observe algorithm to track the maximum power to the load at all condition.

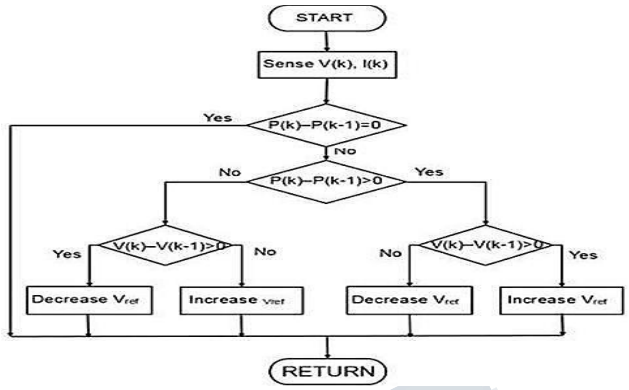

Figure: 4 Perturb and Observe algorithm flowchart

B. Modelling of battery controller

Output voltage from the solar panel is given to dual output isolated flyback converter. First, output from the converter is used to charge the batteries and other output is acting as a input for proposed dual input buck-boost converter. By this, charging of battery and direct powering to BLDC motor can be achieved during excess irradiation condition without any wastage. When the batteries depth of discharge is at 75%, battery will get into charging mode automatically at the same time battery will get disconnect and solar will get connected to power BLDC motor. This process will takes place simultaneously for every 0.5 sec in simulation. Here we use lead-acid batteries parameters are used as mentioned in table 2

TABLE: 2 LEAD-ACID BATTERY PARAMETERS

parameter	Fully charged	Completely discharge
State of charge(soc)	100%	0%
Depth of discharge	75%	100%
Rated capacity	5Ah	2Ahr
Electrolytic specific gravity	1.3	1.1
No-load voltage Voc @25 C	12.7 V	11.7 V

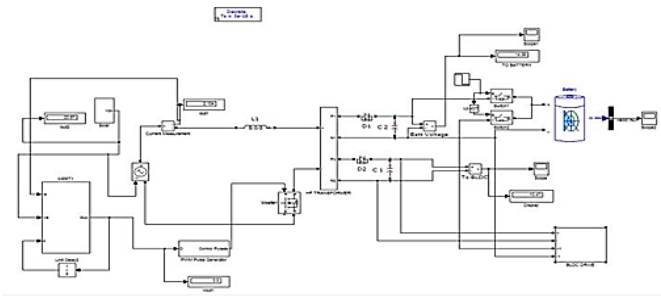

Figure: 5 Simulink model of dual output isolated flyback converter with battery and load

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C. Modelling of proposed dual input buck-boost converter:

Dual input source is used to power the dory boats. One is from solar panel and other is from battery source for backup. Whenever sun's radiation is sufficient, fisherman will use solar energy directly to power the electric BLDC motor otherwise battery will power the motor. There occurs another condition, when the boat is at un-operated condition, battery will get charged from solar panel and it can be used when necessity arises. There are 4 modes of operation in this proposed converter. During first mode of operation, both the sources that is both solar and battery sources are at active state(fig 7). During second stage, power from solar is only used to run the motor and battery is at inactive state (fig 8). During third stage, solar is disconnected only battery source is at on condition (fig 9). During last stage, both the sources are at inactive stage that is boat is at un-operated condition (fig 10).Complete design parameters of dual input buck-boost converter is shown in table 3

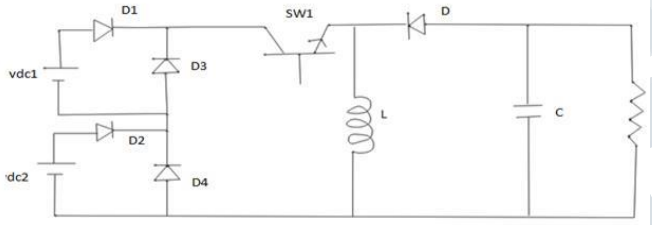

Figure: 6 Proposed dual input buck-boost converter

Mode I:

During mode 1 operation, both the sources that is solar and battery sources are at operating condition. When both the sources that is Solar(Vdc1) and battery source is (Vdc2) is at active state, both voltages at the input side will get added up at Vin as shown in (fig 7). In this stage, diode D1 and D2 will be forward biased and diode D3 and D4 are reverse biased. Thus, source current will enters through diode D1 and D2 and goes through impedance and will come back to the load.

$$Vin = Vdc1 + Vdc2 \quad (7)$$

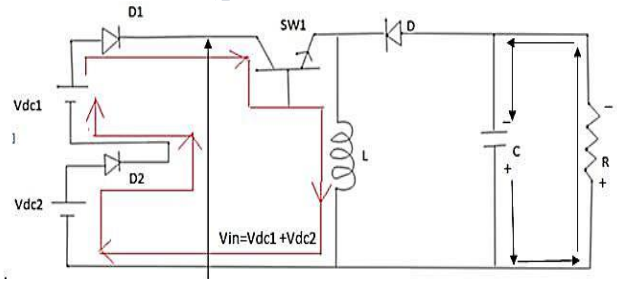

Figure: 7 Mode I of proposed converter

Mode: II

This is applicable when there is high solar irradiation. At this stage, battery is disconnected from the source and boat gets operated completely by solar power. Voltage across "Vin" is the voltage given out by the solar panel. This voltage is boosted to operate the motor (fig 8). At this stage, diode D1 is forward biased and diode D3 is reverse biased. So the current flows from D1 to motor. In reverse path from motor to source, current can't pass through Vdc2 and D2, so D4 is forcedly turn on and conduct current.

$$Vin = Vdc1 \quad (8)$$

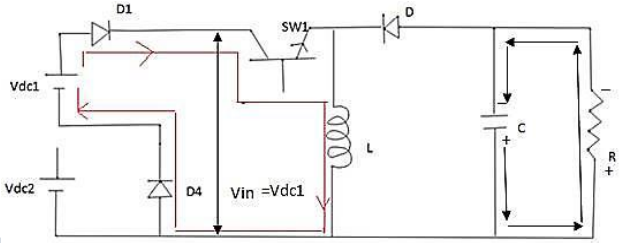

Figure: 8 Mode II operation of proposed converter

Mode: III

This stage is applicable when there is less radiation and during night time.At this stage input power from solar is at inactive state. Boat is operated only at battery. At this stage, battery voltage is alone used to run the BLDC motor. In this stage, diode D2 gets forward biased and D4 get reverse biased. As solar source is disconnected due to insufficiency current passes through diode D3, and forcedly it gets turned on. Current path is shown in (fig 9)

$$Vin = Vdc\ 2 \quad (9)$$

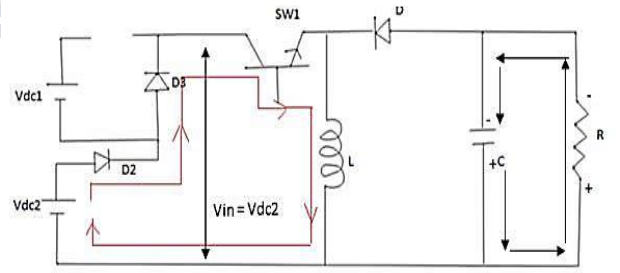

Figure: 9 Mode III operation of proposed converter

Mode: IV

When boat is at unoperated condition both the sources will be at inactive state (fig 10). At this condition, diode D1 and D2 are forcedly turn off, remaining current takes a path through diode D3 and D4.

$$Vin = 0 \quad (10)$$

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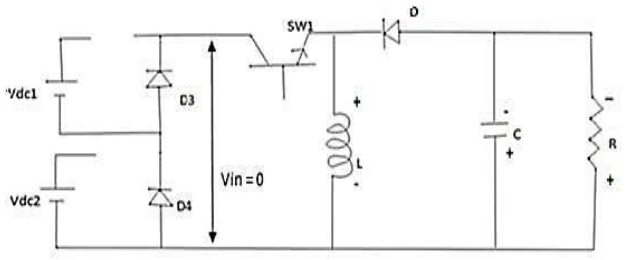

Figure: 10 Mode IV operation of proposed converter

Switching state for two sources are shown below in the table 3. This implicit the switching state s diode clearly during each mode of operation.

TABLE: 3 SWITCHING STATE OF DIODES

state	source state		switching state				Vin
	solar	battery	D1	D2	D3	D4	
1	active	active	on	on	off	off	vdc1+vdc2
2	active	inactive	on	off	off	on	vdc1
3	inactive	active	off	on	on	off	vdc2
4	inactive	inactive	off	off	on	on	0

Design parameter for proposed dual input buck-boost converter. From (Table 4) are the values which are designed for open loop condition.
Design parameter can be calculated by:
Average output voltage:

$$Vo = -(Vs*\alpha)\div(1-\alpha) \quad (11)$$

Where Vo is output voltage and Vs is supply voltage
Inductor value can be calculated by

$$I = Vs\ \alpha \div f\ L \quad (12)$$

TABLE: 4 SIMULATION PARAMETERS FOR PROPOSED CONVERTE

Parameters	value
Input voltage (Vdc1)	8V
Input voltage (Vdc2)	4V
Output voltage (Vo)	24V
Inductor value (L)	29mH
Capacitor value (C)	87µF
Switching frequency (F)	50khz
Duty ratio (α)	0.7

Where ΔI is peak to peak ripple current and f is a switching frequency.

$$L = (V_s\ \alpha)\div(\ I*f) \quad (13)$$

Capacitor value can be calculated by the formula

$$V_c = (I_o\ \alpha)/(f\ C) \quad (14)$$

Here ΔV is peak to peak ripple voltage

$$C = (I_o\ \alpha)\ /(\ V_c f) \quad (15)$$

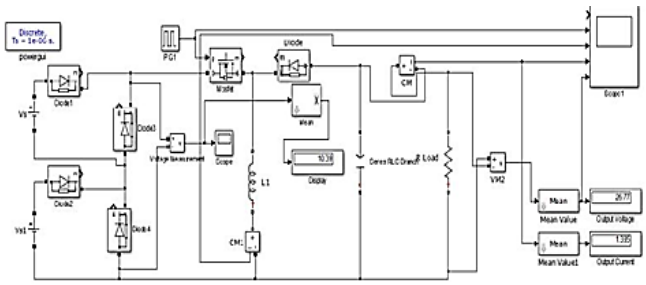

Figure: 11 Open loop simulation of proposed dual input buck-boost converter

D. Modelling of BLDC drive in simulink

PI controller is used to regulate the voltage. The purpose of voltage regulation is to control the speed of the boat. To control the speed of the boat voltage is regulated (fig). When voltage gets decrease, speed also will get decrease. Modelling is designed for single 100 watts BLDC motor. Parameters are showed in the table 5

TABLE: 5 PARAMETERS OF BLDC MOTOR

PARAMETERS	VALUES
Operating voltage	24V
Power output	100 watts
Maximum speed	3434rpm
Maximum torque	0.342
Voltage constant	6.99
Toque constant	0.066732N-mA
Maximum speed @full load	2500rpm

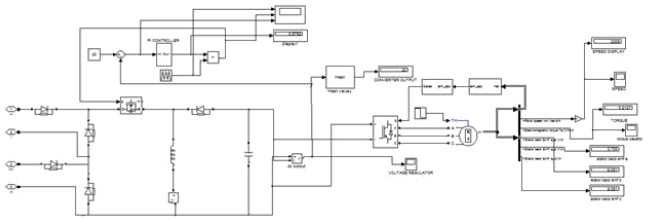

Figure: 12 Modelling of proposed converter with BLDC drive

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IV. RESULTS AND DISCUSSION

Feasibility is tested through simulation using world common tool MATLAB simulink tools. All simulation models shown in above figures are tested based on available components. Simulation results for PV panel, MPPT, charge controller and proposed dual input buck-boost converter is recorded and shown in upcoming figures. Simplified and tedious version of circuits and blocks used are based on the literature survey. By using perturb and observe MPPT algorithm from one 24V operating solar panel we can obtain about 100watts at maximum capacity. Output after maximum power point tracking is shown in figure 13 and figure 14 Which mainly shows the P-V and I-V characteristics of solar panel. By using dual output isolated flyback converter output from solar is divided into two outputs by using high frequency transformer. On adjusting, the turn's ratio of the high frequency transformer two desired output can be obtained. First, output from isolated dc converter is used to charge the battery which is shown in fig 15 and another output is used to drive the BLDC motor simultaneously shown in fig 17.

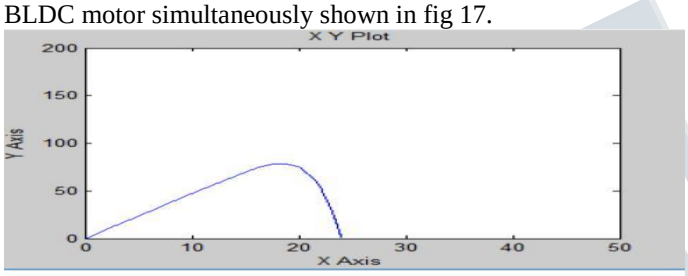

Figure: 13 P-V characteristics of solar panel

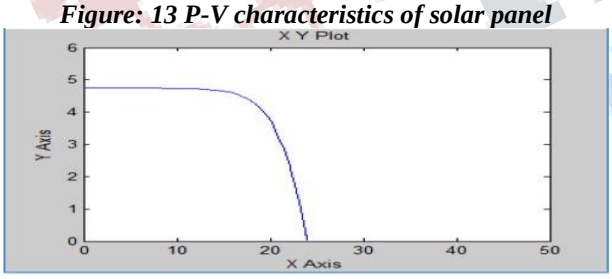

Figure: 14 I-V characteristics of solar panel

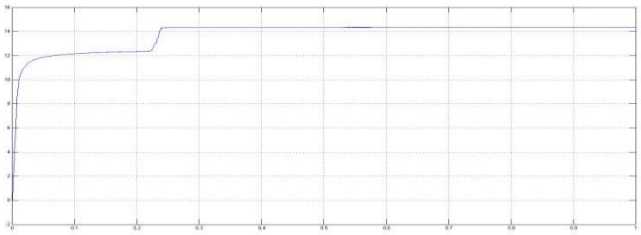

Figure: 15 Output voltage to battery obtained at the end of dual output isolated flyback converter

When the battery depth of discharge is about 75%,it will start charging. The charging and discharging state of the battery is shown in the fig 16.

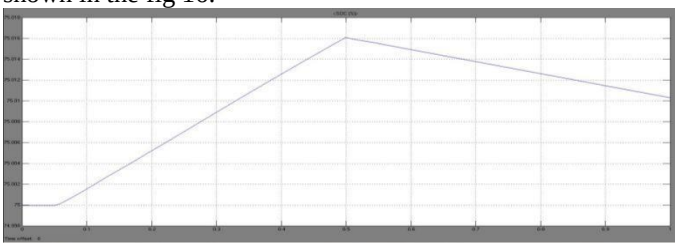

Figure: 16 State of charging and discharging (% SoC)

Open loop simulation based on the given parameters at the the table 4 is simulated and output voltage ,output current and inductor current at open loop condition is shown in (fig 17). In order to regulate the speed of boat (fig 20), Output voltage from the proposed converter must be regulated (shown in fig 19). By this speed of cruiser can be controlled. Analysis is made by regulating to different voltage and corresponding speed of the motor is recorded is shown in fig 21.

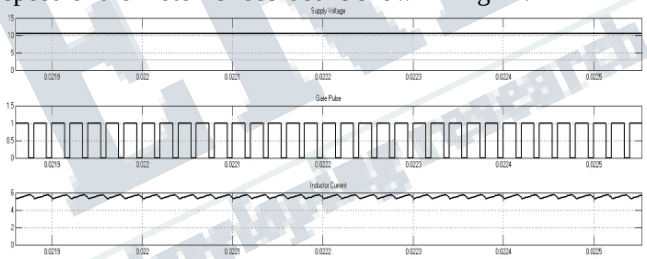

Figure: 17 Open loop simulation result of proposed converter

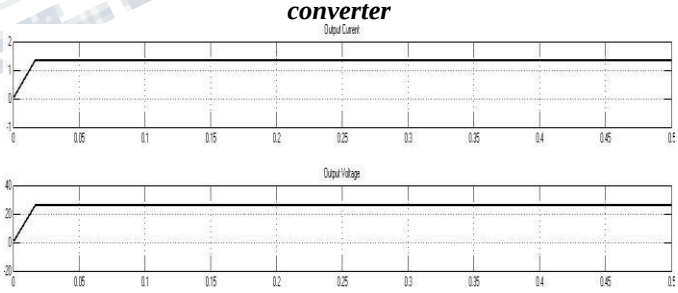

Figure: 18 Output voltage obtained in open loop simulation.

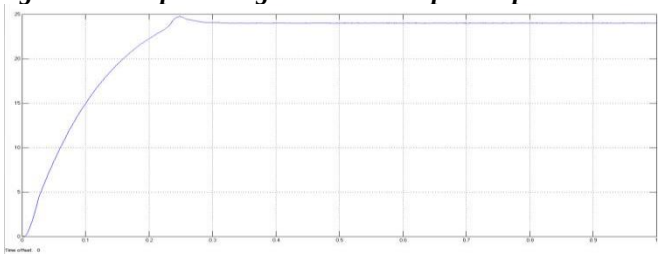

Figure: 19 Output voltage obtained at the end of closed loop simulation.

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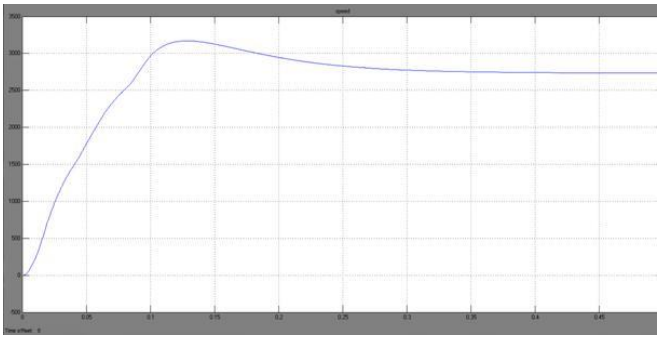

Figure: 20 Output waveform of speed of BLDC motor

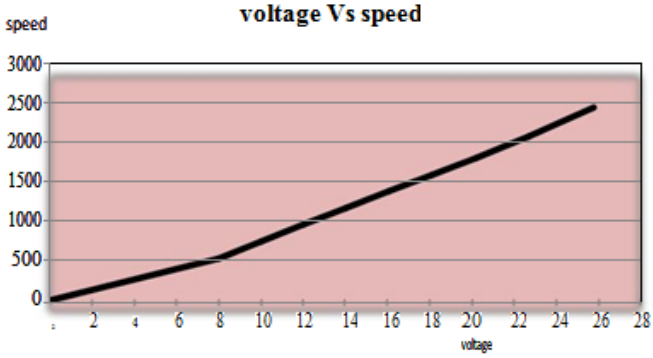

Figure: 21 Different voltage Vs Speed

By varying different load condition, corresponding speed responds is recorded shown in fig 22.

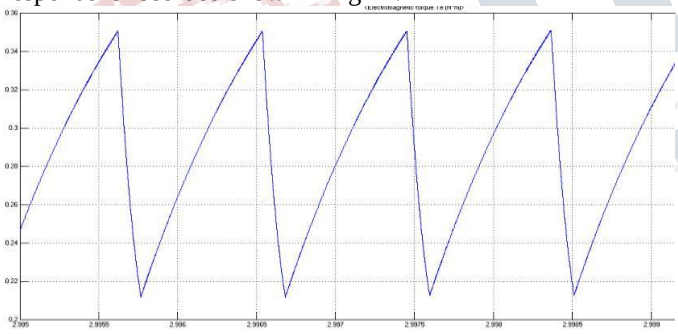

Figure: 21 Output waveform of electromagnetic torque of BLDC motor

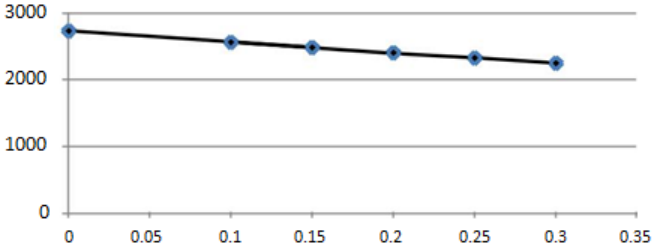

Figure: 22 Different load Vs speed

V. CONCLUSION

Use of transportation is getting increasing day by day which in turn causing global treating like global warming and greenhouse gas effects due to emission of carbon dioxide and carbon monoxide. This indirectly shows over usage of fossil fuel driven vehicles. Conventional Internal Combustion engines are getting doubled even though there is crisis in fossil fuels. Our future generation completely depends on the alternate fuel sources, Which could be probably replenishing renewable energy sources. There are wide encouraging promotions booming from world side (Paris climate change agreement) towards usage of renewable energy sources to reduce the emission and even from Government of India Insisting towards replacement of conventional IC engines to electric vehicles. This concept of renewable energy powered hybrid dory boat drive system could be a transformation toward the electric vehicles on waterway transportation. By the replacement of conventional engines in boat not only air pollution even spillage of oil which is one of the major source of water pollution can be eradicated.

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