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# Electric Boat Using Boost Converter

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## Abstract:

The main objective of this paper is to establish technical and economicalaspects of the application of photovoltaic (PV) and piezoelectric system insailing boat using a boost converter in order to enhance the powergeneration and also to minimize the cost. Performance and control of dc-dcconverter, suitable for photovoltaic (PV) and piezoelectric applications, is presented here. Aboost converter is employed to extract complete power from thePV and piezoelectric source and to feed into the dc load. The power, which is fed into theload, is sufficient to drive a boat. With the help of ProteusSimulink software, PV module and Piezo module with boost converter havebeen designed and simulated.

Keywords— **Boost Converter, Rectifier.**

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## I. INTRODUCTION

The concern of environmental issues nowadays is causingrise in demand of renewable energy that is cheaper andsustainable with less emission. Solar and Piezoelectric energy are considered promising in harnessing renewable energy that are considered cheaper and sustainable. However, theweather conditions, the fluctuation of sun irradiance and the variability in tides aremain limitations of this technology.During Day time Photovoltaicsystem (PV) is a module that is built in a form of array solar panelwhere harnessing of solar energy takes place. PV cell consists ofmultiple thin layers of silicon which is a semiconductormaterial that generates electrical charges when it is exposed tolight. It directlyconverts solar energy into DC electricalenergy. During Night time Piezoelectric transducer acts as the input source for the system and it generates variable AC from the tides of sea water and the AC from the piezo transducer is step up using a step-up transformer and then it is converted into DC voltage by Bridge Rectifier. Then the DC from the Rectifier is given to the converter to get the required DC output. The DC voltage available at the terminals can directly feed various loads such as Battery,LED lighting, DC motors or it may connect to a grid via a proper power converter. Energy consumption has become a big challenge with theemergence of Internet of Things. Electrical powerconverter is one of the main components in this systemwhich plays a critical role in controlling consumed energy. Itserves the aim of providing the desired form of output current(DC or AC) and transferring maximum power from the solarPV module and piezoelectric to the load [10]. In addition, it is used to regulatethe output voltage of system before connecting to the load. There are several types of DC/DC converters that canbe utilized including buck converter, boostconverter and buck-boost converter. Boost converter(step-up) helps to control the output voltage andmaintain it at a desired level regardless the variation in theinput voltage. According to the duty cycle value, the outputvoltage of the boost converter can be either higher orlower than the input voltage. Therefore, this type ofDC/DC converters can be used with this system to achieve thedesired output voltage in spite of the variation of sun radiation and tides.If the generated voltage from the source is low, the converter will cork in the boost mode to stepupthe output voltagethus alwaysmaintains the voltage at the proper level. The switching ofboost converter mode of operation can beachieved by controlling the its duty cycle.In this paper, we have designed and fabricated a boostconverter for this system in order to regulate andmaintain the output voltage of the system regardless thechanging in the input voltage. An Arduino Unomicrocontroller was used to control the Duty Cycle of theconverter via Pulse Width Modulator (PWM) output from theArduino to regulate the output voltage. The developedconverter acts as an interface between the source and theload. The main benefits of this system include the maximizingof transferring power from the system to the load whilemaintain a fixed output voltage at output terminal forinstrumentations which are sensitive to voltage variations.This study adopted the following methodology andcontributions:

(i) Design and fabrication of a boost converter forthis system;

(ii) Implementation of Arduino-based controller for controlling the duty cycle of the developedconverterto continuously adapt the mode of operation basedon the variation of PV and Piezo voltage;

(iii) Evaluating the performance of the developed systemusing both simulation and prototype and analysis ofthe obtained results to assure the switching betweenthe operation modes of the converter (boost) according to the input voltage.

The next section introduces the proposed system architectureand implementation. The results and discussion are introduced.

## PROPOSEDSYSTEM

The process of designing boost converter can bedivided into THREE (3) main stages, which areformulationtheory, simulation design, and hardware fabrication of theprototype. In theformulation theory stages the value ofcapacitor, inductor and the switching frequency aredetermined based on finding from literature reviewon theequation that derived. Next in simulation stage, based on thevalue gathered in formulation stages, the simulation will bedesigned and conducted by using Proteus inorder to evaluate the characteristic of output formed by usingthe datafrom the simulation part. When the simulation givespositive result, then the fabrication of prototype hardwarecomponents can be carried out according to the results.

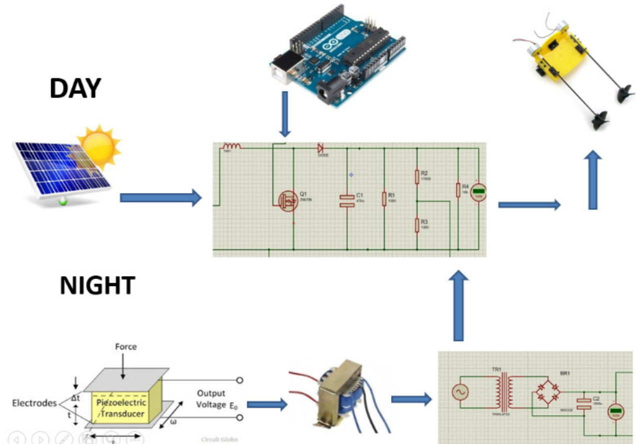


**FIG:1.1 MODEL DIAGRAM**

A)BOOST CONVERTER :

In this System the input DC from the source is step up with the help of this boost converter which step up the input voltage into the voltage we need. A boost converter (step-up converter) is a DC-to-DC power converter that steps up voltage (while stepping down current) from its input (supply) to its output (load). It is a class of switched-mode power supply (SMPS) containing at least two semiconductors (a diode and a transistor) and at least one energy storage element: a capacitor, inductor, or the two in combination. To reduce voltage ripple, filters made of capacitors (sometimes in combination with inductors) are normally added to such a converter's output (load-side filter) and input (supply-side filter).

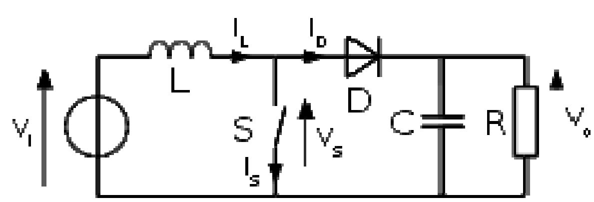


**FIG: 1.2 SCHEMATIC DIAGRAM**

Power for the boost converter can come from any suitable DC source, such as PV and Piezo electric(Rectifier). A process that changes one DC voltage to a different DC voltage is called DC to DC conversion. A boost converter is a DC to DC converter with an output voltage greater than the source voltage.A boost converter is sometimes called a step-up converter since it"steps up" the source voltage. Since power (the output current is lower than the source current.

The key principle that drives the boost converter is the tendency of an inductor to resist changes in current by creating and destroying a magnetic field. In a boost converter, the output voltage is always higher than the input voltage.

(a) When the switch is closed, current flows through the inductor in the clockwise direction and the inductor stores some energy by generating a magnetic field. Polarity of the left side of the inductor is positive.

(b) When the switch is opened, current will be reduced as the impedance is higher. The magnetic field previously created will be destroyed to maintain the current towards the load. Thus the polarity will be reversed (meaning the left side of the inductor will become negative). As a result, two sources will be in series causing a higher voltage to charge the capacitor through the diode D.

If the switch is cycled fast enough, the inductor will not discharge fully in between charging stages, and the load will always see a voltage greater than that of the input source alone when the switch is opened. Also while the switch is opened, the capacitor in parallel with the load is charged to this combined voltage. When the switch is then closed and the right hand side is shorted out from the left hand side, the capacitor is therefore able to provide the voltage and energy to the load. During this time, the blocking diode prevents the capacitor from discharging through the switch. The switch must of course be opened again fast enough to prevent the capacitor from discharging too much.

The basic principle of a Boost converter consists of 2 distinct states

- in the On-state, the switch S is closed, resulting in an increase in the inductor current;
- in the Off-state, the switch is open and the only path offered to inductor current is through the flyback diode D, the capacitor C and the load R. This results in transferring the energy accumulated during the On-state into the capacitor.
- The input current is the same as the inductor current . So it is not discontinuous as in the buck converter and the requirements on the input filter are relaxed compared to a buck converter.

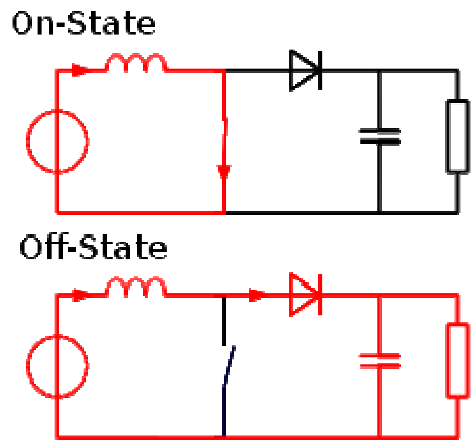


**FIG: 1.3 CONVERTER STATE**

$$V_i = (1 - D)V_o$$

**D-DUTY CYCLE**

$$D = 1 - \frac{V_i}{V_o}$$

TABLE I. DUTY CYCLE VARIATION

| **Ip Voltage (*Vs*)** | **Op Voltage (*Va*)** | **Duty cycle (*k*)** |
|---|---|---|
| 6.0 | 16 | 0.408 |
| 5.4 | 16 | 0.429 |
| 5.0 | 16 | 0.444 |
| 4.2 | 16 | 0.480 |
| 3.6 | 14 | 0.521 |
| 3.0 | 12 | 0.571 |
| 2.8 | 12 | 0.600 |
| 2.0 | 10 | 0.632 |
| 1.8 | 10 | 0.667 |

B)RECTIFIER:

Rectifier circuit which is used in this system is used to convert the AC source from the piezo electric transducer into DC source.An alternating-current (AC) input into a direct-current (DC) output, it is known as a bridge rectifier. A bridge rectifier provides full-wave rectification from a two-wire AC input, resulting in lower cost and weight.

In the diagrams below, when the input connected to the left corner of the diamond is *positive*, and the input connected to the right corner is *negative*, current flows from the *upper* supply terminal to the right along the *red* (positive) path to the output and returns to the lower supply terminal through the *blue* (negative) path.

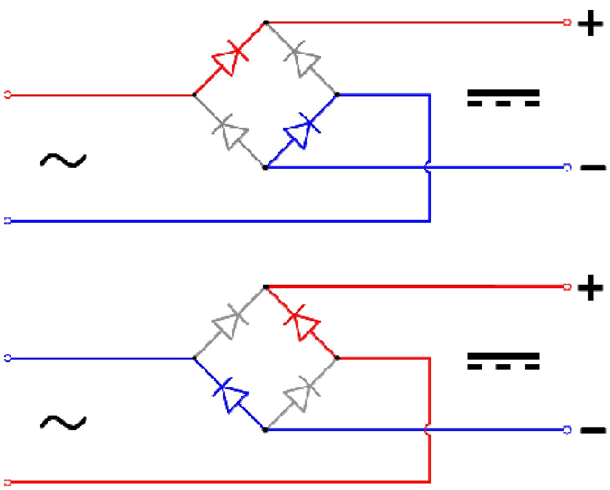

**FIG: 1.4 OPERATING MODEL**

When the input connected to the left corner is *negative*, and the input connected to the right corner is *positive*, current flows from the *lower* supply terminal to the right along the *red* (positive) path to the output and returns to the upper supply terminal through the *blue* (negative) path.

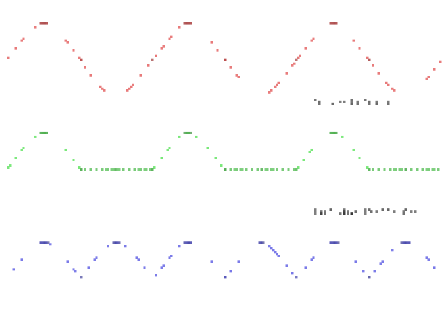

**FIG: 1.5 RECTIFIER WAVEFORM**

C) SIMULATION DESIGN:

According to the abovementioned formulation, the simulation layout and configuration of thedevelopedconverter was designed as depicted. In this study, Proteus Simulator was utilized as a simulation tool. Proteus is the schematic capture and simulation programdesigned for schematic entry, simulation, and feeding todownstage steps, such as PCB layout. In our simulation, thetime delay is set as 0 s and the time pulse period is set to16.67µs to obtain 60 kHz switching frequency. Means, theswitching ON and switching OFF time must equal to oneperiod and their values are changed depending on the desiredduty cycle. In other words, the value of pulse width is equal toduty cycle times. The simulation tests wereconducted for rectification and boost operating mode. The obtained results from simulation experiments will bediscussed in next section.

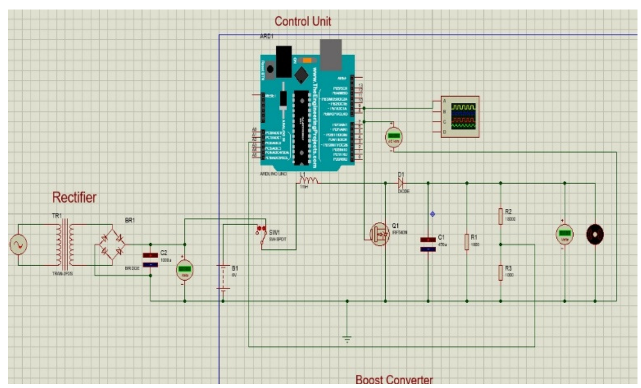


**FIG: 1.6 SIMULATION MODEL**

D) PROTOTYPE FABRICATION:

The materials used to fabricate the prototype of boostconverter in this study are MOSFET IRF540N, diode1N5408, inductor 1mH, capacitor 470µF, load (DC motor)and Arduino UNO microcontroller, inaddition to Piezo Electric transducer connected with Rectifier and PVSolar. Since Arduino is capable to read the analogue value andprovide the PWM output accordingly. In our prototype,Arduino was utilized to control the duty cycle for switchingMOSFET (ON/OFF), and consequently controlling the outputvoltage of the

  

PV solar panel and Piezo Electric with different inputs. Theanalogue ports (A0 - A5) are suitable to read the outputvoltage of the boost converter via a suitable voltagedivider. This voltage value representing a feedback control toPWM control system in order to change the duty cyclethrough the digital output ports for PWM output fromArduino. Software code for generating 60 kHz at the PWMoutput. There is a lot of electrical appliance that are verysensitive toward inconstant input voltage such as LightEmitting Diode (LED). Other than that, we have exploited aDC motor for testing purposes in our work due to simplicityin monitoring changes in motor's speed and sound due tofluctuation in its input voltage.The PV solar panel used it this study is 8V rating the predicted voltage output produced from the solar paneloutdoor is about 2 V – 6 V with high exposure to sunradiation condition. The voltage output of the solar panel isanalyzed with time frame. From the solar panel used, themaximum voltage output produced recorded is 6V and thelowest voltage output is 2V. The lowest output voltagerecorded is when the solar panel is stored indoor with noexposure to sunlight. The voltage output recorded in this studyare presented. Then from theeach Piezo Electric Transducer we can get 0.2V - 0.6V. The series connection of piezo electric transducers we used in this system gives Maximum of 5.8V and minimumof 1.8V which is the AC voltage is step up with the help of step up transformer and then converted into DC voltage with the help of rectifier circuit and given as DC input to the boost converter circuit. The step-up DC voltage from the converter circuit is given to the DC motor which is connected with the propeller helps to run the boat.

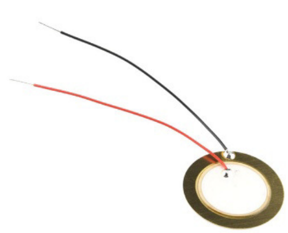

**FIG: 1.7 PIEZO ELECTRIC TRANSDUCER**

A piezoelectric sensor is a device that uses the piezoelectric effect to measure changes in pressure, acceleration,vibration, strain,or force b y converting them to an electrical charge(AC).

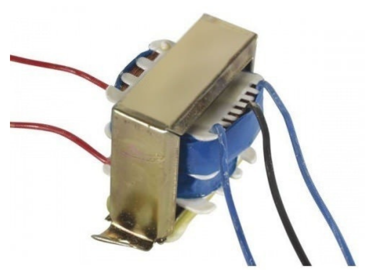

**FIG: 1.8 STEP-UP TRANSFORMER**

A transformer in which the output (secondary) voltage is greater than its input (primary) voltage is called a step-up transformer. The step-up transformer decreases the output current for keeping the input and output power of the system equal..

TABLE II

| **Component** | **Value** |
|---|---|
| Capacitor | 470uF, 1000uF |
| Inductor | 1mH |
| Resistor | 1KΩ, 18KΩ |
| MOSFET | IRF540N (N-Channel) |
| Diode | 1N5408 |
| Step-up transformer | 1:2 ratio(2A) |
| ARDUINO | UNO |
| Rectifier Bridge | - |
| DC Motor | - |
| Piezoelectric Transducer | - |

## RESULTS AND DISCUSSION

This section presents results of boost converteroperation in both simulation and practical prototype. Thepurpose of this part is to evaluate the performance of the boostconverter circuit in performing boostprocesses, the desired output from theboost converter is 16V. The objective is to obtained the desired output voltagewhich is 16 V.

  

The results represent three mode of operationbased on THREE (3) different input voltage used in thisexperiments, (2V, 4 V, 6 V). During day time PV panel acts as the input source and the DC voltage from the PV source is boosted and used to run the DC motor and then in night time the input souce isswitched to piezo electric and the AC from the piezo transducer is rectified into Dc and boosted with converter to run the boat.

I.DAY TIME

PV Solar acts as the input source and boost converter started when the dutycycle, *k* is more than 0.4, thus the converter steps-up the outputvoltage to be higher than input voltage and achieving thedesired output. In order to test the developed boost mode, 4V input voltage was applied at the inputterminal of the converter, thus Arduino PWM increased theduty cycle to become more than 0.65which resulting inincreasing the output voltage to 16 V. When the input voltage is 4V, the dutycycle is adjusted by set up the pulse width of switching voltageto 10.35µs for a period of 16.6667µs, the duty cyclebecame0.5. At this duty cycle, the buck-boost converter converts 4 Vinput voltage to 16 V output. HereinArduino has adjusted the duty cycle automatically via PWMoutput to attain the required output voltage (16 V) at all-timebased on the feedback measured voltage. It is obvious that theboost converter able to perform boost voltage process toensure a fixed output voltage. Consequently, our convertercan boost the lowest output voltage generated by the solarpanel at lower radiation due to changing the angle of thesunlight to the solar panel plate during day time.

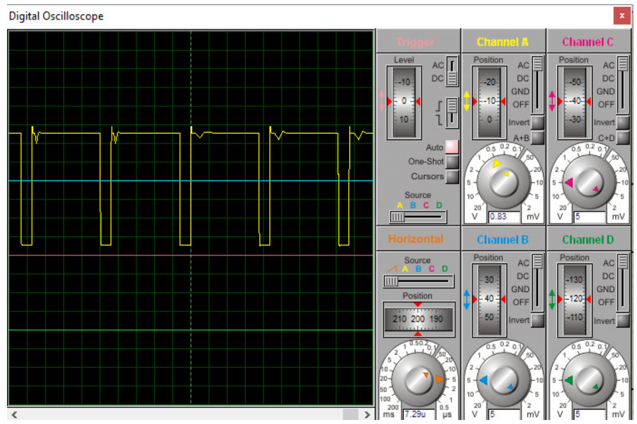


**FIG: 1.9 OUTPUT WAVEFORM IN DAY TIME**

II.NIGHT TIME

Piezoelectric transducer acts as the input source series connection of piezo transducers gives minimum of 1.8V and maximum of 5.8V AC the step-up transformer increase the voltage and the rectifier used converts the AC into DC and boost converter started when the dutycycle, *k* is more than 0.4, thus the converter steps-up the outputvoltage to be higher than input voltage and achieving thedesired output. In order to test the developed boost mode, 5.2V input voltage was applied at the inputterminal of the converter, thus Arduino PWM increased theduty cycle to become more than 0.6 which resulting inincreasing the output voltage to 16 V. When the input voltage is 5.2V, the dutycycle is adjusted by set up the pulse width of switching voltageto 11.44µs for a period of 16.6667µs, the duty cycle became0.6. At this duty cycle, the buck-boost converter converts 5.2Vinput voltage to 16 V output. HereinArduino has adjusted the duty cycle automatically via PWMoutput to attain the required output voltage (16 V) at all-timebased on the feedback measured voltage. It is obvious that theboost converter able to perform boost voltage process toensure a fixed output voltage. Consequently, our convertercan boost the lowest output voltage generated by the piezoelectric at lower pressure due to change in tides of the water during night time.

  

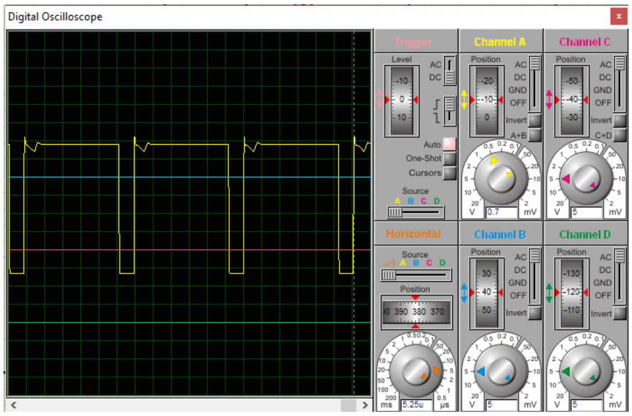


**FIG: 1.10 OUTPUT WAVEFORM IN NIGHT TIME**

## CONCLUSION

Solar PV and Piezoelectric powered sailing boat using boost converter is proposed here. The effectiveness of theproposed control scheme is tested. This is a new and innovative application which is fully environmentalfriendly and is almost pollution less. As the upper portion of the boat is unused, solar panels are implemented and the piezoelectric transducers are fitted in the lower part of the boats in that portion quite easily, no extra space is required. Fuel cost is not required in day time due to thepresence of sunlight and battery cost is not required in night timedue to tides in water. lastly, energy payback period will be lesser than diesel run boat.In this paper, we have developed an Arduino-based Boost converter to avoid the high thermal losses and poorefficiency of the existing linear voltage regulators. Thedesigned converter can provide sensitive instrumentationswith a fixed output voltage from the PV solar and Piezoelectric system at alltimes. The design and fabrication of the converter were carriedout using simulation and prototype. The obtained results provethe system efficiency, accuracy and cost effectiveness. Thepotential market of the developed voltage controller includingbut not limited to renewable energy industry, DC motors drivecircuits and battery power systems.

## ACKNOWLEDGMENT

This research was supported by SreeSowdambika College of Engineering (SSCE), to contribute the society, a solution for the problem.

## REFERENCES

[1] V. Devabhaktuni, M. Alam, S. S. S. R. Depuru, R. C. Green II, D.Nims, and C. Near, "Solar energy: Trends and enabling technologies,"*Renewable and Sustainable Energy Reviews,* vol. 19, pp. 555-564, 2013.

[2] J. Twidell and T. Weir, *Renewable energy resources*: Routledge,2015.

[3] P. Denholm and R. M. Margolis, "Evaluating the limits of solarphotovoltaics (PV) in traditional electric power systems," *Energypolicy,* vol. 35, pp. 2852-2861, 2007.

[4] G. K. Singh, "Solar power generation by PV (photovoltaic)technology: A review," *Energy,* vol. 53, pp. 1-13, 2013.

[5] F. Wang, Z. Mi, S. Su, and H. Zhao, "Short-term solar irradianceforecasting model based on artificial neural network using statisticalfeature parameters," *Energies,* vol. 5, pp. 1355-1370, 2012.

[6] O. P. Mahela and A. G. Shaik, "Comprehensive overview of gridinterfaced solar photovoltaic systems," *Renewable and SustainableEnergy Reviews,* vol. 68, pp. 316-332, 2017.

[7] J. P. Ram, T. S. Babu, and N. Rajasekar, "A comprehensive review onsolar PV maximum power point tracking techniques," *Renewable andSustainable Energy Reviews,* vol. 67, pp. 826-847, 2017.

[8] W. A. Jabbar, M. Ismail, and R. Nordin, "Evaluation of energyconsumption in multipath OLSR routing in Smart City applications,"in *Communications (MICC), 2013 IEEE Malaysia InternationalConference on*, 2013, pp. 401-406.

[9] W. A. Jabbar, M. Ismail, and R. Nordin, "MBA-OLSR: a multipathbattery aware routing protocol for MANETs," in *Intelligent Systems,Modelling and Simulation (ISMS), 2014 5th International Conferenceon*, 2014, pp. 630-635.

[10] M. A. Abdullah, A. Yatim, C. W. Tan, and R. Saidur, "A review ofmaximum power point tracking algorithms for wind energy systems,"*Renewable and sustainable energy reviews,* vol. 16, pp. 3220-3227,2012.

[11] A. Amir, H. S. Che, A. Amir, A. El Khateb, and N. A. Rahim,"Transformerless high gain boost and buck-boost DC-DC convertersbased on

  

extendable switched capacitor (SC) cell for stand-alonephotovoltaic system," *Solar Energy,* vol. 171, pp. 212-222, 2018.
[12] M. H. Rashid, *Power electronics handbook*: Butterworth-Heinemann,2017.
[13] I. Anand, S. Subramaniam, D. Biswas, and M. Kaliamoorthy,"Dynamic Power Management System employing single stage Power Converter for Standalone Solar PV Applications," *IEEE Transactionson Power Electronics,* 2018.
[14] N. Foster, B. McCray, and S. McWhorter, "A Hybrid Particle SwarmOptimization Algorithm for Maximum Power Point Tracking of SolarPhotovoltaic Systems," *2017 NCUR,* 2017.
[15] F. Mendez-Diaz, B. Pico, E. Vidal-Idiarte, J. Calvente, and R. Giral,"HM/PWM Seamless Control of a Bidirectional Buck-BoostConverter for a Photovoltaic Application," *IEEE Transactions on Power Electronics,* 2018.
[16] N. Multisim, "Powerful Circuit Design and Teaching Software–National Instrument [Internet Source]," *Access Mode: http://www.ni.com/multisim.*
[17] Solar Photovoltaic Powered Sailing Boat Using Buck ConverterSoumya Das, Pradip Kumar Sadhu, Nitai Pal, Gourav Majumdar, SaswataMukherjee *" International Journal of Power Electronics and Drive System (IJPEDS)"*Vol. 6, No. 1, March 2015, pp. 129~136 ISSN: 2088-8694
[18] Solar-Electric Boat Giuseppe Schirripa Spagnolo, Donato Papalillo, Andrea Martocchia, Giuseppe Makary Department of Electronic Engineering, University "Roma Tre", Roma, Italy,Received February 4, 2012; revised March 2, 2012; accepted March 15, 2012
[19]Hybrid Power System Design for Electric Boat with Solar Irradiance ForcastingWaleed Obaid* 1 , Abdul-Kadir Hamid2, Chaouki Ghenai3,ECE Department, University of Sharjah Sharjah, United Arab Emirates

  