FUZZY CONTROLLER BASED LOW COST HIGH EFFICIENCY CONVERTER FOR AUTONOMOUS PHOTOVOLTAIC WATER PUMPING SYSTEM

K.Sudha Rani, PG Scholar, EEE,lakireddyBalireddy College of Engineering, nagarjunasudha01@gmail.com

E.RaghuBabu,Assistant Professor,EEE,lakireddyBalireddyCollegeof Engineering

Abstract—This paper proposes a low cost converter for autonomous photovoltaic water pumping system based on fuzzy controller. The proposed converter i.e. the two inductor boost converter achieves ZVS/ZCS conditions.The operation of two inductor boost converter along with the three phase inverter and three phase induction motor is described.The classic topology of the TIBC has features like high voltage gain and low input current ripple. A solar tracking system is modeled using Matlab/Simulink and a fuzzy logic control is designed to control the duty cycle of TIBC.Simulation results show a power output 210w and efficiency of 98%is achieved for DC-DC converter.

Index Terms—Solar power, DC-DC converter,Voltage source inverter, Photovoltaic Water Pumping System

INTRODUCTION

Now a day's most of the people across the world have not sufficient water to drink. Due to this large amount of people is migrated from one place to another. Where the main source of water is from rain or distant rivers in such place this work is very useful for drinkable, consumption as well as irrigation. There is no need of electric power topump the water and treatment through conventional systems. To solve all these issues PV solar power generation is the best way to eradicate all the problems. This type of energy source is cheaper and these types of systems areexisted from so many years nearly three decades [1].

This system mainly consists of solar panel, an electronic controller, a motor and a water pump. The most important thing in control system has to firstly and most important to obtain the maximum power from the solar panel by tracking the sunlight. The pump [2] in the system isrunning on electricity which is produced by photovoltaic panels or the thermal energy available from collected sunlight. Photovoltaic powered systems are becoming more popular because

(i) In remote areas there is no adequate power lines to water pumping sites due to this reason supply fails to meet the demand.
(ii) Fossil fuel causes lot of environment degradation.
(iii)Gradually increasing the cost of fossil fuel based electricity and
(iv)Decreasing the cost of PV electricity.

Most of the converters available in market are based on an intermediate storage systemuses a lead–acid batteries and DC motors are used drive the water pump. The batteries are used to run the motor even when low climatic conditions. Basically this type of batteries have a low life span approximately two years only, which is comparatelylow with usage of 20 years of a PV module, and also high installation and maintenance cost.Most of the systems use low-voltage DC motors, it does not require boost voltage hence there is no boost stage between the PV module and the motor. But DC motorrequires higher maintenance cost and low efficiency compared to induction motors, due to this reasons it is not suitable for applications in isolated areas.

PUMP CONTROLLERS & STORAGE SYSTEM:

Every system requires a special controller similarly solar pumps also needed a special controller to be powered directly by PV modules (without batteries). The function of the controller is an automatic transmission, which allows the pump to start and run even in low light conditions that means overcast or early morning& evening. With the helpof battery source, the controller may convert 12 Volt battery power to 30 Volts. The pumps have capable of low flow due to this water must be accumulated in a tank so that it can be released on demand. There are three ways to do this: (1) pumping directly to a pressure tank, (2) using storage tank with a booster pump and pressure tank, (3) using an elevated storage tank with gravity flow. There are different control strategies have been proposed in literature for obtaining maximum power; Perturb & Observe[4], Incremental Conductance, Short-Current Pulse, Constant Voltage, Open Circuit Voltage, Artificial Neural Network [6]etc. The utilization efficiency however, can be further improved by employing a hillclimbing MPPT [5] technique such as the Perturb and Observe (P&O) algorithm [4]. It is a simple algorithm and is easy to implement with analog and digital circuits.The selection of a proper dc–dc converter plays an important role for maximum power point tracking (MPPT) operation. Selection of photovoltaic convertermainly depends on factors such as cost, efficiency, flexibility and energy flow. Flexibility means the ability of the converter to maintain the output with the varying input. Whereas the energy flow means the continuous current to the converter. PV pumping systems without battery can provide a cost effective use of solar energy. Following are the features of current topology: high efficiency due to the low energy available; low cost; no need to manual operating; requires less maintenance, and high life span comparable to the usable life of 20 years of a PV panel.

I. PROPOSED SYSTEM

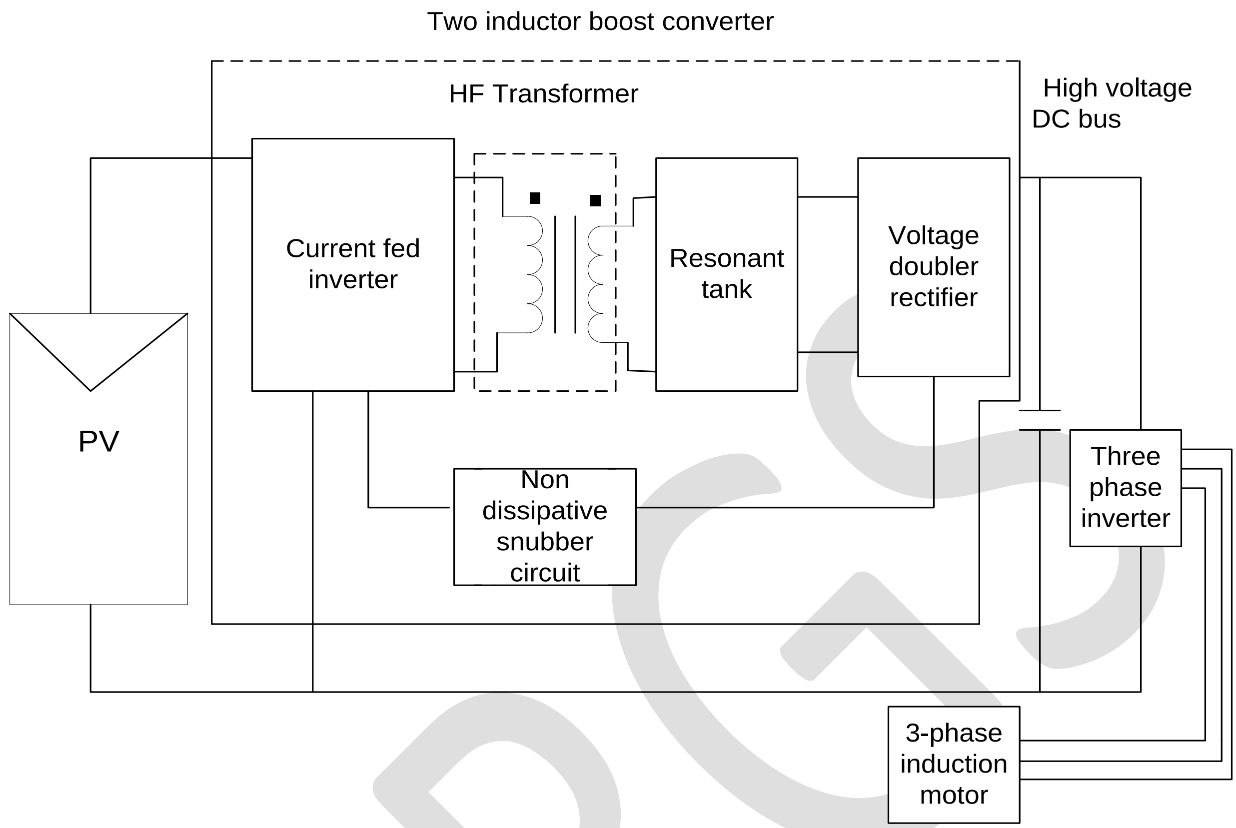

Figure 1: Simplified block diagram of proposed system

The proposed system mainly consists of two inductor boost converter (TIBC) DC-DC converter, three phase inverter and three phase induction motor. The boost converter comprises of current fed inverter, high frequency transformer, non-dissipative snubber circuit, resonant tank and voltage double rectifier. The sunlight directly fell on the PV panel then the solar energy converted into electrical energy. The energy produced by the panel is fed to the motor through a converter withtwo power stages: a DC/DC TIBC stage to boost the voltage of the panels and aDC/AC three-phase inverter to convert the DC voltage to three-phase AC voltage.

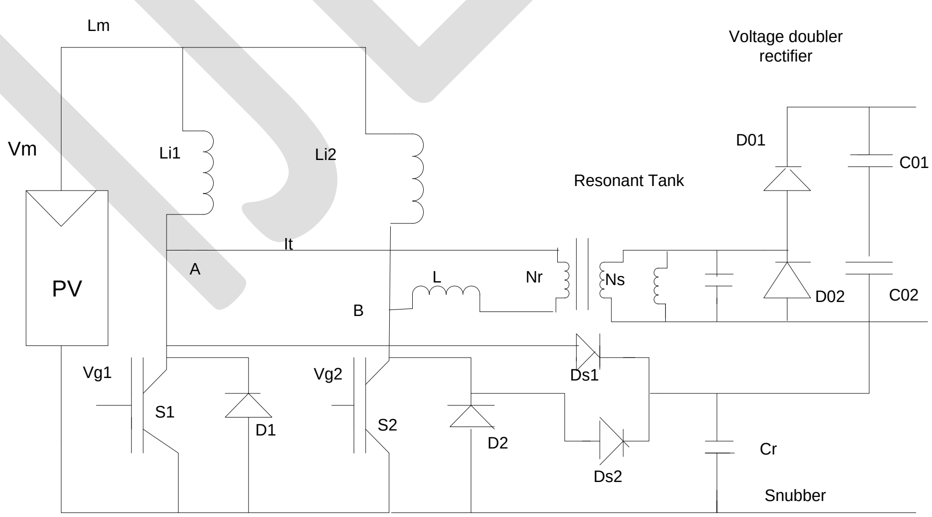

Figure 2: Proposed two inductor boost converter

To analyze the proposed converter some of the assumptions are need to take during switching interval. The input inductors L_{i1},L_{i2} are large so that their current is almost constant. The capacitors C_{o1},C_{o2} and C_s also large enough to maintain constant voltage but the output capacitors C_{o1} and C_{o2} are much larger than C_r to clamp the voltage.

In hard switching operation of TIBC both switches S1 and S2 operates at an overlapped at a duty cycle. When both switches S1 and S2 are turned ON L_{i1}, L_{i2} are charged by the input energy. When S1 is open the energy stores in L_{i1} is transferred to C_{o1} through the transformer and rectifier diode D_{o1}.Similarly when S2 is opened the energy stores in L_{i2} is transferred to C_{o2} through the transformer and rectifier diode D_{o2}.

There are two resonant process occur when multi resonant tank is introduced. They are

1. When both switches are closed the leakageinductance L_r participates along with capacitance C_r in the resonance at the primary current switching and current polarity inversion here the ZCS operation occurs.
2. At the time of conduction time interval.
3. If any switch is on L_r is associated in series with L_{i1} and L_{i2} not participating on the transformers secondary current resonance formed only by L_m and C_r.

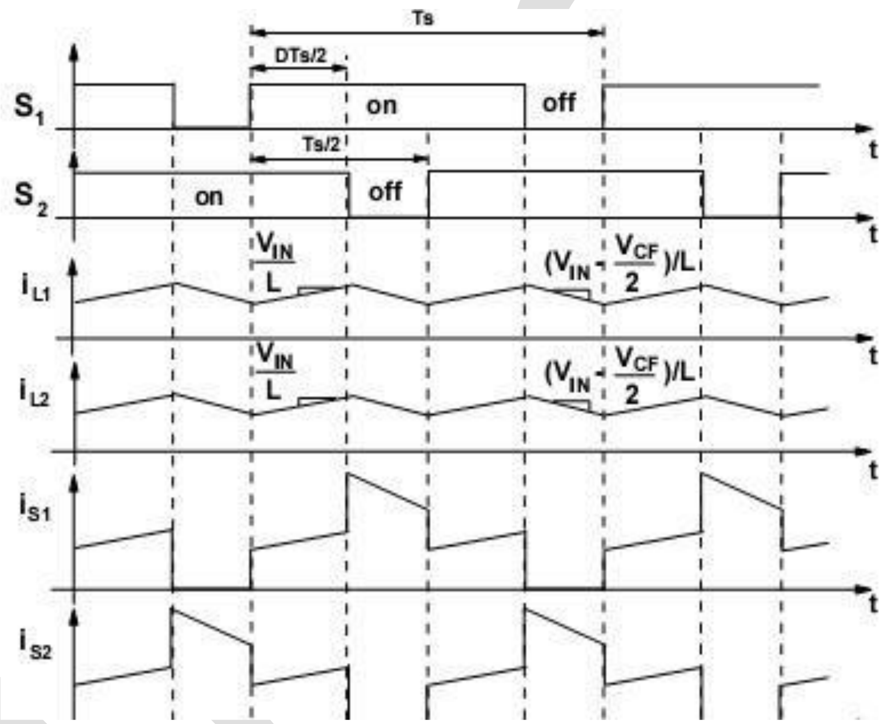

Figure 3: ON & OFF conditions of switches S_1& S_2

III.PROPOSED FUZZY LOGIC CONTROLLER

There are so many logic controllers are used to control the system. Previously there are three main control systems are used they are fixed duty cycle control, MPPT control, Hysteresis control.The operation of fixed duty cycle makes the converter work with the constant voltage gain.

$$\frac{Vout}{Vin} = Kv = \frac{1}{1-D}\left(2\frac{Ns}{Np} + 1\right) \text{ ----- (1)}$$

Where D represents duty cycle of switch

Ns/Np represents the transformers turns ratio

a. FUZZY LOGIC CONTROLLER APPLIED TODC – DC CONVERTER

In 1975 scientist called Mamdani and Assilian were invented fuzzy inference technique. They first attempt was to control the steam engine and boiler by using set of linguistic rules that are obtained from human operators.

Through a Fuzzy Logic Controller is an expert it can operate by its knowledge and observation without any mathematical equations. The FLC consists of following components:

The fuzzification: It converts the real input values to fuzzy values to be interpreted by the inference mechanism. The rule-base (a set of if-then) it contains the fuzzy values by means of a linguistic approach to attain good control of the converter.

Inference mechanism: It emulates the best way to control the system by taking the experts decision.

The defuzzification:It makes the quite opposite to the fuzzification takes the inference mechanism values and converts them into actual output values. To design the fuzzy logic control it is necessary to define the inputs given below; the first input is the error (e(k)) the equation of error is given by equation (2) and $V_{Ref}$is the voltage reference. The second input is change in error(Δe (k))is given by the equation (3) where *e(k)* is the error at the *k*th sampling and *e(k-1)* is the error at the previous *k*th sampling.

$$e(k) = V_{Ref} - V_0(k) \qquad \text{----- (2)}$$

$$\Delta e(k) = e(k) - e(k-1) \qquad \text{----- (3)}$$

Vo(k)is the sampled output voltage of the boost converter

$V_{Ref}$is the voltage reference.

Those inputs are multiplied by gains g0and g1 respectively and then they are evaluated in the fuzzy controller. The FLC output is the change in the duty cycle Δd (k)which is given by the equation (4)and it is scaled by the gain *h*.

$$d(k) = d(k-1) + h\Delta d(k)T_s \qquad \text{----- (4)}$$

Where $\Delta d(k)$ is the change in duty cycle of the Kthsample.

b. Rule Base

The rule base is defined relation between the inputs and output with the rules of type *IF-THEN*. There are 11 fuzzy sets for each linguistic variable which generates 121 rules that can be expressed as a Mamdani linguistic fuzzy model, the rule base equation is given below

IF e is $Ai_1$and Δe isAi_2, THEN Δd_i is B_i --------- (5)

Where e and Δeare the input linguistic variables, Δd_i the output linguistic variable, $Ai_1$and $Ai_2$are the values for each input linguistic variables on the universe of discourse and B_i is the value in output in the universe of discourse.

Table I: Fuzzy Rules relating Linguistic Variables

	Change in Error (CE)										
Error	NVB	NB	NM	NS	NVS	ZE	PVS	PS	PM	PB	PVB
NVB	PVB	PVB	PVB	PVB	PVB	PVB	PB	PM	PS	PVS	ZE
NB	PVB	PVB	PVB	PVB	PVB	PB	PM	PS	PVS	ZE	NVS
NM	PVB	PVB	PVB	PVB	PB	PM	PS	PVS	ZE	NVS	NS
NS	PVB	PVB	PVB	PB	PM	PS	PVS	ZE	NVS	NS	NM
NVS	PVB	PVB	PB	PM	PS	PVS	ZE	NVS	NS	NM	NB
ZE	PVB	PB	PM	PS	PVS	ZE	NVS	NS	NM	NB	NVB
PVS	PB	PM	PS	PVS	ZE	NVS	NS	NM	NB	NVB	NVB
PS	PM	PS	PVS	ZE	NVS	NS	NM	NB	NVB	NVB	NVB
PM	PS	PVS	ZE	NVS	NS	NM	NB	NVB	NVB	NVB	NVB
PB	PVS	ZE	NVS	NS	NM	NB	NVB	NVB	NVB	NVB	NVB
PVB	ZE	NVS	NS	NM	NB	NVB	NVB	NVB	NVB	NVB	NVB

IV SYSTEM DESIGNPARAMETERS

A. Specifications:

The project is carried out by using MATLAB software. The specifications of

Parasitic elements used in the converter are given in below table II.

Parameters	**Values**
Converter input current ripple	5%
Nominal bus voltage	350v
TIBC Switching frequency	100KHZ
Inverter switching frequency	7.7KHZ
Constant voltage gain	11.69
Transformers turns ratio N_{s}/N_{p}	2.25

Table II: Converter design specifications

The main parameters of the used motor and panel specifications are given in table III.

Parameters	**Values**
PV model	KD210GX
PV power	210W

International Journal of Engineering Research and General Science Volume 6, Issue 4, July-August, 2018
ISSN 2091-2730

PV open circuit voltage	29.9v
PV short circuit voltage	6.98A
PV maximum MPP voltage	26.6v
Motor Nominal power	0.2 HP
Motor Nominal Voltage	220V
Motor nominal frequency;	60hz

Table III: Motor and Panel specifications.

B.SIMULATION RESULTS

PV panel outputs:

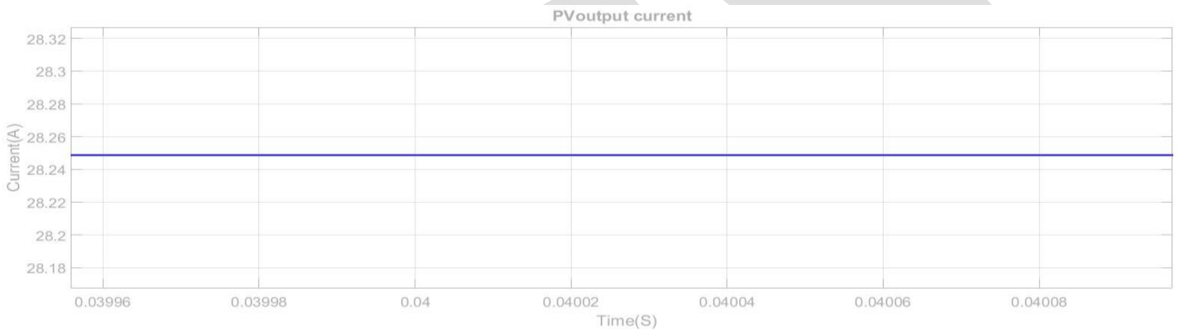

FIGURE 4: Current from PV panel

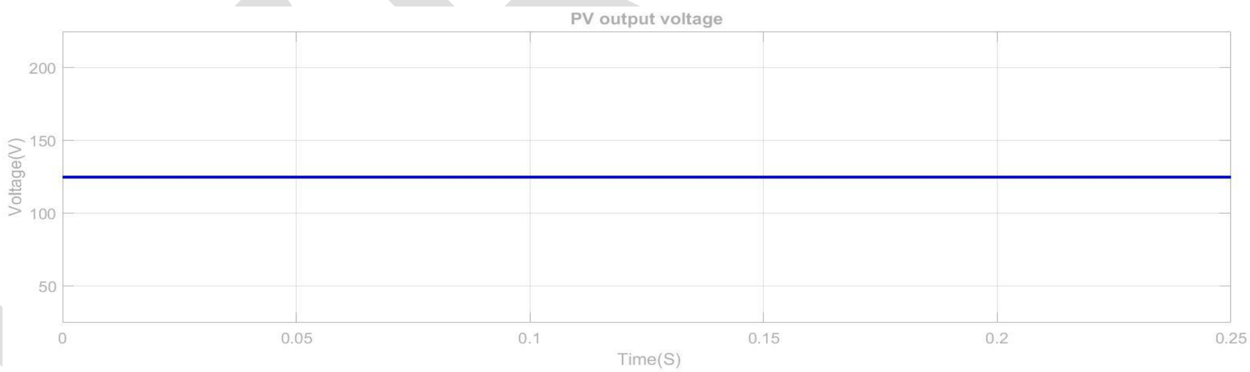

Figure 5: Voltage from PV panel

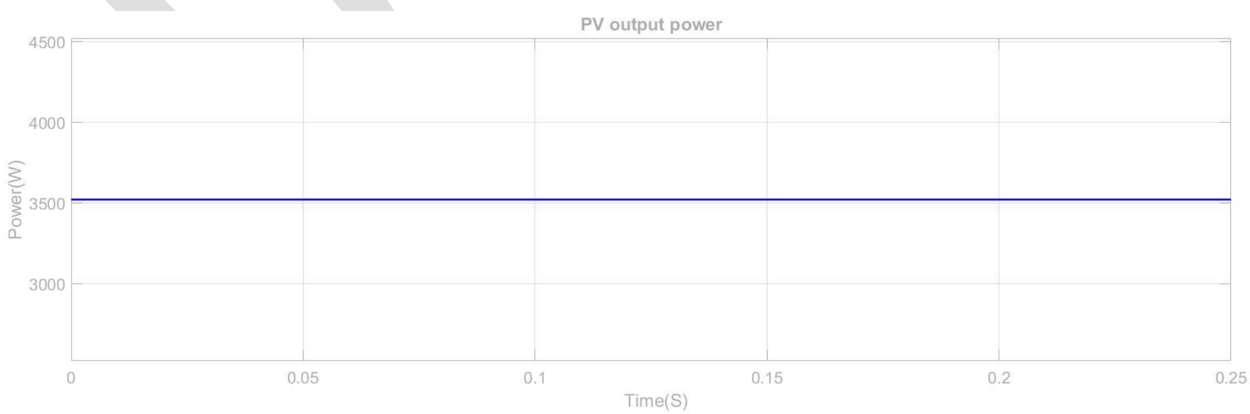

Figure 6: Power from PV panel

International Journal of Engineering Research and General Science Volume 6, Issue 4, July-August, 2018
ISSN 2091-2730

MOSFET output waveforms:

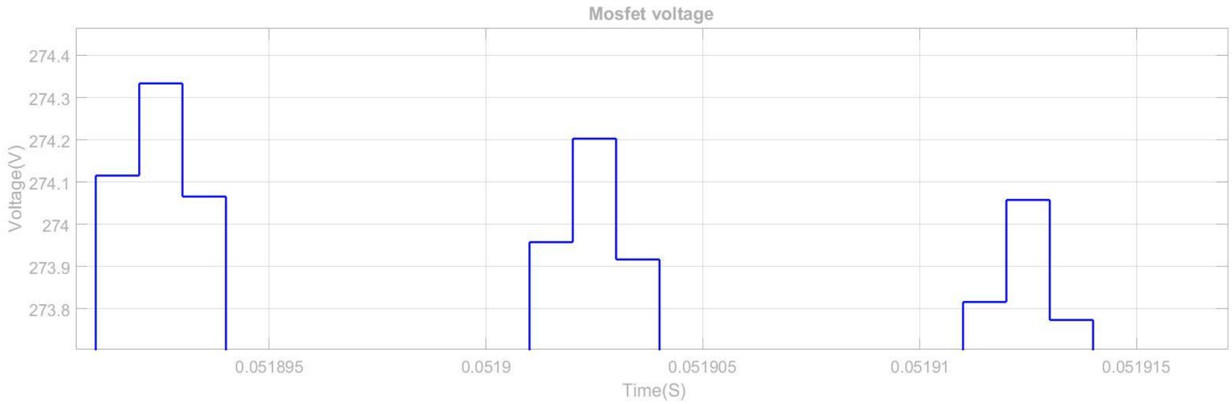

FIGURE 7:MOSFET S_2 Voltage

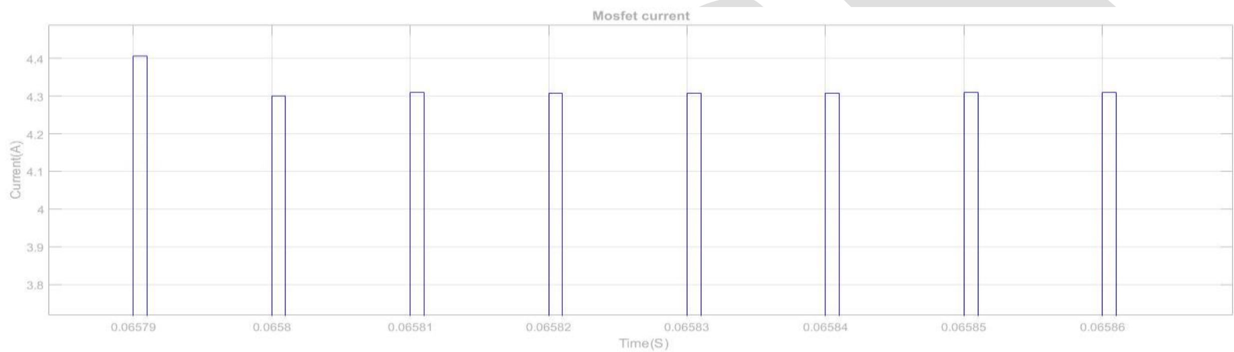

Figure 8:MOSFETS_2Current

DC output waveforms:

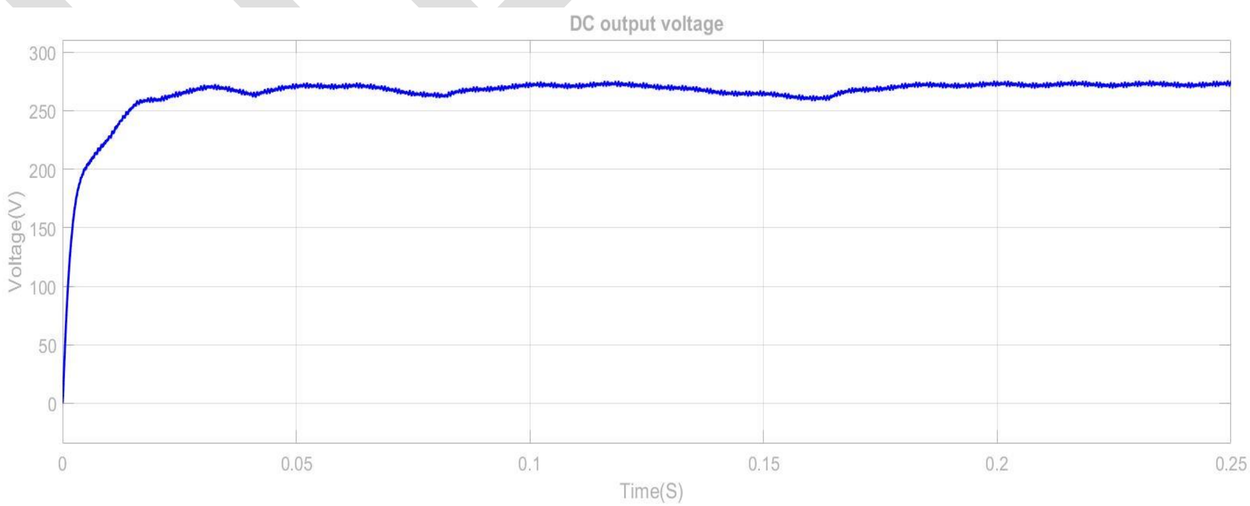

Figure 9:DC output voltage

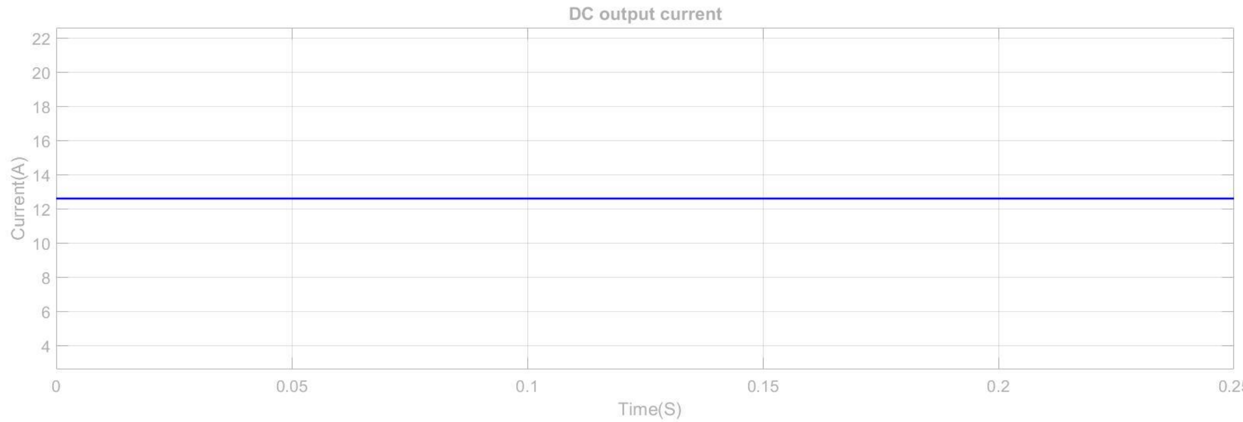

Figure 10:DC output current

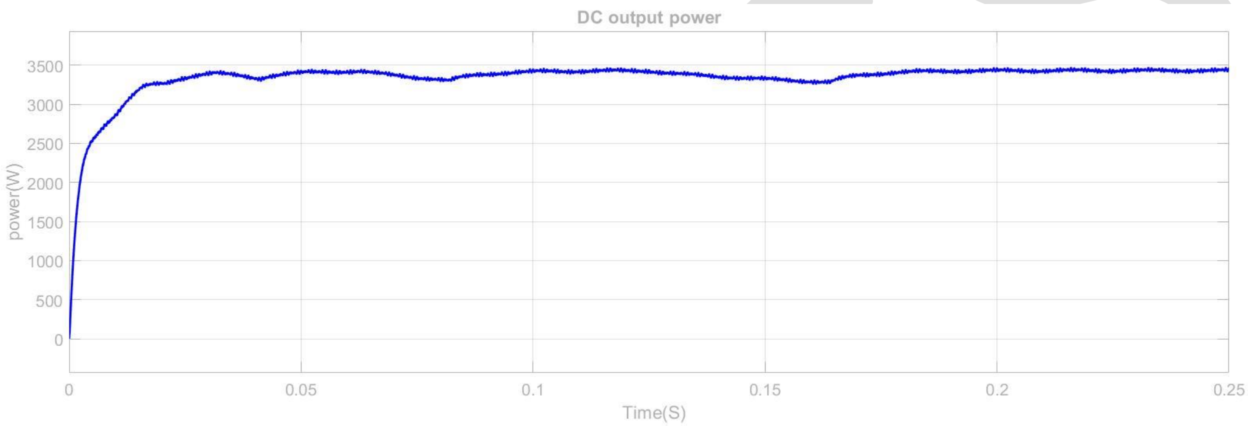

Figure 11: DC output power

Motor output characteristics:

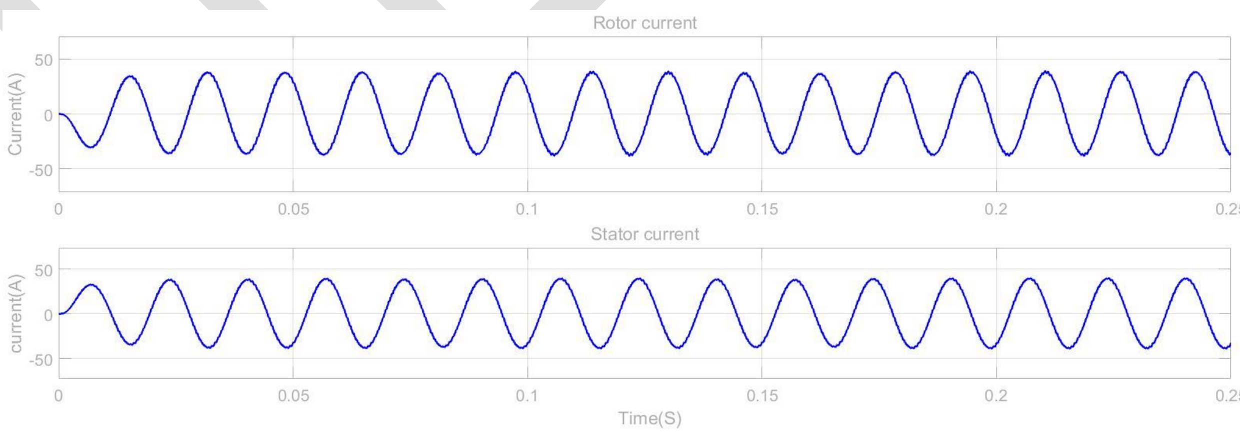

Figure12: Stator rotor current

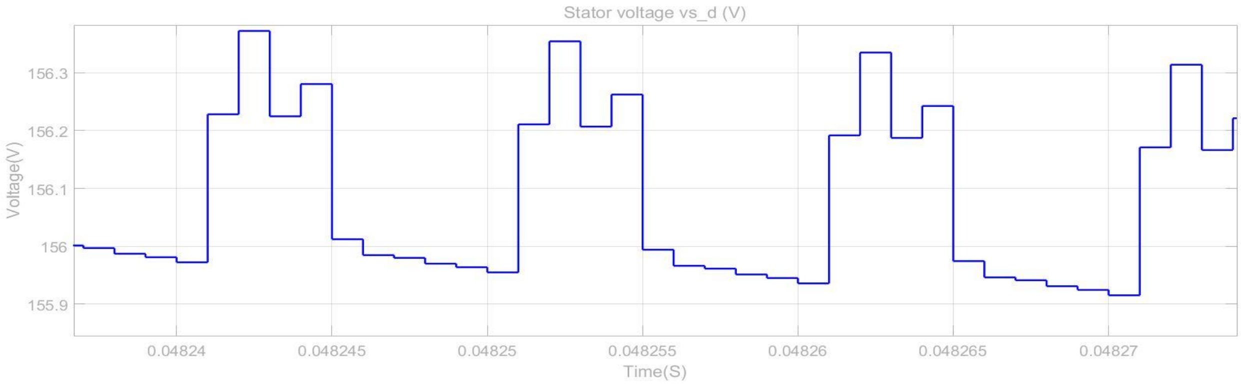

Figure 13:d-axis Stator voltage (v)

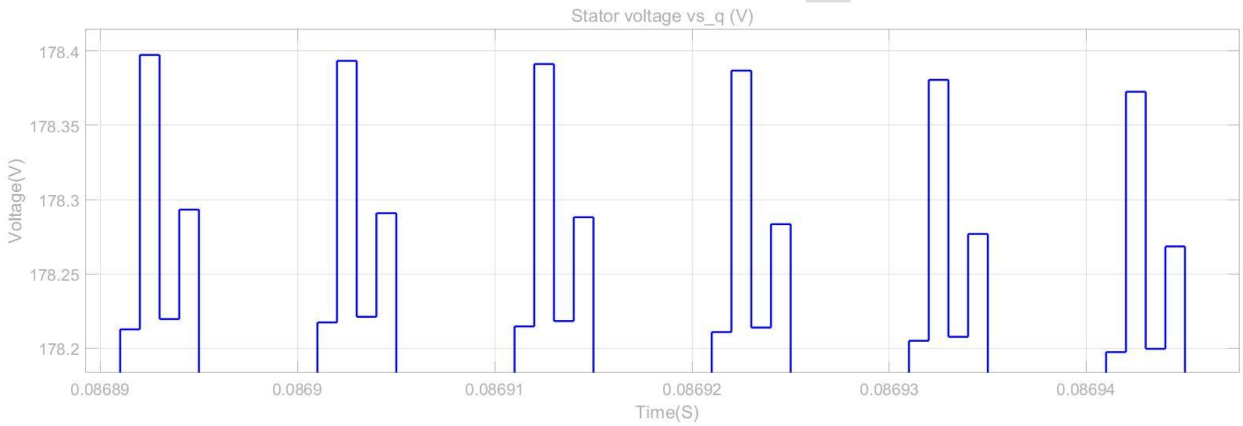

Figure 14:q-axis stator voltage (v)

Three phase inverter waveforms:

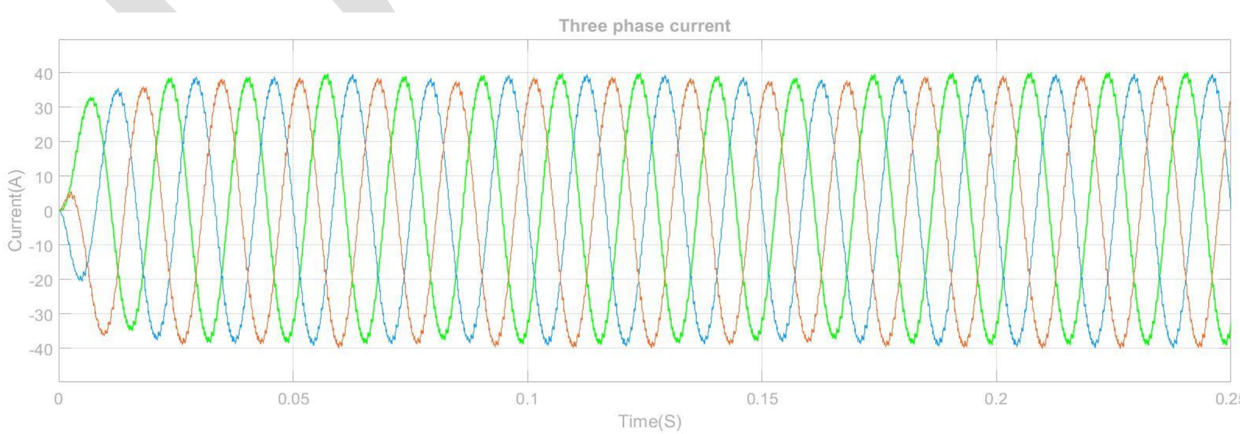

Figure 15: Three phase inverter current

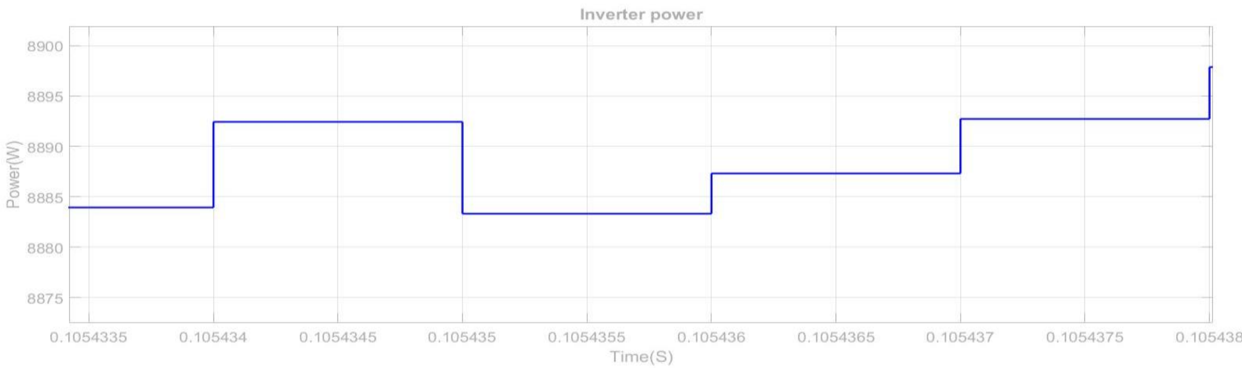

Figure 16: Inverter power

CONCLUSION

This paper presented a converter for photovoltaic water pumping and treatment systems without the use of storage elements. The converter was designed to drive a three-phase induction motor directly from PV solar energy and was conceived to be a commercially viable solution having low cost, high efficiency and robustness.

REFERENCES:

[1] P Sadasivam, MKumaravel, Krishna Vasudevan and Ashok Jhunjhunwala, "Analysis of Subsystems Behaviour and Performance Evaluation of Solar Photovoltaic Powered Water Pumping System", Indian Institute of Technology Madras, Chennai, Tamilnadu, 600036, India 2014.

[2] Author H. Harsono, "Photovoltaic water pump system", Ph.D. dissertation, Dept. Intell. \
Mech. Syst. Eng., Faculty Kochi Univ. Technol., Kochi, Japan, Aug. 2003

[3] M. A. Vitorino and M. B. R. Correa, "High performance photovoltaic pumping system using induction motor", in Proc. Brazilian Power Electron. Conf., 2009, pp. 797804.

[4] Mohammed A. Elgendy, Bashar Zahawi and David J. Atkinson, "Assessment of Perturb and Observe MPPT Algorithm Implementation Techniques for PV Pumping Applications", IEEE Transactions on sustainable Energy, Vol. 3, No. 1, January 2012.

[5] Ali HmidetRabiaaGammoudi and Othman Hasnaoui and RachidDhifaouiHammamet, "Analog MPPT Controller Circuit used in Photovoltaic Pumping Systems", The fifth International Renewable Energy Congress IREC 2014 March 25.

[6] dr. A. Moussi , a. Saadi, a. Betka, g.m. Asher,"photovoltaic pumping system technologies and trends", larhyss journal, issn 1112-3680, june 2003.

[7] b.chittibabu, r. Sudharshankaarthik, nayankumardalei, r.vigneshwaran, rabinarayan das,"pv energy conversion system for water pump applications– modeling & simulation", department of electrical engineering, nit, 13th january 2013.

[8] victorcaracas, guilherme de carvalhofreitas, louisfelipe, "implementation of a high efficiency, lifetime, and low cost converter for an autonomous pv water pumping system"students member ieee, louisantonio de souza, member ieee, 2013 ieee.

[9] v.chitra and r.s.prabhakar, "induction motor speed control using fuzzy logic controller", world academy of science, engineering and technology 23, 2006.

[10]Guilherme De CarvalhoFarias, Student Member, Ieee,Luis Felipe Moreira Teixeira, Student Member, Ieee, And Luiz Antonio De Souza Ribeiro, Member, Ieee,"Implementation Of A High-Efficiency, High-Lifetime And Low-Cost Converter For An Autonomous Photovoltaic Water Pumping System",Ieee Transactions On Industry Applications, Vol. 50, No. 1, January/February 2014.