SIMULATION OF TIBC BASED PHOTOVOLTAIC INDUCTION MOTOR DRIVE FOR AGRICULTURAL PURPOSE

Neethu Raj P R
PG Scholar
Dept. Of Electrical & Electronics
NSS College of Engineering, Palakkad
neethuraj42@gmail.com

Vasanthi V
Professor
Dept. Of Electrical & Electronics
NSS College of Engineering, Palakkad

***Abstract*— This paper presents water pumping system using renewable source (solar) without the use of chemical storage batteries. This converter-inverter drive system is used to drive the induction motor. The converter used here is two inductor boost converter (TIBC), which consist of a resonant tank, voltage doubler rectifier and a snubber circuit. TIBC is designed to drive the three phase induction motor from PV energy. TIBC converter is also known as current fed multi resonant converter having high voltage gain and low input current ripple. Converter switches are controlled through hysteresis controller and ZCS resonant topologies. Solar PV power fluctuates according to irradiation level of sunlight and hence tracking of maximum power at all time is mandatory. SPWM control with third harmonic injection is used to trigger the IGBT's in the inverter. The development is oriented to achieve a more efficient, reliable, maintenance free and cheaper solution than the standard ones, that uses DC motors or low voltage synchronous motors. The proposed method is verified with MATLAB/SIMULINK and the system simulation confirms the performance of the proposed system**

Keywords–– **PV cell, TIBC-Two inductor boost converter, AC motor drive, MPPT, P&O- Perturb & Observe algorithm**

INTRODUCTION

Lack of electricity is one of the main troubles in the development of rural India. India's grid system is considerably under developed, with major sections of its populace still surviving off-grid. Hence standalone system is most welcome and necessary in rural area of India. Moreover, environmental issues such as population and global warming effects are driving researchers towards the development of renewable energy sources including solar systems. One of the most beneficial applications of PV standalone systems is water pumping, particularly in rural areas that have a considerable amount of solar radiation and have no access to national grids. The presence of batteries allows motor pump system to operate at its rated power even in any conditions of solar radiations [1]. The system with batteries have low life span (average two years) which is very small compared to the useful life of 20 years of solar panel. So a converter inverter drive system is proposed for water pumping application without battery. Such systems are not new, which have been developed more than three decades, but most of the available

converters in India are based on the intermediate energy storage systems ie, it is performed with the use of lead acid batteries[2].

The majority of previously proposed commercial systems use low voltage DC motors [3]. The drawback of such a system is, DC motors have less efficiency and require high maintenance due to the presence of commutators and brushes in it. Due to this reason DC motors cannot be used in isolated areas, where specialized persons are not available for its maintenance and operation. More sophisticated systems have already been developed with the use of low voltage synchronous motor. But such systems are too expensive [4][5]. So it can't be used in poor communities. In [6] PV is integrated with fuel cell for water pumping. But the major problems are the cost of fuel cell and the available technology of fuel cell is at moderate level in India. The design of induction motor drive system without battery demands the solution for the operation of drive under variable power restrictions in [7]. Due to this, it demands the high efficient, low cost, robust, high life span DC-DC converter for induction motor based battery less water pumping system. A DC-DC converter is needed to boost the output voltage of PV panel. Many of the voltage fed converters have already been developed for the same [8]. Due to the presence of large input current ripple; these converters are forces to place the large filter capacitor at its input side. Basically it is electrolytic in nature, which has small life time; thus it affects the overall life span of the system before failure of the converter. The current fed converters offers more advantages than voltage fed converters. The current fed converters are derived from boost converters, so it consists of inductor at its input side. This inductor itself reduce large input current ripple, thus it eliminate the need of large electrolytic capacitors. The classical topologies of this kind are current fed push pull converter [9, 10] the current fed full bridge [11].These converters still have high voltage spike due to leakage inductance of the transformer. The resonant topologies are able to utilize the parasitic components such as leakage input current ripple, thus it eliminate the need of large electrolytic capacitors. The classical topologies of this kind are current fed push pull converter [9, 10] the current fed full bridge [11].These converters still have high voltage spike due to leakage inductance of the transformer. The resonant topologies are able to utilize the parasitic components such as leakage inductance and winding capacitance of transformer to achieve zero current switching (ZCS). The presence of voltage doubler circuit again reduces the needed transformer turns ratio. So a cheaper transformer can be used in the proposed converter. This paper is organized as following sections. In section II proposed system is described. In section III & IV describes control strategy and design respectively. Simulation results are discussed in section V.

II. PROPOSED SYSTEM

The entire system was designed to use a single PV module to meet the requirements ie low cost and higher efficiency. The maximum power developed by the panel is fed to induction motor drive through converter. The proposed system consists of two power stages. A DC-DC two inductor boost converter (TIBC) stage to boost the voltage of the panel and a three phase inverter to convert the DC output of TIBC converter to three phase AC voltage. The block diagram of the proposed converter is shown in fig.1.The inverter is based on classical topology and it uses sine PWM (SPWM) strategy with third harmonic injection [12]. Third Harmonic injection improves the output voltage level compared to ordinary SPWM and it cancels all third harmonic and its multiples.

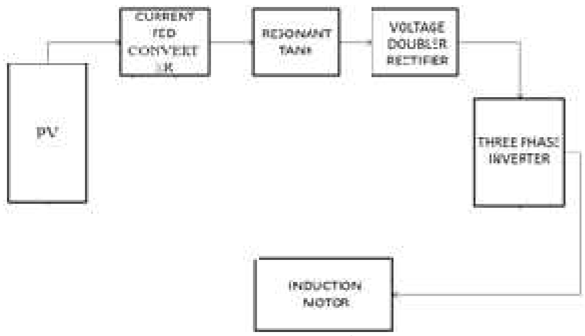


Fig.1 Block Diagram of the proposed system

The current fed converter used in the proposed system is shown in fig.2. This converter consists of two inductors at its input side, hence it is known as two inductor boost converter. The classical TIBC require minimum operating load to maintain its output voltage. ie TIBC can't be operated in no load or low load condition. In such condition TIBC input inductors are charged even if there is no load current. So the energy transferred to the capacitor can't transfer completely to load which results increase in output voltage. In the proposed system motor is variable load.so it will demand low power at low speed or at transients (start up & stop). To solve such condition Hysteresis controller with snubber can be used.

The main features of this converter are that small number of components, simple circuit, easy transformer flux balance [13, 14] common ground gate driving for both input switches.

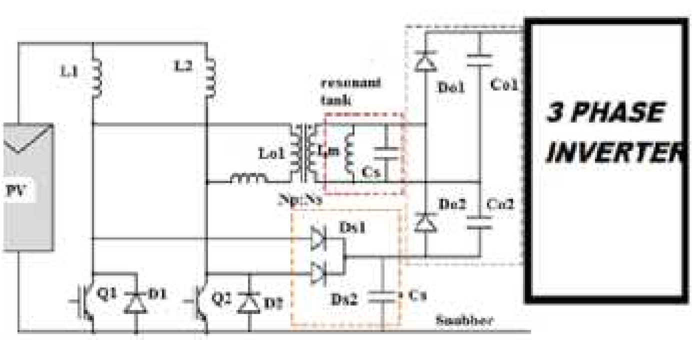


Fig.2.Modifeid TIBC Converter

One important feature is the input current is distributed equally through the two inductors, thus its current ripple amplitude is halved at twice the switching frequency. The presence of snubber circuits makes the converter as a non isolated converter, which has no undesirable effect on PV motor drive.

The TIBC is operated on the basis of overlapped fixed duty cycle. During one switching period two resonant processes are occurring. 1) When both input switches are turned on, then the leakage inductance L_r is also participated in the resonance with C_r α L_m. 2) when at least one switch is opened, then L_m and C_r participated in the resonance.

The hysteresis controller is active only when the output voltage of the converter higher than threshold value. With the help of added snubber the primary switches are turned off because there is still a path for the current in input inductors and the energy stored in the inductor directly transferred to the snubber capacitors. Due to turn off of the switch output voltage starts to decrease and switches will again turn on with fixed duty cycle when output voltage reaches lower threshold.

The fig.3 shown below is the inverter circuit. The output of the TIBC Converter given to inverter fed induction motor. Inverter is operated on the basis of sine pulse width modulation (SPWM) with third harmonic injection. SPWM with third harmonic injection cancels third harmonics and its multiples.

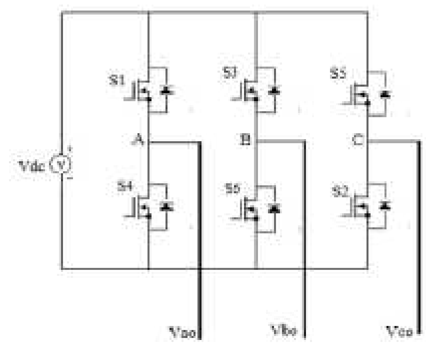


Fig.3.Inverter circuit

III. CONTROL OF THE SYSTEM

The entire control of the system consists of three main aspects.

1) During the normal operating condition, fixed duty cycle switching scheme is used to control the input switches.
2) Hysteresis control is used during no load and start up of the system. Since motor is a variable load so it will demand low power at some operating points. (low speed and start up/stop transients). So in such condition hysteresis controller along with fixed duty cycle is used.
3) MPPT algorithm along with PI controller and V/F controller is used to set the speed of the motor and thus achieving the energy balance of the system at MPP voltage.

IV.a) Fixed Duty cycle control

Two inductor boost converter is a multi resonant converter. ie two resonant process are occur in one switching period. In order to occur resonance, definite time interval in the switching period are necessary. The converter may no longer operate at ZCS condition, by altering the fixed Duty cycle or switching period for controlling the output of the converter. To avoid this condition, fixed Duty cycle should be used. The operation of fixed Duty cycle is to make the converter to works with constant voltage gain K_V.

$$\frac{V_o}{V_i} = K_V \frac{1}{1-D}(2\frac{N_s}{N_p} + 1)$$

Where $\frac{N_S}{N_P}$ is the turns ratio of the transformer.

IV. b) Hysteresis Controller

The proposed system uses modified TIBC. Classical TIBC doesn't consist of hysteresis controller and snubber circuit. The classical TIBC can't operate in the no load or low load conditions. This modified TIBC with snubber uses hysteresis controller for overcome the low load conditions.

IV.c) MPPT Controller

Photovoltaic system has nonlinear current vs voltage and power vs voltage characteristics, continuously varied with irradiation and temperature. It is shown in figure 4. This curve is for particular value of irradiation and temperature. V_m is the voltage corresponding to maximum power P_m. There are many MPPT (Maximum Power Point Tracking) algorithms are available to track the continuously varying maximum power of the PV array. The task of a MPPT in PV system is to continuously tune the system so that it draws maximum power from the solar array regardless of weather or load condition. MPPT algorithm helps to keep the operating point of the system at MPP voltage.

In the proposed system perturb and observe method is used because of its simple implementation and fast dynamic response [15]. This MPPT method is based on the shape of the power vs voltage curve of the panel.

IV.d) V/F Controller (inverter drive control)

One important thing is that, there should be a minimum DC voltage on the inverter DC bus necessary to drive the motor at a specified power level. To satisfy this condition, the v/f controller was used to maintain approximately constant motor flux. This controller generates nominal torque at any speed below its rated value. Consider that the centrifugal water pump has its torque proportional to the square of the motor speed and that the frequency (f) in the volt/hertz control is proportional to the voltage (V) , the motor output power (P) can be expressed as a cubic function of the motor voltage.

The overview of the control system is shown in fig.4

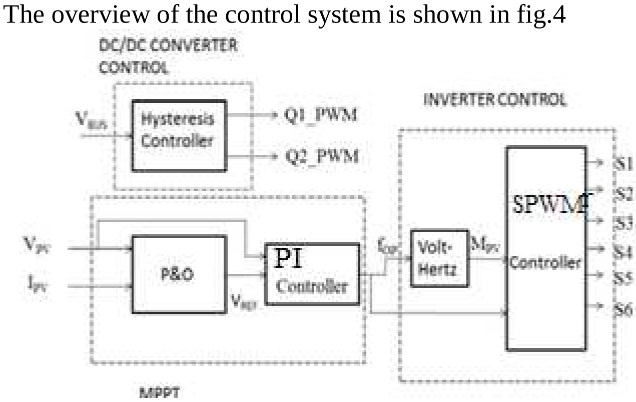


Fig.4control of the system

Based on the measured voltage and current, the MPPT algorithm along with PI controller estimates the operating frequency. The motor is drives at this frequency. A v/f controller calculates the modulation index for the switching pattern. The switching is done by SPWM with third harmonic injection.

V. SIMULATION RESULTS & DISCUSSIONS

The figure 5 below shows the simulation set up of converter.

The proposed system is verified with MATLAB/SIMULINK version 2014. The 26 V from the PV array using MPPT algorithm is as input and produce 350V output. The control of the primary switches was simulated using a fixed duty cycle and a Hysteresis controller with its upper limit and lower limits are 360 and 340 respectively. The fig. 6 .a) shows the output voltage, it is 350V. From fig.6.b) average input current is 11.8 A. This current is distributed through inductors and its average value is 5.4 A. shown in fig. 6.c).

The ZCS condition of input switch is shown in fig. 6.d). The figure show that both turn on & turn off occurs at almost ZCS.

Fig. 6.e) shows drain to source voltage of the switches. It is observed that there are no voltage spikes or increased voltage stress over the switches. It is shown that diode also satisfy the ZCS condition. The operation under ZCS condition allows the use of fast recovery diodes instead of expensive silicon carbide ones, thus reducing the cost of the system

Fig.7 simulation set up of inverter motor Drive. The simulation parameters are as follows.

Switching frequency of inverter is taken as 27* 60 KHz

Motor specification: 5 HP, 4 pole, 1800 rpm, flux= (1/60)

The simulation results for different values of PV current corresponding to irradiation is shown below in table II.

Initially speed of the motor is very small (due to inertia it can't run at maximum speed), it take some time to reach steady state. At time t=30 sec, a small increase in speed due to change in solar irradiation. The solar radiation is made to change at t= 30s.

Upto 30 Sec, its speed is 1460 rpm because the output of PI controller (after processing the MPP voltage and pv voltage) is 49 Hz. After that the speed changes to 1600 rpm corresponding to the frequency 54 Hz. This is because solar irradiation is made to change at 30 Sec, Mpp voltage is determined by using the hill climbing algorithm. The fig. 8.b) shows the estimated frequency ie output of PI controller.

Centrifugal pump is like fan load. So load torque T= Kw^2.it is shown in fig.8.c). The inverter is controlled by using the SPWM with third harmonic injection. Fig. 8.d) shows the modulating wave with harmonic injection.

Fig 8.e) shows the output power of the motor. Up to 30 s, output power of induction motor drive is 1325W. The power is changes to 1720W at 30 s, due to change in solar irradiation.

TABLE I SIMULATION PARAMERTERS (CONVERTER)

Components	Value
Input inductors Li1& Li2	100 micro Henry
Leakage Inductance Lr	1.3 micro Henry
Magnetizing inductance Lm	3083 micro Henry
Snubber capacitor Cs1	4.5 micro farad
Output Capacitor	1.5micro Farad
transformer	N2/N1=2.3
Resonant capacitor	5.8 nano Farad

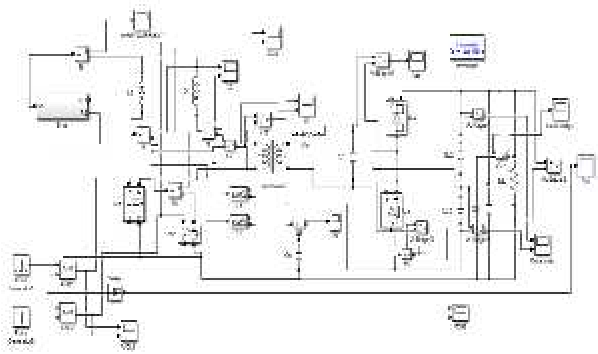
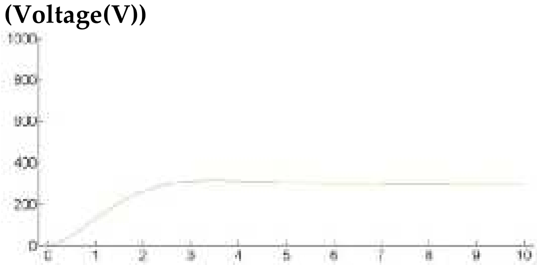


Fig.5.simulation set up of converter

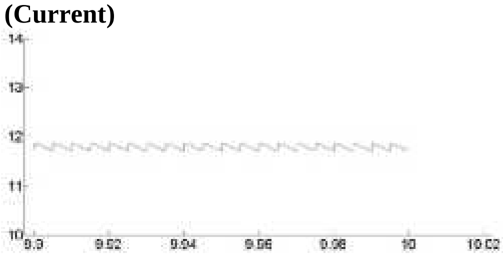
(Voltage(V))



time(s)

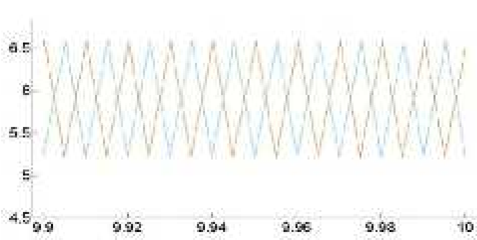
(a)

(Current)



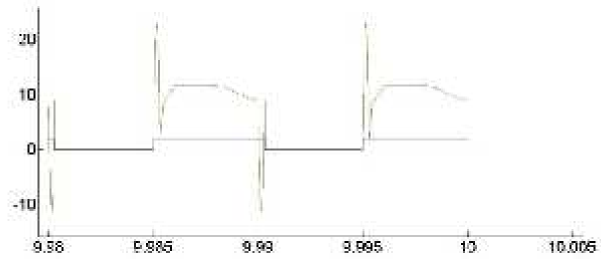
time (s)

Current (b)



time (s)

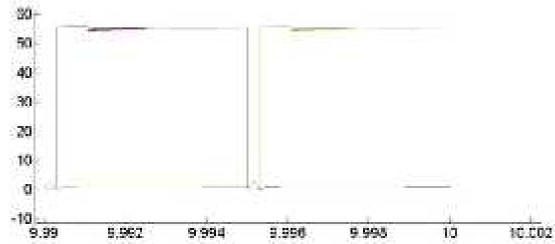
(Current (A))



time(s)

(d)

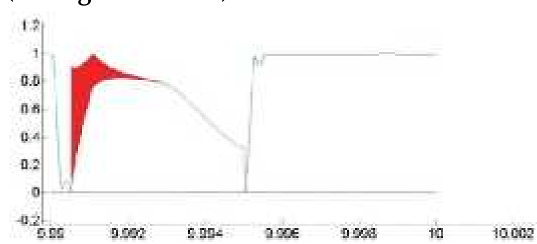
(Voltage(V))



time (s)

(e)

(Voltage & current)



time (s)

(F)

Fig.6 Simulation of Converter (a) output voltage, (b) input current, (c) current through inductors, (d) ZCS condition of switch Q_1 , (d) voltage across switches, (e) ZCS condition of rectifying Diode

.

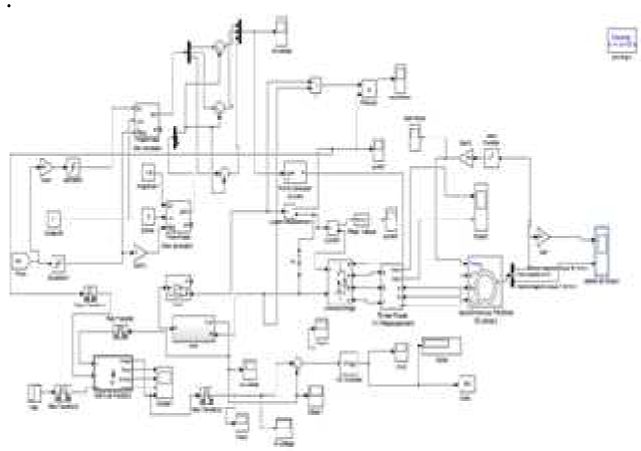


Fig.7 shows the simulation set up of inverter fed induction motor drive.

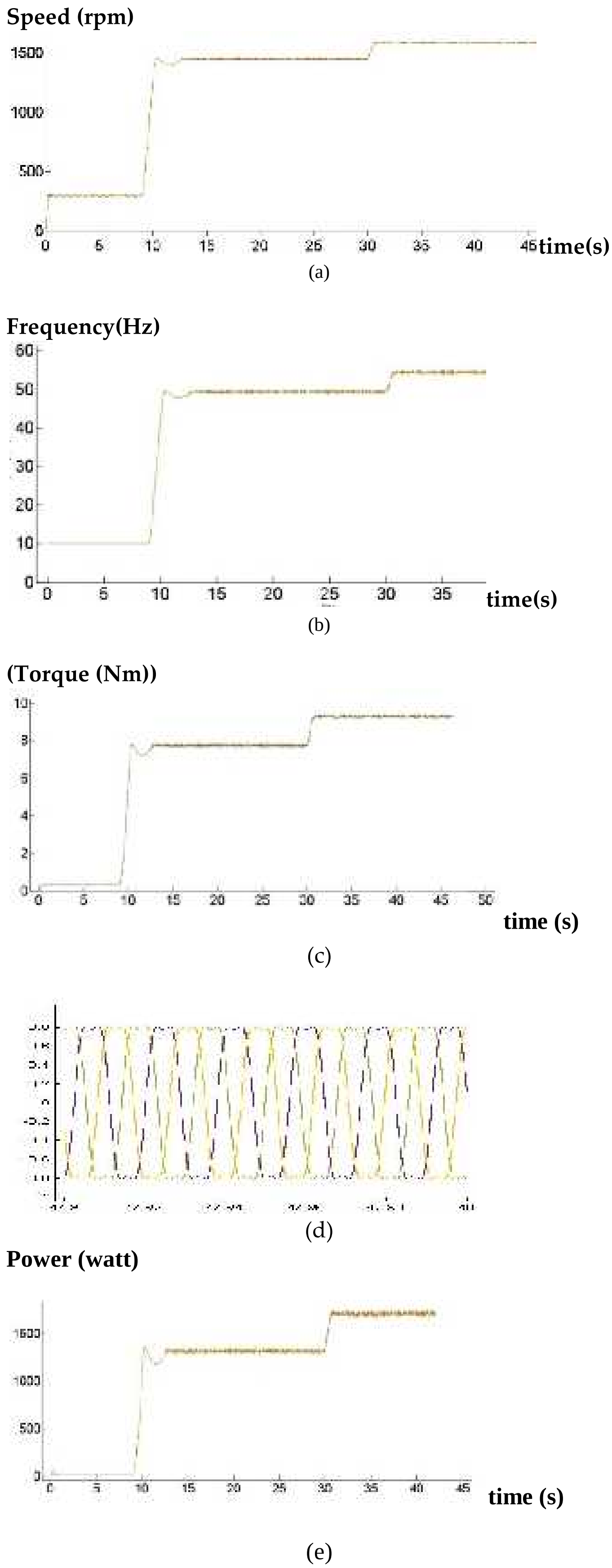


Fig. 8 Simulation of Inverter Drive (a) Speed of the Motor, (b) output of PI controller, (c) Load Torque, (d) modulating wave with third harmonic injection, (e) output power of Induction motor drive

TABLE II. SIMULATION RESULTS

PV current (amp)	PV power (input -watt)	Speed (rpm)	Load Torque (Nm)	Output power (watt)	Efficiency (%)
1	460	860	2.75	430	93.47
2	890	1210	5.25	830	93.25
3	1410	1460	7.8	1325	93.97
4	1840	1600	9.3	1720	93.47

VII. CONCLUSION

In this proposed system, a converter inverter drive system for water pumping using a photovoltaic array is analysed. 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. The TIBC converter used here has low input current ripple, low cost and high step-up characteristics. The multi resonant tank provides high voltage gain and absorbs the parasitic parameters of the transformer. By employing the voltage doubler at the load side, the turns ratio of transformer could be halved. With this TIBC system, the input voltage of 26.6 Volts is boosted to 350 volts. The output of the converter system is given to the inverter system and motor is controlled under v/f strategy. Here SPWM with third harmonic injection control is used. MPPT control is provided to operate the PV cell at maximum power.

REFERENCES

[1] H. Harsono, “Photovoltaic water pump system,” Ph.D. dissertation, Dept. Intell. Mech. Syst. Eng., Faculty Kochi Univ. Technol., Kochi, Japan, Aug. 2003

[2] M. Chunting, M. B. R. Correa, and J. O. P. Pinto, “The IEEE 2011international future energy challenge—Request for proposals,” in Proc. IFEC, 2010, pp. 1–24

[3] D. Tschanz, H. Lovatt, A. Vezzini, and V. Perrenoud, “A multi-functional converter for a reduced cost, solar powered, water pump,” in Proc. IEEE ISIE , 2010, pp. 568–572

[4] G.Terode, K. Hameyer, and R. Belmans, “sensorless control of a permanent magnet synchronous motor for PV powered water pump system using the extended kalman filter” in Electrical Machines and Drives, 1999.Nineth International Conference on (Con.publ.No.468), pp.366-370, 1999

[5] M. Dubey, S. Sharma, and R. Saxena, “Solar pv standalone water pumping system employing pmsm drive”in Electrical Electronics and Computer science (SCEECS), 2014 IEEE Students Conference on pp. 1-6, March 2014

[6] A.B.C.S.B. Slama and A chrif, “Efficient design of a hybrid (pv-fc) water pumping system with separate mppt control algorithm,” IJCSNS International journal of Computer Science and Network Security, vol.12, pp. 53-60, January 2012.

[7] M. A. Vitorino, M. B. R. Correa, C. B. Jacobina, and A. M. N. Lima, “Aneffective induction motor control for photovoltaic pumping,” *IEEE Trans.Ind. Electron.*, vol. 58, no. 4, pp. 1162–1170, Apr. 2011.

[8] W. Li, L. Fan, Y. Zhao, X. He, D. Xu, and B. Wu, “High step-up and high efficiency fuel cell power generation system with active clamp flyback forward converter,” *IEEE Trans. Ind. Electron.*, vol. 59, no. 1, pp. 599–610, Jan. 2012.

[9] Ahmed m. Atallah, Almoataz y. Abdelaziz, and Raihan S. Jumaah
“Implementation of perturb and observe mppt of pv system with direct
control method using buck and buckboost converters.Department of electrical power & machine, faculty of engineering,ain shams
University, Cairo, Egypt

[10] N. Barsoum, “Implementation of a prototype for a traditional solar tracking system,” in *Computer Modeling and imulation 2009. EMS '09. Third UKSim European Symposium on*, pp. 23– 30, Nov 2009.

[11] P.Andrada and J.Castro, “Solar photovoltaic water pumping system using a new linear actuator,” in *GAECE, Drives Group Electronically Commutated UPC Depart-ment of Electrical Engineering , Engineering EPS Vilanova Avenue VictorBalagues /n, 08800*.

[12] T. Esram and P. Chapman,“Comparison of photovoltaic array maximum power point tracking techniques,” *Energy Conversion, IEEE Transactions on*, vol. 22, pp. 439–449, June 2007.

[19]. João Victor Mapurunga Caracas, Student Member, IEEE, Guilherme de Carvalho Farias, 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 Autonoomous photovoltaic waterpumping system" IEEE Trannsactions on Industrial applicayions, Vol.50 No.1, January/February 2014

[20] Bo Yuan, Student Member, IEEE, Xu Yang, Member, IEEE, Xiangjun Zeng, Jason Duan, Member, IEEE, Jerry Zhai, and Donghao Li "Analysis and Design of a High Step-up Current-Fed Multiresonant DC–DC Converter With Low Circulating Energy and Zero-Current Switching for All Active Switches" IEEE transactions on industrial electronics, vol. 59, no. 2, february 2012