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High Step-up Converter –Inverter Based Induction Motor Drive System with Various Levels of Solar Irradiation

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Abstract: Recent developments in drives have produced high step up converter based DC-AC converters applied to induction motor drives. High step up converter and inverters find their way between PV and SPIM. This paper deals with High Step-up Converter –Inverter Based Induction Motor Drive (HSCIBIMD), with various levels of solar irradiation .The objective of this work is to minimize the harmonic content in the armature current of HSBIMD system. The output of PV is stepped up using high step up converter, inverted and is applied to the induction motor. This HSCIBIMD system is designed and simulated using MATLAB/simulink and tested using PIC. The hardware results are compared with the simulation results. The results indicate that the harmonics in the load current are minimum. Analysis, simulation results and experimental results are presented in detail.

Keywords- High step up converter-inverter based induction motor drive Photo Voltaic; Voltage Source Inverter; Total Harmonic Distortion.

INTRODUCTION

Power generation from renewable energy sources become popular now-a-days, due to the energy crisis, environmental pollutions and depletion of fossil fuels. Among all the renewable energy sources such as wind energy, fuel cells, tidal energy, etc, Power generation from solar energy using (PV) system has received great attention, in research.[1]-[4]. The PV panels convert light energy into electrical energy and generated low output voltage. Therefore the PV system employs high step-up converter inverter system to transform electrical power to the load or grid [5]. The conventional boost conversion and flyback converts can step up the voltage, but with low efficiency, due to parasitic parameters or leakage inductance. High efficiency of the system can be obtained by having extreme duty cycle and high turns ratio, but results in large conduction losses, diode reverse recovery problems, large leakage inductances and for copper losses in windings respectively. In recent years, many topologies of converters have been developed.[7]-[14]. Among all types of converters, high step-up, DC-DC converter with the inverter improves power-conversion efficiency and provides a stable DC link to the inverter. [15].Fig.1. shows the block diagram of PV system with PV panel and micro inverter along with a floating active switch is designed to isolate the DC current from the PV panel, when AC module is off grid or in the non operating conditions. This isolation ensures the safe operation of internal components. For high step-up operation of DC-DC converters, analysis have been made for switched inductor and switched capacitor type DC-DC converters [16],[17], voltage lift type[18], coupled inductor type [19],[20],with increased turns ratio of coupled inductor to obtain higher voltage gain. Y.Ping Hsieh et-al proposed a novel high step up DC-DC converter [21], utilizes two capacitor and one coupled inductor.

K.Chigh Tseng et-al presented a high step up converter with voltage multiplier modules in [22],to achieve high step up voltage gain .A novel high step-up DC-DC converter with a switched –coupled inductor-capacitor structure is proposed by Hong chantia et-al in [23]. A DC-DC boost converter step up the DC voltage from the PV system in [24], a DC-DC boost converter of 12V/24V closed loop is used in solar powered LED lighting system [25].

The above literature does not deal with PV based high step up converter, inverter system.

The presented work propose high gain step up converter between PV & VSI. The block diagram of conventional system is shown in Fig 1.1. DC is applied to the VSI and the output of VSI is applied to the induction motor.

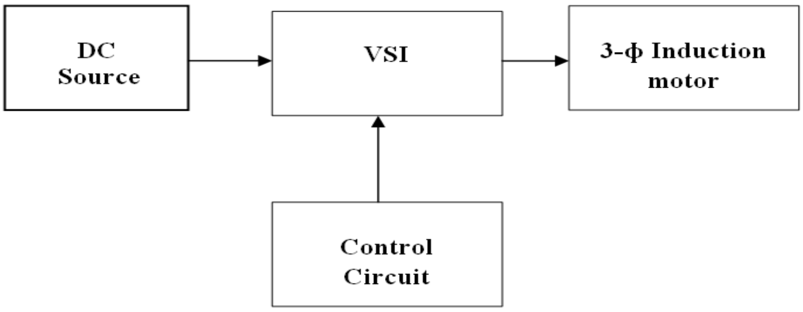

Fig 1.1 Block Diagram of Existing System.

Block diagram of proposed HSCBIMD is shown in Fig 1.2. DC source is replaced by PV system and high gain up converter.

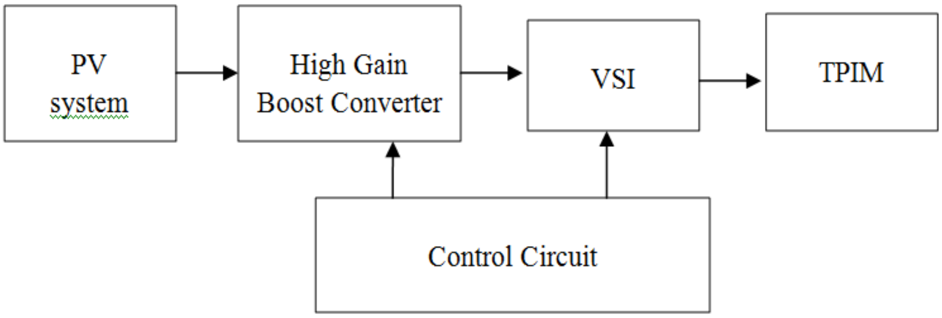

Fig 1.2 Block Diagram of proposed HSCBIMD system

High step up converter is proposed to reduce the voltage ripple at the input of the inverter. The PV system with HSC is shown in Fig 2.1. The proposed high step up converter circuit is shown in Fig.2.2. This circuit consists of a coupled inductor T_1, the number of primary winding N_1 is similar to the inductor present in a conventional boost converter. The capacitor C_1 and the diode D_1 receive leakage inductor energy from N_1. The secondary winding N_2 of coupled inductor is connected with capacitor C_2 and diode D_2 in series with N_1 to boost the voltage. The diode D_3 is the rectifier diode connected with output capacitor C_3.

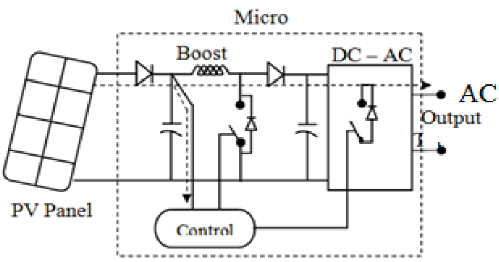

Fig.2.1.PV system with high step up converter micro inverter

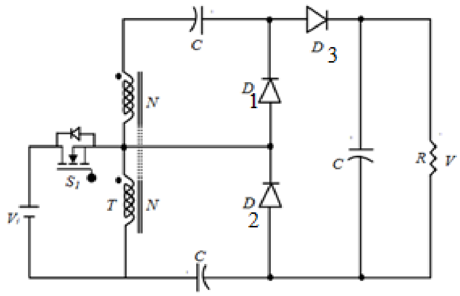

Fig.2.2.High Step up Converter

The proposed high step- up converter has the following features [15]:

(1). Large step-up voltage conversion ratio is obtained with the connection of two pairs of inductors, capacitors and diodes.

(2). The leakage inductor energy of the coupled inductor T1 can be utilised for recycling, thus increasing the efficiency and restraining the voltage stress across the switch.

(3). During non-operating condition, floating active switch effectively isolates the PV panel from the load.

The paper is organized as follows: Section II deals with operating principle. Steady stat analysis is given in section III. Simulation and experimental results are given in sections IV and V respectively. The work is concluded in section VI.

II. OPERATING PRINCIPLES OF THE PROPOSED CONVERTER

The proposed high step up converter simplified circuit is shown in Fig.2. The coupled inductor T1 of the proposed converter is represented as a magnetising inductor Lm, primary leakage inductance L_{k1}, secondary leakage inductance L_{k2} and an ideal transformer to simplify the analysis the following assumptions have been made in[15],

(1). All the components are ideal, except the leakage inductance of coupled inductor T1, the on-state resistance and all parasitic capacitances of the main switch S1 are neglected.

(2). The capacitors C1~C3 are sufficiently large and the voltage across the are considered to be constant.

(3). The ESR of capacitor C1~C3 and the parasitic resistance of coupled inductor T1 are neglected.

(4). The turns ratio 'n' of the coupled inductor T1 windings is equal to N2/N1.

The continuous conduction mode operation of proposed converter is discussed by the following modes of operation.

Mode II (t_1, t_2)

Source energy Vin is connected in series with N2, C1 and C2 .Lm also receiving energy from Vin.S1 remains on and D3 is conducting i_{Lm}, $i_{Lk1}$and l_{d3} are increasing. Lm and L_{k1} are staring energy from Vin. C1 and C2 discharges their energy to capacitor C3 and the load R. The i_{in} , i_{d3} and discharging current i_{c1} and i_{c2} are increasing mode II ends at T=T2 when S1 is turned off.

Mode III (t_2, t_3)

When S1 is off, L_{k2} charging C3, only D1 and D3 are conducting. Leakage inductor energy of L_{k1} flows through D1 to change capacitors C1 during this time interval L_{k2} is connected in series with C2 to charge C3 and the load. At T=T3 i_{Lk2} decreases and reaches zero, this mode ends.

Mode IV (t_3, t_4)

Stored energy in Lm is released to C1and C2.diodes D1 and D2 are conducting. Leakage energy still flowing through D1 keeps changing C1, i_{Lk1} and i_d, are continually decreased C3 discharges through load R. The energy transfer results in decreasing of i_{Lk2} and i_{Lm}, but increases in i_{Lk1} . This modes when i_{Lk1}=0 at T=T4.

Mode V (t_4,t_5)

Only Lm is constantly releasing energy to C2, D2 conducting i_{Lm} is decreasing due to magnetizing inductor energy flowing through coupled inductor T1 to N2. D2 continuously charging C2. C3 discharged to the load R. This mode ends with switching on S1, for the next switching period.

III. STEADY STATE ANALYSIS OF PROPOSED CONVERTER

The steady state analysis of proposed high step up converter has been carried out by considering modes II and IV of the continuous conduction mode operation. The equations can be written as [15],

$$v_{Lm} = V_{in} \quad (1)$$

$$v_{N2} = nV_{in} \quad (2)$$

From mode IV

$$v_{Lm} = -V_{C1} \quad (3)$$

$$v_{N2} = nV_{C2} \quad (4)$$

Applying a volt-second balance on the magnetising inductor Lm yields

$$\int_0^{DT_S} (V_{in})dt + \int_{DT_S}^{T_S} (-V_{C1})dt = 0 \quad (5)$$

$$\int_0^{DT_S} (nV_{in})dt + \int_{DT_S}^{T_S} (-V_{C2})dt = 0 \quad (6)$$

The voltage across the capacitors C_1 and C_2 are obtained as

$$V_{C1} = \frac{D}{1-D} V_{in} \quad (7)$$

$$V_{C2} = \frac{nD}{1-D} V_{in} \quad (8)$$

From mode II, the output voltage

$$V_O = V_{in} + V_{N2} + V_{C2} + V_{C1} \text{ becomes}$$

$$V_O = V_{in} + nV_{in} + \frac{nD}{1-D} V_{in} + \frac{D}{1-D} V_{in} \quad (9)$$

The DC voltage gain M_{CCM} can be given as

$$M_{CCM} = \frac{V_O}{V_{in}} = \frac{1+n}{1-D} \quad (10)$$

IV.SIMULATION RESULTS

HSCIBIMD system is modelled, simulated and the results are analysis in this section. Circuit diagram of high step –up converter with VSI is shown in Fig.3. The measurement of solar power is shown in Fig.4. The power output is 118 W .The inductance value of high step-up converter is taken as L= 10mH and the capacitance values ar is C_1=C_2 =2200 $\mu F.$ C_3= 1000 µF. The output voltage of solar system is shown in Fig.5. and its value is 47.57V. The output voltage of step-up converter is shown in Fig .6. and its value is 70 Volts.

The output voltage waveforms of inverter are shown in Fig.7, and the peak value is 70V. The output current is shown in Fig.8. and its peak value is 10A. The motor speed response is shown in Fig.9. and its value is 1000 RPM. The output power is shown in Fig.10. and its value is 135W. The frequency spectrum is shown in Fig.11, and the THD is 12.5%. The fundamental component of current is 9.6A.

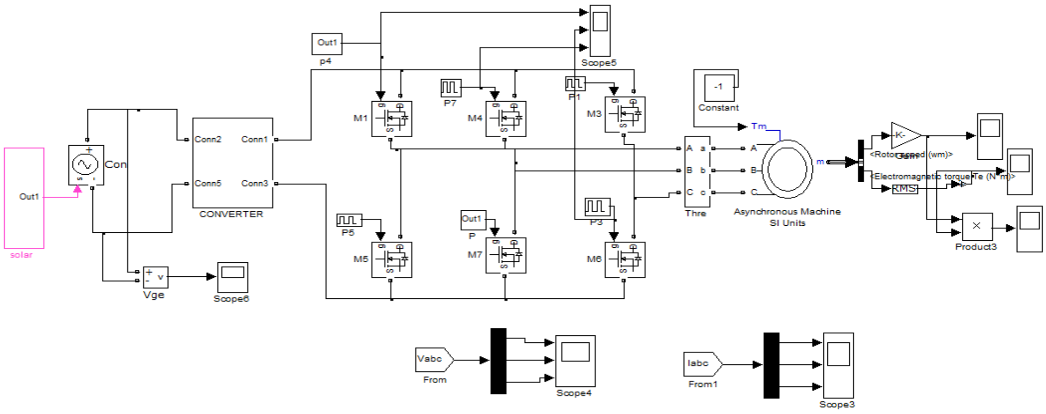

Fig.3. High step up converter with VSI

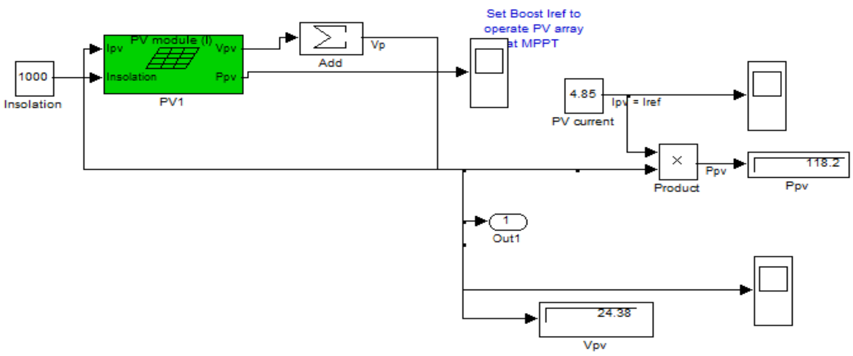

Fig.4. Measurement of Solar Power

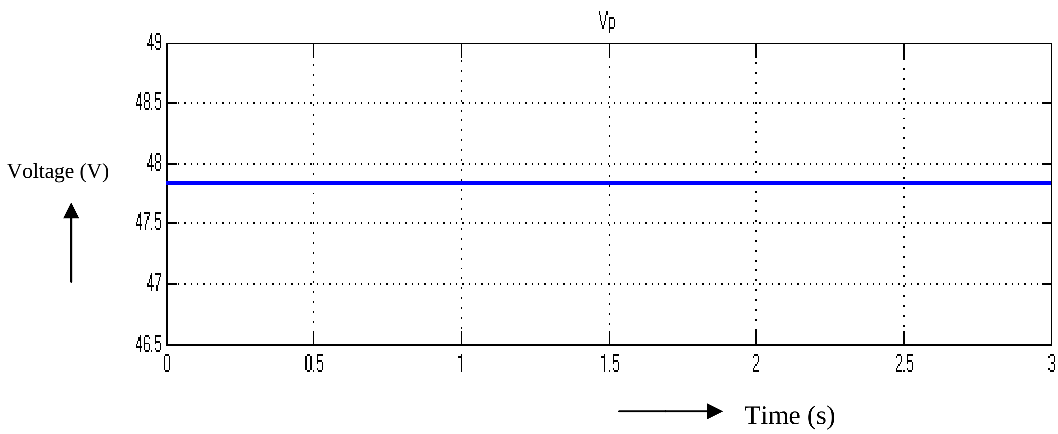

Fig.5. Output voltage of solar system

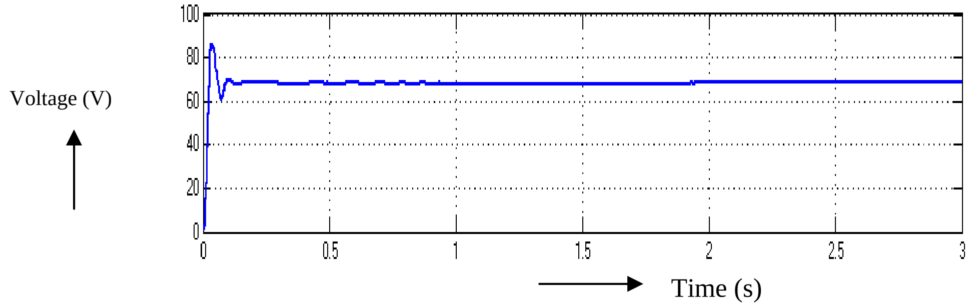

Fig .6. Output voltage of step up converter

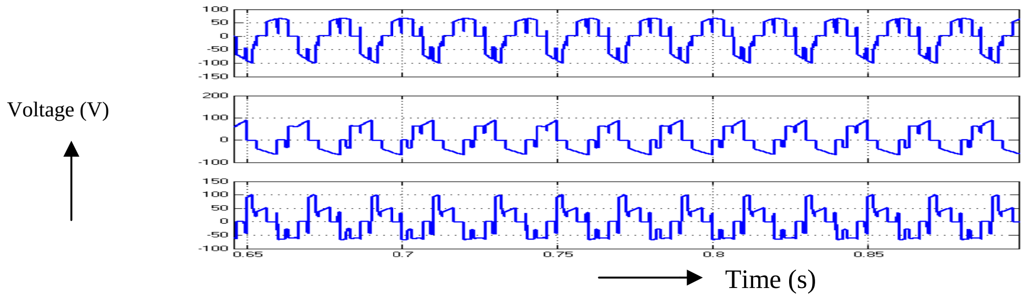

Fig.7. Output voltage of inverter

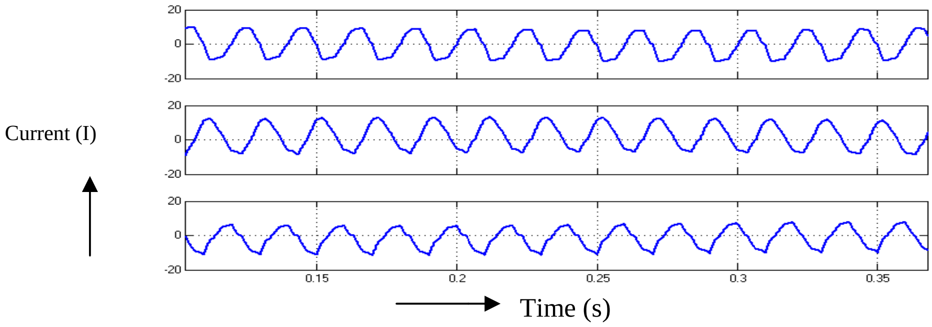

Fig.8 Output current of inverter

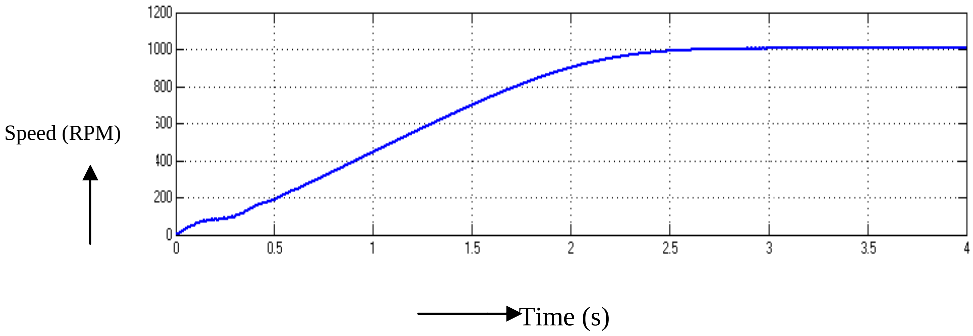

Fig.9.Motor speed

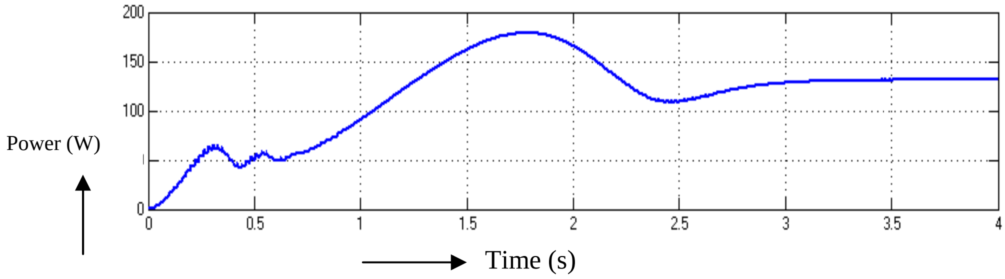

Fig.10. Output power of inverter

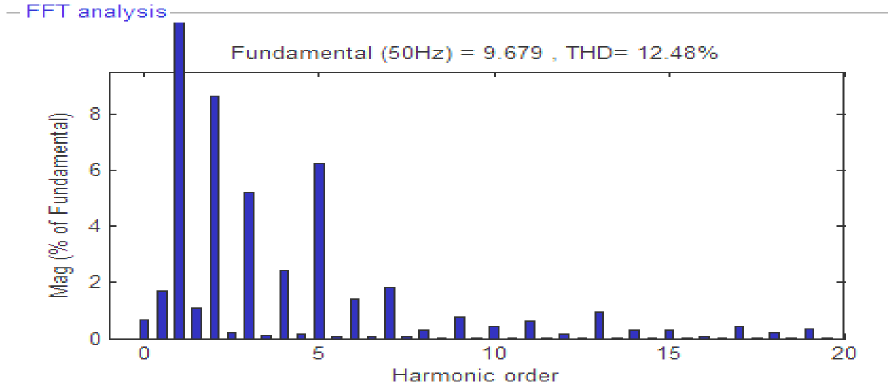

Fig.11. Measurement of THD

TABLE I Variation of V_O and P_O with solar Irradiation

Solar irradiation	Vo(V)	Po(W)
940	58	100
950	62	110
960	65	117
970	67	128
980	69	131

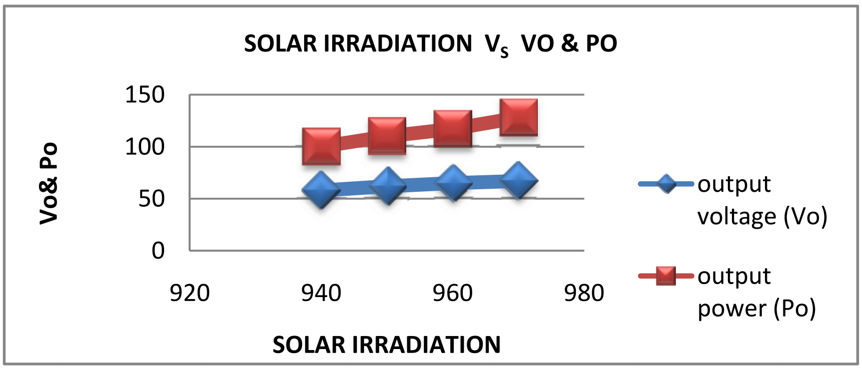

Fig.12.Various levels of solar irradiation and corresponding output voltage and output power.

The comparison of output voltage of the system Vo and output power Po pertaining to various levels of solar irradiation is shown in Table I.

The variation of output power and voltage is shown in Fig.12. The output power increases from 110W to 131W when solar irradiation increases from 940 to 980. The simulation parameters are given in Table II.

V. EXPERIMENTAL RESULTS

The hardware circuit is implemented for HSCBIMD system. The hardware consists of solar panel, control board, inverter board, HSC board and TPIM. The hardware set up is shown in Fig.13. A 0.5 HP 3-phase, 400 V, induction motor is used as a load. Input voltage for high step up converter is given in Fig.14.Output voltage of high step up converter is shown in Fig.15. The output phase voltage of inverter is shown in Fig.16.

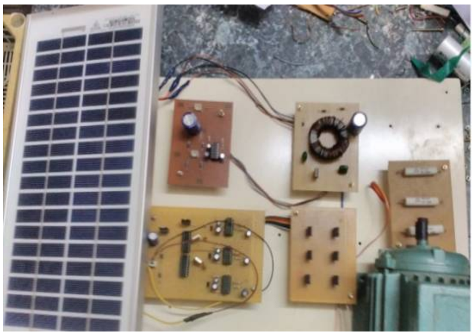

Fig.13. Hardware of HSCBIMD

Fig.14. Input voltage of - High step up converter

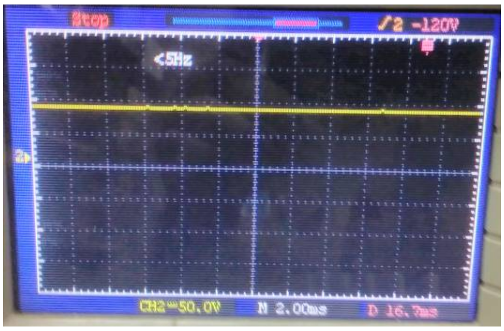

Fig.15. Output voltage of High step up converter

Fig.16.Output phase voltage of inverter

TABLE II Simulation Parameters

Parameters	Values
Inductance(L)	10mH
Capacitor(C)	2200µF
Filter Capacitor	1000µF
Frequency	50Hz
V_{in}	48V
V_0	82V
Duty ratio	0.6

TABLE III Hardware parameter

Parameters	Values
Inductance (L)	10mH
Capacitor (C)	2200µF
PIC Microcontroller	16F84A
Regulator IC 7812	12V
Regulator 7805	5V
Filter Capacitor	1000µF
Driver IC	IR2110
MOSFET	IRF840 500V,8A

The input voltage and output voltage of high step-up converter are shown in Fig .15 and Fig16 respectively. The input DC voltage is 48V and converter output voltage is 75V. The output phase voltage of inverter is 75V shown in Fig.16. Hardware parameters are given in Table-3. It can be seen from section IV and V that the experimental results match with simulation results.

VI. CONCLUSION

This work has depicted the variation of output power in HSCIBIMD system with change in solar irradiation. This work has presented simulation and experimental results of HSCIBIMD system. The principle of operation and results are presented. Where the solar irradiation is varied from 940 to 980, the output power varies from 100W to 131W. The harmonic details for motor current are presented and % THD is 12.5.

The experimental results are obtained for HSCIBIMD system. The results obtained are clear examples of improvement in performance. The advantages of proposed system are use of green energy and reduced output voltage ripple. The disadvantage of HSC is that it is suitable for low power. Closed loop PI & FLC controlled systems will be investigated in near future.

REFERENCES

[1] S.R.Bull, "Renewable energy today and tomorrow," Proc.IEEE.,Vol.89,No.8. pp.1216-1226,Aug.2001.
[2] S.Rahman, "Green power; What is it and where can we find it? " IEEE Power Energy mag.,Vol.1,No.1,pp.30-37,Jan/Feb.2003.
[3] J.A.Gow and C.D.Manning, "Photovoltaic converter system suitable for use on small scale and stand-alone or grid connected applications," proc. Inst. Electr. Eng.-Electr. Power Appl., Vol.147, No.6. pp.535-543,Nov.2000.
[4] T.J.Liang, Y.C.Kuo,and J.F.Chen, "Single stage power to voltaic energy conversion system," proc. Inst. Electirc .Eng-Electric .Power Appl., Vol.148,No.pp.339-344, Jul.2001.
[5] K.C.Tseng, C.C.Huang, and Wei-Yuan Shih, "A high step-up converter with a voltage multiplier module for a photovoltaic system," IEEE Transaction on Power Electronics. Vol.28. No.6.June 2013.
[6] Hongchen Liu, Fie Li, and Jian Ai, "A novel high step-up dual switches converter with coupled inductor and multiplier cell for renewable energy system," IEEE Transaction on Power Electronics, Vol.31, No.7., July 2016
[7] S.M.Chen, T.J.Liang, L.S.Yang, and J.F.Chen, " A safety enhanced high step-up DC-DC converter for AC photovoltaic module application," IEEE Transaction Power Electronics ., Vol.27,No.4,pp.1809-1817, Apr.2012.
[8] Y.Zhao, W.H.Li, and X.N.He, "Single-phase improved active clamp coupled-inductor-based converter with extended voltage doubler cell," IEEE Trans. Power Electron., Vol.27, No.6, pp. 2869-2878, Jun.2012.
[9] F.L.Luo, " Six self lift DC-DC converters, voltage lift technique," IEEE Trans. Ind. Electron., Vol.27, No.6 , pp. 2869-2878, Jun.2012
[10] B.Axelrod, Y.Berkovich, and A.Ioinovici, "Switched-capacitor/switched-inductor structures for getting transformerless hybrid DC-DC PWN converters," IEEE Trans. Circuits Syst. I, Vol.55. No.2, pp.687-696, Mar.2008.
[11] M.Prudenete, L.L.Pfitscher , G.Emmendoerfer, E.F.Romaneli, and R.Gules, "Voltage multiplier cells applied to non-isolated DC-DC converters ." IEEE Trans. Power Electron., Vol.23, No.2, pp. 871-887, Mar.2008.
[12] W.Li.Y.Zhao, Y.Deng, and X.He, " Interleaved converter with voltage multiplier cell for high step-up and high-efficiency conversion," IEEE Trans. Power Electron., Vol.25, No.9. pp.2397-2408, Sep.2010.
[13] F.L.Tofoil, D.S.Oliveira, Jr., R.P.Torrico-Bascope, and Y.J.A.Alcazar, "Novel nonisolated high –voltage gain DC-DC conveers based on 3SSC and VMC" IEEE Trans. Power Electron., Vol.27 , No.9. pp.3897- 3907, Sep 2012.
[14] Y.J.A.Alcazar , , D.S.Oliveira, Jr., F.L. Tofoil, and R.P.Torrico-Bascope, "DC-DC nonisolated boost converter based on the three-state switching and voltage multiplier cells," IEEE Trans. Ind. Electron.,Vol.60, No.10, pp.4438-4449,Oct 2013.
[15] Shih-Ming Chen, Tsorng-Juu Liang, Lung-Sheng Yang, and Jiann-Fug Chen, "A safety enhanced,high step- up DC-DC converter for AC photovoltaic module application," IEEE Trans. Power Electronics , Vol.27, No.4, Apr.2012.
[16] T.Umeno, K.Takhashi, F.Ueno, T.Inoue, and I.Oota, " A new approach to low ripple- noise switching converters on the basis of switched-capacitor coverters," in Proc.IEEE Int.Symp. Circuits Syst., Jun.1991, pp.1077-1080.
[17] B.Axelrod, Y.Berkovich, and A.Ioinovici, "Switched-capacitor / switched-inductor structures for getting transformer less hybrid DC-DC PWN converters," IEEE Trans. Circuits Syst. I.REg. papers, Vol.55, No.2, pp.687-696, Mar.2008.
[18] M.Zhu and F.L.Luo, "Voltage-lift-type cuk converters : Topilogy and analysis," IET Power Electron.,Vol.2, No.2, pp. 178-191, Mar.2009.
[19] T.J.Liang and K.C.Tseng , "Analysis of integrated boost-flyback step-up converter," IEE Proc. Electrical Power Appl., Vol.152, No.2, pp. 217-225, Mar.2005.
[20] Q.Zhao and F.L.Luo, "High efficiency ,high step-up DC-DC converters," IEEE Trans. Power Electron.,Vol.18, No.1, pp. 65-73, Jan.2003.
[21] Yi-Ping Hsieh, Jiann-Fuh Chen, Tsorng-Juu Liang, and Lung-Sheng Yang, "Novel high step-up DC-DC converter for distributed generation system," IEEE Trans. Industrial Electronics , Vol.60, No.4, Apr.2013.
[22] Kuo-Ching Tseng, Chi-Chih Huang , and Chun-An Cheng, " A high step-up converter with voltage-multiplier modules for sustainable energy applications," IEEE Journal of Emerging and Selected Topics in Power Electronics, Vol.3, No.4, Dec 2015.
[23] Hongchen Liu , Jian Ai, and Fei Li , " A novel high step-up converter with a switched-coupled-inductor-capacitor structure for sustainable energy systems," Journal of Power Electronics, Vol.16, No.2, pp.436-446, Mar 2016.
[24] Kelam Bhargav, Santhi Mary Antony .A, "MPPT Controller Based Solar Power Generation Using A Multilevel Inverter," International Journal of Engineering and Technology , Vol 8 No 1, pp 265-273, Feb-Mar 2016.
[25] P.Sathya, .R.Natarajan, "Design and Implementation of 12V/24V Closed loop Boost Converter for Solar Powered LED Lighting System," International Journal of Engineering and Technology , Vol 5 No 1, pp 254-264, Feb-Mar 2013.

BIBLIOGRAPHY

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