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Implementation of Switched-Coupled-Inductor DC–DC Step-Up Converter fed Induction motor drive Applications

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Abstract-*In this paper, a coupled inductor based high step-up dc–dc converter for high step-up Induction motor drive applications is proposed. The concept is to utilize two capacitors and one coupled inductor. The two capacitors are charged in parallel during the switch-off period and are discharged in series during the switch-on period by the energy stored in the coupled inductor to achieve a high step-up voltage gain. In addition, the energy stored in the coupled inductor is recycled; the voltage stress of the main switch is reduced. The switch with low resistance RDS (ON) can be adopted to reduce the conduction loss and the reverse-recovery problem of the diodes is alleviated. Not only lower conduction losses but also higher power conversion efficiency is benefited from lower turns ratios. The operating principle and steady-state analyses are discussed in detail. Induction motors have been used more in the industrial variable speed drive system. Bye using induction motor the frequency of the voltage is applied to the stator through power electronic devices, which allows the control of the speed of the motor. The operating principles and the steady-state analyses of the proposed converter are discussed in detail. The simulation results are obtained using MATLAB/SIMULINK software.*

Key words- Coupled inductor, DC-DC converter, Induction motor, switched capacitor, Transformer less converter.

I. INTRODUCTION

The conventional STEP-UP dc-dc converter is easy to control and its structure is very simple. But in this case, this converter will be operated at extremely high duty ratio near unity, to achieve high step-up voltage gain [1].This will cause high conduction loss due to the reverse recovery problems of output diode and large input current.However, the voltage gain and the efficiency are limited.Isolated converters can achieve high voltage gain withoutoperating at extreme duty ratio. But the voltage stressacross the switch is higher, and the efficiency is alsoreduced. So an active clamp technique can be introducedto improve the efficiency. But this will increase thenumber of components used, moreover the weight and sizeof the converter is higher which reduce the power density.

Worldwide power generation systems nowadays, dc–dc step-up converters have been frequently adopted for low-power conversion applications. Previous research on various converters for high step-up applications [2] has included the analysis of the switched-inductor and switched capacitor type, the transformer less switched-capacitor type and the voltage-lift type [3]. Some converters, which are the combination of boost and fly back converters or the combinations of other types of converters, are developed to carry out a high step-up voltage gain by using a coupled-inductor technique. However, the leakage inductance of the coupled-inductor will cause a high voltage spike on active switches when the switches were turned off.

This paper presents a novel high step up dc-dc converter renewable energy applications. The proposed circuit consists of a coupled inductor and

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two voltage multiplier cells in order to obtain high voltage step up .In addition a capacitor is charged using the energy stored in the coupled inductor, which increases the voltage transfer gain. The energy used in the leakage inductance is recycled with the use of active clamp circuit. In this proposed topology the voltage stress across the switch is reduced. Therefore a main power switch with low resistance R_{DC} (on) can be used to reduce the conduction losses.

A conventional boost converter can achieve high voltage gain only with a higher duty ratio.[4].At high dutycycle low conversion efficiency, reverse recovery and EMI problems[5] occur resulting in the deterioration of theperformance of the system. Some transformer based converters can achieve high voltage gain by adjusting the turn'sratio of the transformer .However, the leakage inductance of the transformer will cause serious problems such asvoltage spikes on the main switch and high power dissipation [6].switched capacitors and voltage lift techniques [7]have been used to achieve high voltage gain. High charging current through the switches increases conduction losses inthese structures. Coupled inductors based converters can achieve high step up voltage gain by adjusting the turn's ratios.However, the energy stored in the leakage inductor causes voltage spikes in the main switches and deteriorates theconversion efficiency[8].As a solution for this problems coupled inductor with active clamp circuit waspresented[9].However ,the conversion ratio was not large enough .As a solution for the above mentioned problemsthis paper presents a new topology.

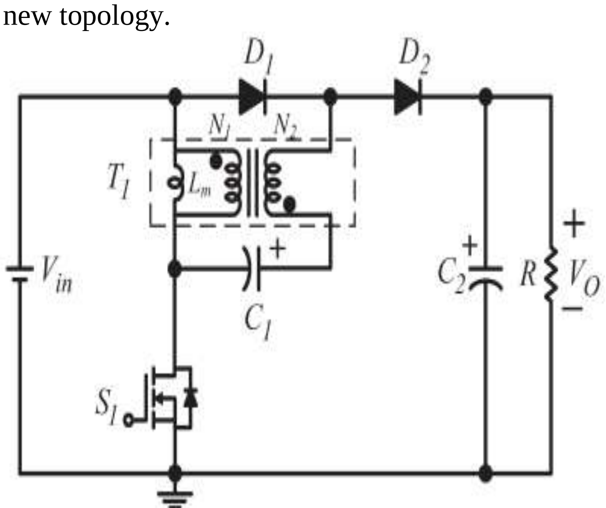
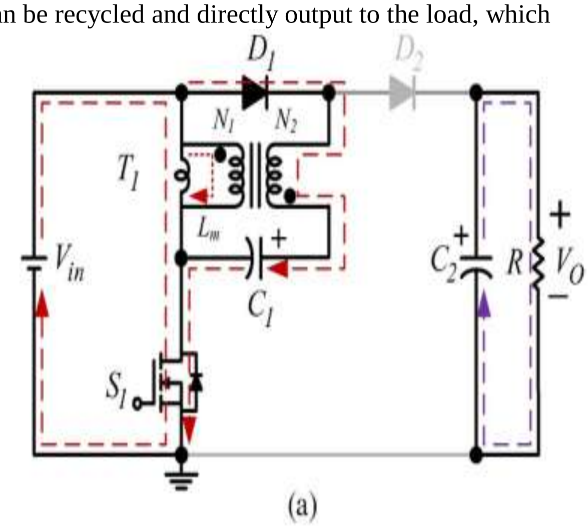


Fig.1. Circuit configuration of the proposed converter.

A small resistor or a resistor–capacitor–diode snubber can be used to dissipate this leakage energy and suppress the voltage spike, [10] but these simple solutions are unable to benefit the converter efficiency. Alternatively, employing an active clamp technique to recycle the leakage energy can achieve soft switching for active switches [11]. This active clamp technique directly increases the part count and the complexity of control. Nevertheless, the power conversion efficiency and voltage gain of step-up converters are restrained by either the parasitic effect of passive components, such as the reverse recovery issue of diodes, or the switching losses and conduction losses of power switches.

The proposed converter is shown in Fig. 1. Two diodes D1 and D2 and capacitor C1 comprise a conventional voltage-lift network. A coupled inductor T1, along with a single active switch S1, is inserted between capacitor C1 and diodes D1 and D2. Coupled inductor T1 plays the role of energy storage and a transfer device. The magnetizing inductor Lm of coupled inductor T1 is equivalent to the input inductor of a conventional boost converter. Switching capacitor C1 obtains energy from input source Vin and secondary winding N2 and then releases it to output capacitor C2 and load R through output rectifier diode D2.

The proposed converter has several features. First, the coupled inductor transfers energy when the active switch is either turned on or turned off, which increases the usage of the coupled inductor. Second, switched capacitor C1 obtains energy from the input source Vin and secondary winding N2 of the coupled inductor; hence, the voltage conversion ratio can be efficiently enlarged. Third, the charging current of switched capacitor C1 has been constrained by leakage inductance, which can effectively reduce the inrush current of the switching capacitor. Fourth, the leakage inductor energy of the coupled inductor can be recycled and directly output to the load, which



(a)

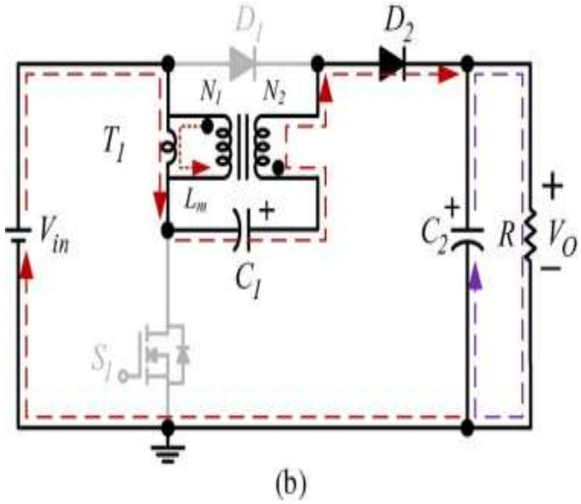


Fig.2. Current flowing path in two operating modes during one switching period in the CCM operation. (a) Mode I. (b) Mode II.

Successfully increases the power conversion efficiency. Finally, the proposed converter consists of few components; hence, the demand for a compact size and a high power density can be achieved. Compared with a conventional fly back converter, the proposed converter has lower voltage stress on the switch, and it requires a lower duty ratio to reach a high voltage ratio.

II. OPERATING PRINCIPLES AND STEADY-STATE ANALYSIS

The proposed converter is simply operated by a single switch without zero switching network and complex control. Fig.2 briefly illustrates two steady operating states of the proposed converter. Only the operating principles in the continuous conduction mode (CCM) are discussed in this section. Because parasitic resistance and the capacitance of the active switch and leakage inductance are neglected, the transient states in the operating principle will not be discussed here. The following assumptions are made for the analysis.

1) All components are ideal.
2) Capacitors C1 and C2 are sufficiently large that the voltages on them are considered constant.
3) The turn's ratio n of the coupled inductor T1 winding is equal to N2/N1.
4) The magnetizing inductance has been integrated into the primary winding N1 of coupled inductor T1.

The two steady operating states are described as follows.

A. Operating Principles

Mode I [t0, t1]: The energy is being stored in this mode. Active switch S1 and diode D1 are conducted, and diode D2 is turned off. During this mode, switched capacitor C1 receives energy from the input source and coupled inductor T1. Because the charging current from input source Vin flows to switched

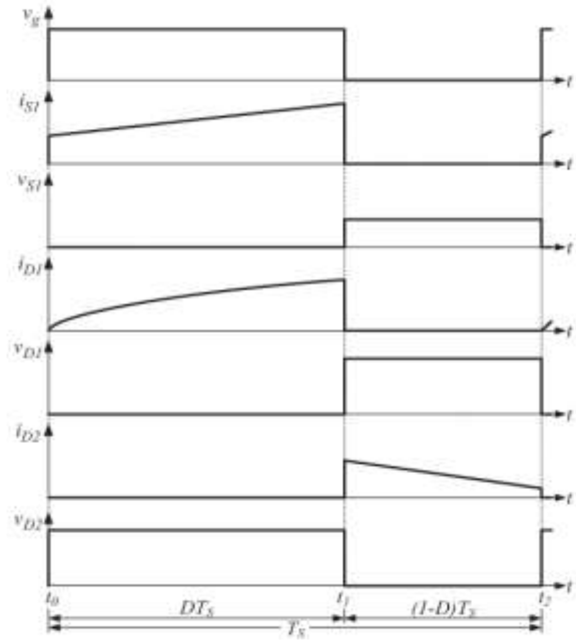


Fig.3. Typical waveforms of the proposed converter in the CCM operation

capacitor $C1$ through diode $D1$ in series with the secondary winding $N2$ of coupled inductor $T1$, the voltage on switched capacitor $VC1$ is equal to $(1 + n)V$in. Meanwhile, the energy from input source Vinis also being stored in magnetizing inductor Lm. The current path is shown in Fig. 2(a). This mode ends when switch $S1$ is turned off at $t = t1$.

Mode II* [*t*1, *t*2]*:The energy is being released in this mode. Active switch $S1$ and diode$D1$ are turned off, but diode $D2$ is conducting. During this mode, energy is being released throughthe series-connected path that consists of input source Vin, magnetizing inductor Lm, switched capacitor $C1$, secondary winding $N2$, and diode $D2$ to charge capacitor $C2$ and load$R$. The energy of secondary winding $N2$ is coupled from magnetizing inductor Lm at the primary side of the coupled inductor. The energy is released through the current path shown in Fig. 2(b). This mode ends when switch $S1$ is turned on at the beginning of the next switching period.

The typical waveforms of several key components in the CCM operation are shown Fig. 3. Vg is the gate signal of active switch S1.

B. Steady-State Analysis

The steady-state analysis only takes the CCM operation into consideration, and the leakage inductances at the primary and secondary sides are neglected. Applying a

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volt-second balance on the primary winding N1 of the coupled inductor yields

$$V_{N1} = \frac{D}{1-D} V_{\text{in}} \tag{1}$$

The voltage VN2 of secondary winding N2 is n times of VN1, i.e.,

$$V_{N2} = \frac{nD}{1-D} V_{\text{in}} \tag{2}$$

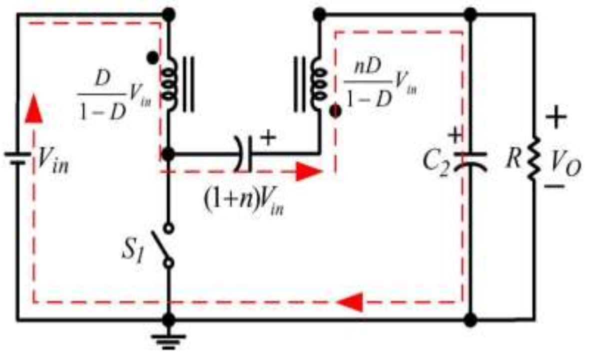
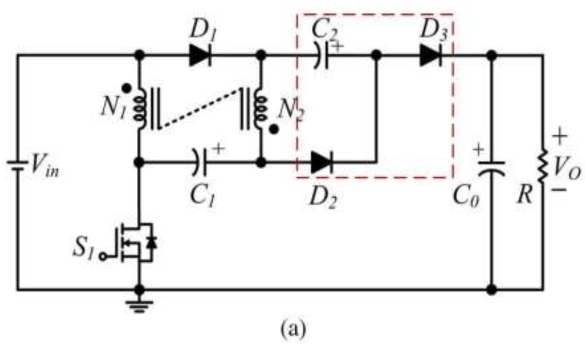


Fig.4. Voltage distribution of the major components during the steady-state CCM operation.

The output voltage will be the sum of input source Vin, the voltage on switched capacitor C1, and the primary and secondary voltages of the coupled inductor, where the respective voltages are illustrated in Fig. 4.

The voltage conversion ratio of the CCM is derived as follows:

$$M_{V\_CCM} = \frac{V_O}{V_{\text{in}}} = 1 + \frac{D}{1-D} + (1+n) + \frac{nD}{1-D} = \frac{2+n-D}{1-D} \tag{3}$$



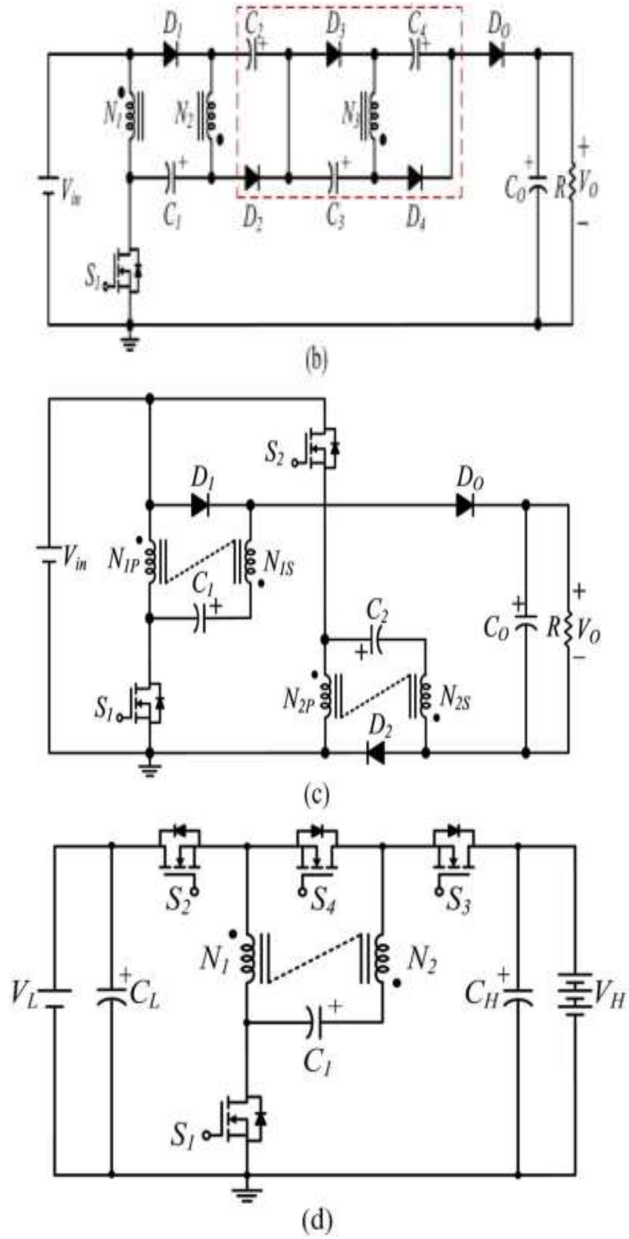


Fig.5. Derivative converters (a) proposed converter combined with a voltagelift network. (b) Multiple cascaded switched-coupled-inductor converter. (c) Interleaved switched-coupled-inductor converter. (d) Bidirectional switched-coupled-inductor converter.

And the voltage conversion ratio of the discontinuous conduction mode (DCM) can be derived as

$$M_{V\_DCM} = \frac{D_L \cdot D \cdot T_S \cdot R}{2(1+n) \cdot L_m} = \frac{D_L \cdot D}{2(1+n) \cdot \tau_m} \tag{4}$$

Where DL is the period of time when the magnetizing current decreases from its peak value to zero. When the proposed converter operates in the boundary conduction mode, the voltage gains under the CCM and DCM operations are equal. The boundary normalized

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magnetizing-inductance time constant τ LmB can be found as follows:

$$\tau_{LmB} = \frac{L_{mB}}{RT_S} = \frac{D(1-D)^2}{2(1+n)(2+n-D)} \quad (5)$$

III. DERIVATIVE CONVERTERS

The proposed converter can be varied and applied to other derivative converters. By adding a voltage-lift network at the output, the voltage conversion ratio of the converter can be enlarged, which is demonstrated in Fig.5 (a). When applying series-connected multiple coupled-inductor windings and multiple diode–capacitor networks to the proposed converter, the output voltage can be directly enlarged by adding a number of switched-coupled-inductor modules, which is shown in Fig.5 (b). In Fig.5(c), the converter utilizes the switched coupled-inductor technique. Two switched-coupled-inductor modules are charged in parallel during the switch-on period and discharged in series during the switch-off period, which also achieves a high step-up voltage conversion ratio. By adding one active switch and replacing the output diode with a switch, the proposed converter will transform to a bidirectional converter shown in Fig.5 (d).

IV.INDUCTION MOTOR

Induction Motor (1M) An induction motor is an example of asynchronous AC machine, which consists of a stator and a rotor. This motor is widely used because of its strong features and reasonable cost. A sinusoidal voltage is applied to the stator, in the induction motor, which results in an induced electromagnetic field. A current in the rotor is induced due to this field, which creates another field that tries to align with the stator field, causing the rotor to spin. A slip is created between these fields, when a load is applied to the motor.

Compared to the synchronous speed, the rotor speed decreases, at higher slip values. The frequency of the stator voltage controls the synchronous speed. The frequency of the voltage is applied to the stator through power electronic devices, which allows the control of the speed of the motor. The research is using techniques, which implement a constant voltage to frequency ratio. Finally, the torque begins to fall when the motor reaches the synchronous speed. Thus, induction motor synchronous speed is defined by following equation,

$$\boldsymbol{n_s = \frac{120f}{p}}$$

Where f is the frequency of AC supply, n, is the speed of rotor; p is the number of poles per phase of the motor. By varying the frequency of control circuit through AC supply, the rotor speed will change.

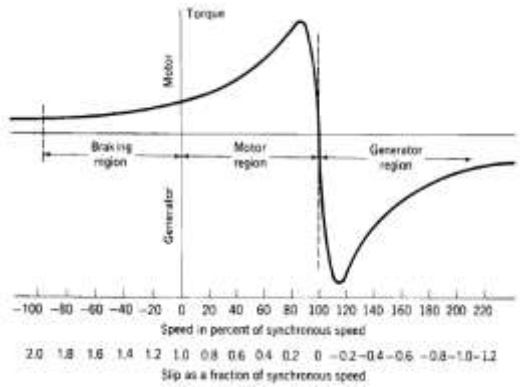


Fig.6.Speed torque characteristics of induction motor.

V.MATLAB/SIMULATION RESULTS

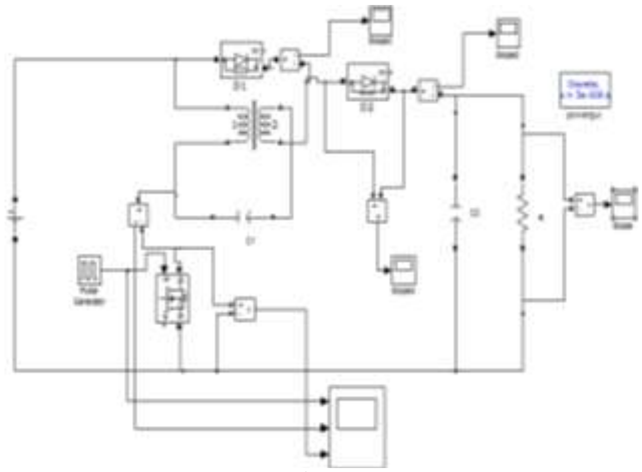
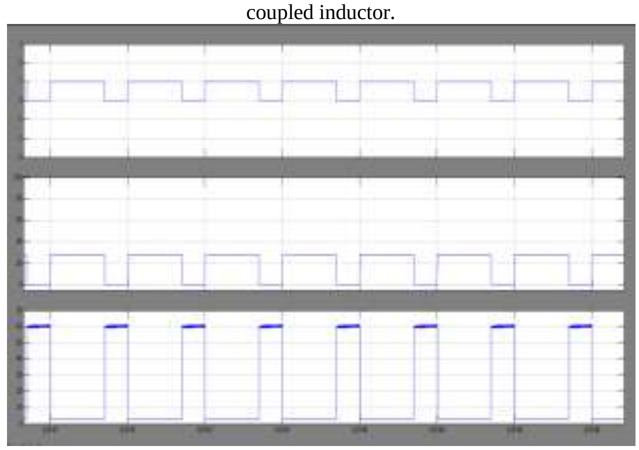
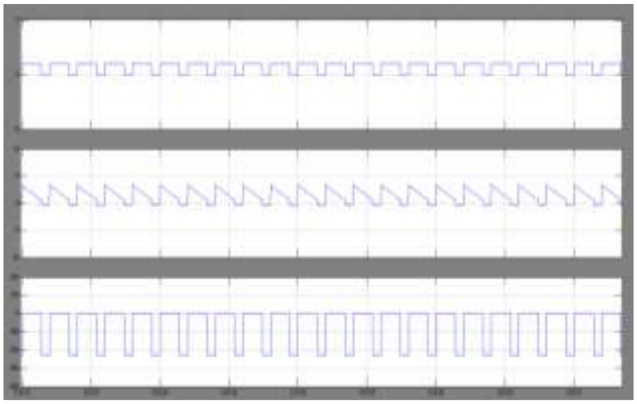


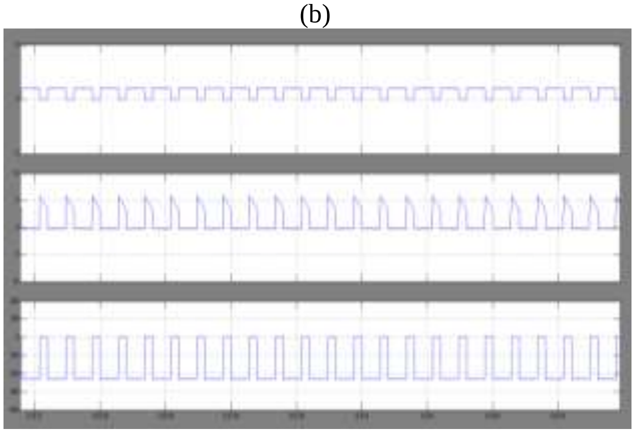
Fig.7. MATLAB/Simulink circuit for high step up DC-DC converter with coupled inductor.



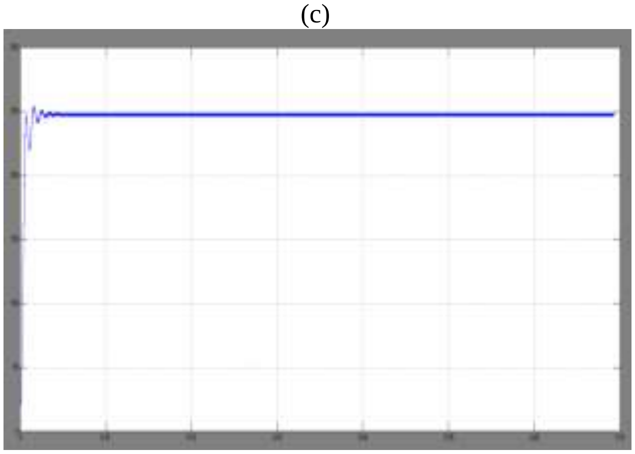
(a)



(b)



(c)



(d)

Fig.8. Current and voltage waveforms of (a) active switchS1, (b) diodeD1, and (c) output diodeD2, (d) Converter output voltage

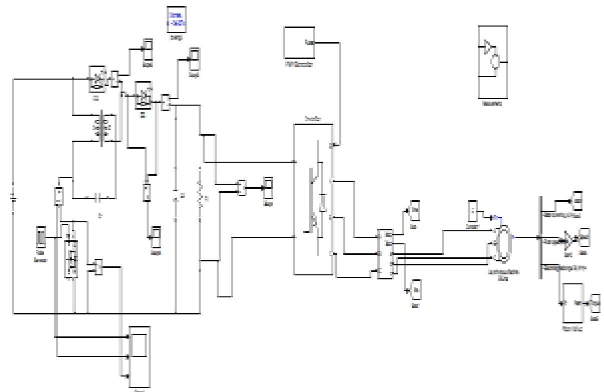


Fig.9Matlab/Simulink circuit for coupled inductor high step up DC-DC converter with induction motor drive system.

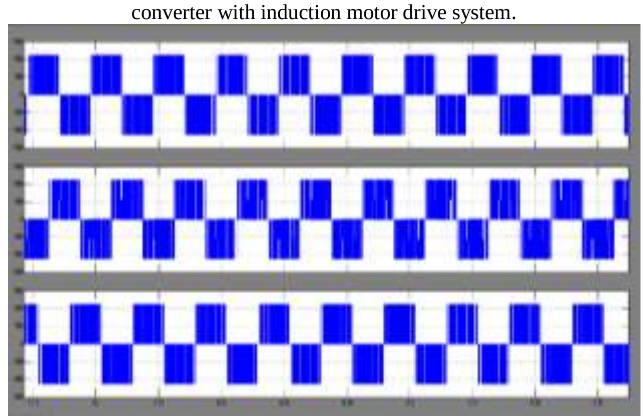


Fig.10. Inverter output voltage

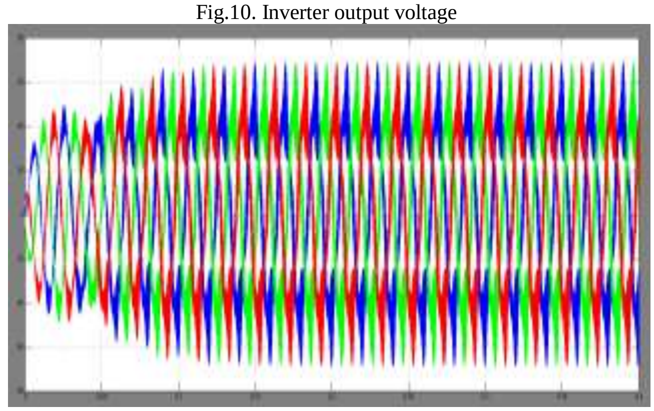


Fig.11. Output current

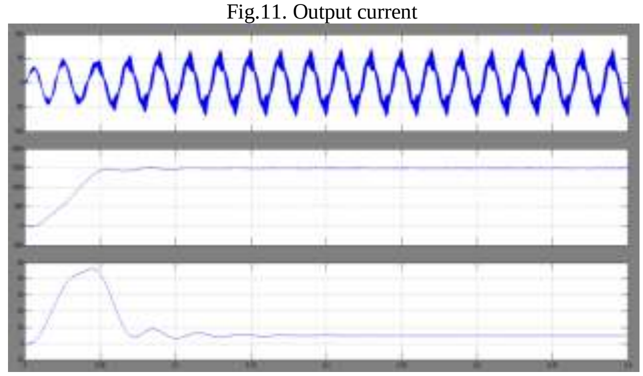


Fig.12. Stator current, Speed, Torque of Induction motor

VI.CONCLUSION

However, the extensive use of power electronics basedequipment with pulse width modulated variable speeddrives are increasingly applied in many new industrialapplications that require superior performance.The proposedconverter has successfully implemented an efficient highstep-up conversion through the voltage multiplier module.The interleaved structure reduces the input current rippleand distributes the current through each component. Inaddition, the lossless passive clamp function recycles theleakage energy and constrains a large voltage spike acrossthe power switch. Meanwhile, the voltage stress on thepower switch is restricted and much lower than the outputvoltage.Efficiency can beadjusted with the designed parameters of Induction motor at requiredtorque. The novel capability of canceling the input currentripple at an arbitrarily preselected duty cycle. This isaccomplished without increasing the count of the number ofcomponents. In addition, the converter features a highvoltage gain without utilizing extreme values of duty cycle; it is best suitable for the induction motor drive applications.

REFERENCES

[1] W. Li, Y. Zhao, J. Wu, and X. He, "Interleaved highstep-up converter with winding-cross-coupled inductorsand voltage multiplier cells," IEEE Trans. PowerElectron., vol. 27, no. 1, pp. 133–143, Jan. 2012.

[2] J. C. Rosas-Caro, J. M. Ramirez, F. Z. Peng, and A.Valderrabano, "A DC–DC multilevel boost converter," IETPower Electron., vol. 3, no. 1, pp. 129–137, Jan. 2010

[3] Z. Dongyan, A. Pietkiewicz, and S. Cuk, "A three-switchhigh-voltage converter," IEEE Trans. Power Electron., vol.14, no. 1, pp. 177–183, Jan. 1999.

[4] D. Maksimovic and S. Cuk, "Switching converters withwide DC conversion range," IEEE Trans. Power Electron.,vol. 6, no. 1, pp. 151–157, Jan. 1991.

[5] B. Axelrod, Y. Berkovich, and A. Ioinovici, "Switchedcapacitor/ switched-inductor structures for gettingtransformer less hybrid DC–DC PWMconverters," IEEETrans. Circuits Syst. I, Reg. Papers, vol. 55, no. 2, pp. 687–696, Mar. 2008.

[6] R. D. Middle brook, "Transformerless DC-to-DCconverters with large conversion ratios," IEEE Trans. PowerElectron., vol. 3, no. 4, pp. 484– 488, Oct. 1988.

[7]S. Ben-Yaakov, "Behavioral average modeling andequivalent circuit simulation of switched capacitorsconverters," IEEE Trans. Power Electron., vol. 27, no. 2,pp. 632–636, Feb. 2012.

[8] Y. P. Hsieh, J. F. Chen, T. J. Liang, and L. S. Yang,"Novel high step-upDC–DC converter for distributedgeneration system," IEEE Trans. Ind.Electron., vol. 60, no.4, pp. 1473–1482, Apr. 2013.

[9] S. M. Chen, T. J. Liang, L. S. Yang, and J. F. Chen, "Acascaded highstep-up DC–DC converter with single switchfor microsource applications,"IEEE Trans. Power Electron.,vol. 26, no. 4, pp. 1146–1153,Apr. 2011.

[10] C. S. Leu, P. Y. Huang, and M. H. Li, "A novel dual inductorboost converter with ripple cancellation for high voltage-gainapplications," IEEETrans. Ind. Electron., vol.58, no. 4, pp. 1268–1273, Apr. 2011.

[11] AzuanBin Alias: Modeling and simulation of three phase inverter with PWM using MATLAB/SIMULINK,University of Malaysia Pahang, NOVEMBER 2007.