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A Novel Non-Isolated Closed-Loop Controlled DC-DC Boost Converter for Induction Motor Drive with PV as Source

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ABSTRACT: In a renewable energy system like solar energy or fuel cell based industrial system due to low voltage at the source there is a need of high step-up dc-dc converter, while to run an induction motor ultimately we need an inverter, it takes high voltage from step-up dc-dc converter as input. To combine the advantages of the high voltage gain of a switched-capacitor (sc) converter and better output regulation of a switched-mode dc-dc converter, a scheme of integrating the two types of converters is proposed in this paper. The main concept behind it is when the switch is turned on, the inductor is charged, and the capacitors are connected in series to supply the load, and when the switch is turned off, the inductor discharges the energy to charge capacitors in parallel, the voltages are controlled by PWM method. Therefore a high voltage gain, good regulation converter can be obtained. The proposed dc-dc converter is of closed-loop controlled to get the constant voltage. The proposed high voltage converter is fed to an Induction motor with the help of a diode clamped inverter. The operating principles and voltage gains are analyzed. The proposed concept is designed using Matlab/Simulink software.

KEYWORDS: Renewable sources, High step-up converter, Switched capacitor (sc), Closed-loop controller, Induction motor.

I.INTRODUCTION

The amassing usage of conventional fossil energy has harmfully exaggerated the atmosphere on a large-scale, such as environmental contamination and greenhouse effect. Meanwhile, there has been a growing demand for energy with the development of society. Since traditional fossil is not renewable, it is faced with the problem of energy storage. Therefore, it is necessary to develop new energy that is clean and renewable to replace traditional fossil energy. Solar energy and hydrogen energy are promising, and photovoltaic (PV) and fuel cell power generation as the utilization method of the two new energy types have been applied on a large scale.

In a single-phase system with a two-stage structure, if the line voltage is 220V, the bus voltage of the grid-connected inverter needs to be as high as 380V. However, the output voltages of PV and fuel cells are generally ranged from 25 to 45 V, which are much lower than the bus voltage. Thus, a dc-dc converter with a high voltage gain is needed

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to boost the outputs of PV and fuel cells. By increasing the turn's ratio of the transformer in isolated converters, a high voltage gain can be obtained. How-ever, a too large turn's ratio will lead to a large leakage inductor. As a result, the voltage stress of the switch will be increased; where as the efficiency of the converter is degraded.

Among the non-isolated dc-dc converters, the boost converter is usually used for voltage step up. However, the duty cycle will approach to unity when the output voltage is much higher than the input voltage. Thus, the current ripple of the inductor and turn-off current of the power device are large, which results in large conduction loss, switching loss, and thus low efficiency [10], [11]. By cascading another boost converter, a high voltage gain can be easily obtained [12]. However, too many components are required, leading to high cost and low overall efficiency.

Introducing a coupled inductor into the non-isolated converter and selecting an appropriate turns ratio of the couple inductor can increase the voltage gain effectively. However, a snubber circuit is needed to absorb the energy stored in the leakage inductor. This will lead to circuit complexity and low efficiency. In [13]-[17], the active-clamp technique is incorporated to suppress the voltage spike of the switch and regenerate the energy stored in the leakage inductor to the load, which leads to improved efficiency. However, the input current of the proposed converter is pulsating, and the resonance between the leakage inductor and the parasitic capacitor of the output diode is severe.

The switched-capacitor (SC) converter can be obtained a high voltage gain, but the input current is pulsating, and the load and the line regulation is poor. Meanwhile, the voltage gain is predetermined by the circuit structure [18]. By incorporating the SC structure into te switching mode dc-dc converters, the voltage gain can be dramatically increased with an appropriate duty cycle while the voltage regulation is achieved [18]-[20]. Moreover, the pulsating input current can be reduced. However, there still exist some deficiencies in the converters. For example, the circuit proposed in[18] cannot be infinitely extended. Thus, in the situation where an enormous voltage gain is needed, the duty cycle is still relatively large. Moreover, the voltage of the elementary circuit proposed in [19] and [20] is not high enough. When an extension circuit is added to increase the voltage gain further, the topology will be complicated and with high cost.

The voltage gain of the SC converter is high, but the output voltage is not regulated. The output regulation of the non-isolated switching-mode dc-dc converter is excellent, but the voltage gain cannot be too high for achieving high efficiency. This paper process combination method of the SC converters and the switching mode dc-dc converter. The basic approach is introducing multiple capacitors into the switching-mode dc-dc converted. When the switch is off, the energy released from the inductor is used to charge the capacitors in parallel. When the switch is on, the capacitors are connected in series to supply the load. Thus the voltage gain is decreased, leading to small ripple current and turn-off current of the switch, and the high efficiency can be expected. Meanwhile, the voltages of the capacitors are well regulated, thus achieving a tightly regulated output voltage. In addition, the new converters proposed in this paper can be infinitely extended when an enormous voltage gain is needed.

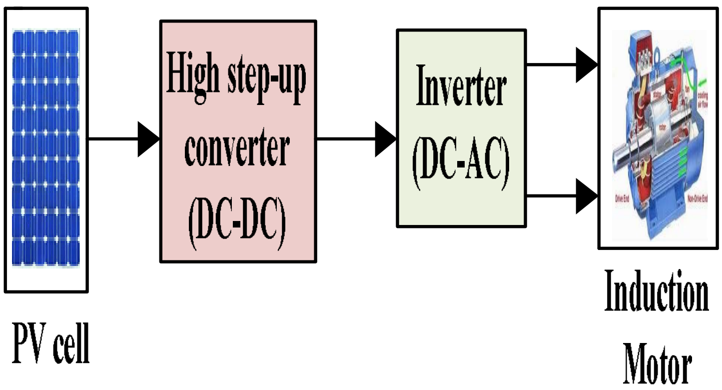

Fig 1 Block diagram of proposed system.

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An induction motor is an asynchronous Ac machine which is having stator and rotor. The proposed Non-isolated dc-dc converter is connected to induction motor with the help of inverter. The whole concept can be applied to renewable energy sources. Fig 1 show the block diagram of proposed PV based high step-up non-isolated converter fed to induction motor drive.

II. NON-ISOLATED HIGH STEP-UP DC-DC CONVERTER WITH SWITCHED CAPACITOR UNIT

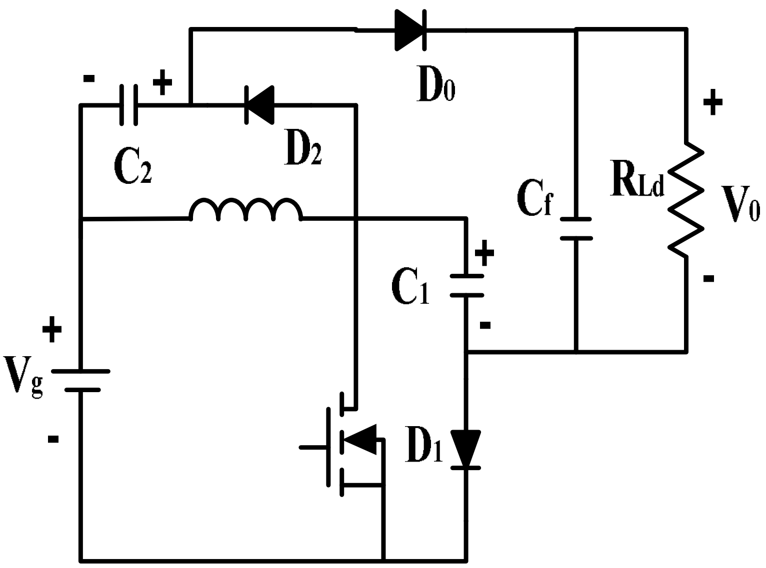

Fig.2 Block diagram of proposed non-isolated dc-dc converter

To obtain a high voltage gain, the SCs in fig.2 should be connected in series as many as possible when switch Q is on. Moreover, the polarities of the capacitors to be connected in series should be different at the connection point. Likewise, C_1 and C_3 cannot be connected in series because the negative terminals of the two capacitors are connected through the input voltage source. The series-connected capacitors are connected to the output filter capacitor C_f and load resistor R_{LD} through diode D_0.Noted that D_0 is used to prevent the output from being in parallel with one of the SCs when the power switch Q is turned off and the diodes conduct.

In fig 2, when Q is turned on, the input voltage source charges the inductor .Meanwhile; C_2 is in series with the voltage source and C3 to supply the load through Q. When Q is turned off the inductor charges C2 and C3 simultaneously, and the load is powered by C_f .In this converter, one of the SCs is the boost capacitor and the other one is the buck-boost capacitor. The two capacitors and the voltage source are connected in series to supply the load.

$$M = V_0/V_{g\,=}\ 1/1\text{-}Dy + Dy/1\text{-}Dy + 1= 2/1\text{-}Dy$$

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III. CLOSED-LOOP CONTROLLED HIGH STEP-UP CONVERTER

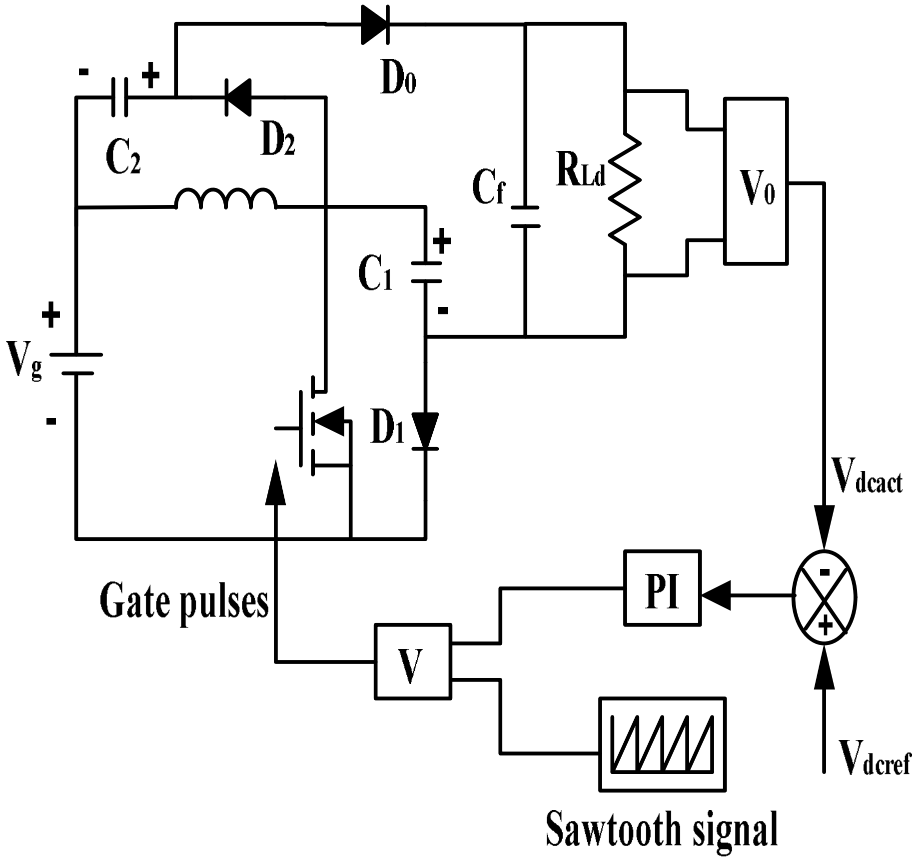

Fig.3 Block diagram of proposed non-isolated dc-dc converter with closed-loop controller

The above fig 3 shows the closed-loop diagram of proposed dc-dc converter. To maintain output voltage constant a feedback system is implemented for open loop dc-dc converter. The closed-loop system is consisting of a proportional integral controller, saw-tooth pulse generator and a relational operator to compare signals from controller. A reference voltage is set for desired value of voltage; in this case it is 400V and compared it with open-loop voltage or actual voltage of the converter. The voltage error is observed and it is given to a PI controller for error compensation. The controller will give a compensated signal which is used for PWM operation as reference signal. A user defined signal saw-tooth is generated which is used as carrier signal for PWM operation. The two signals are compared with an operator and generated pulses are given to the switches.

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IV. NON-ISOLATED CLOSED-LOOP CONTROLLED DC-DC BOOST CONVERTER FOR INDUCTION MOTOR DRIVE

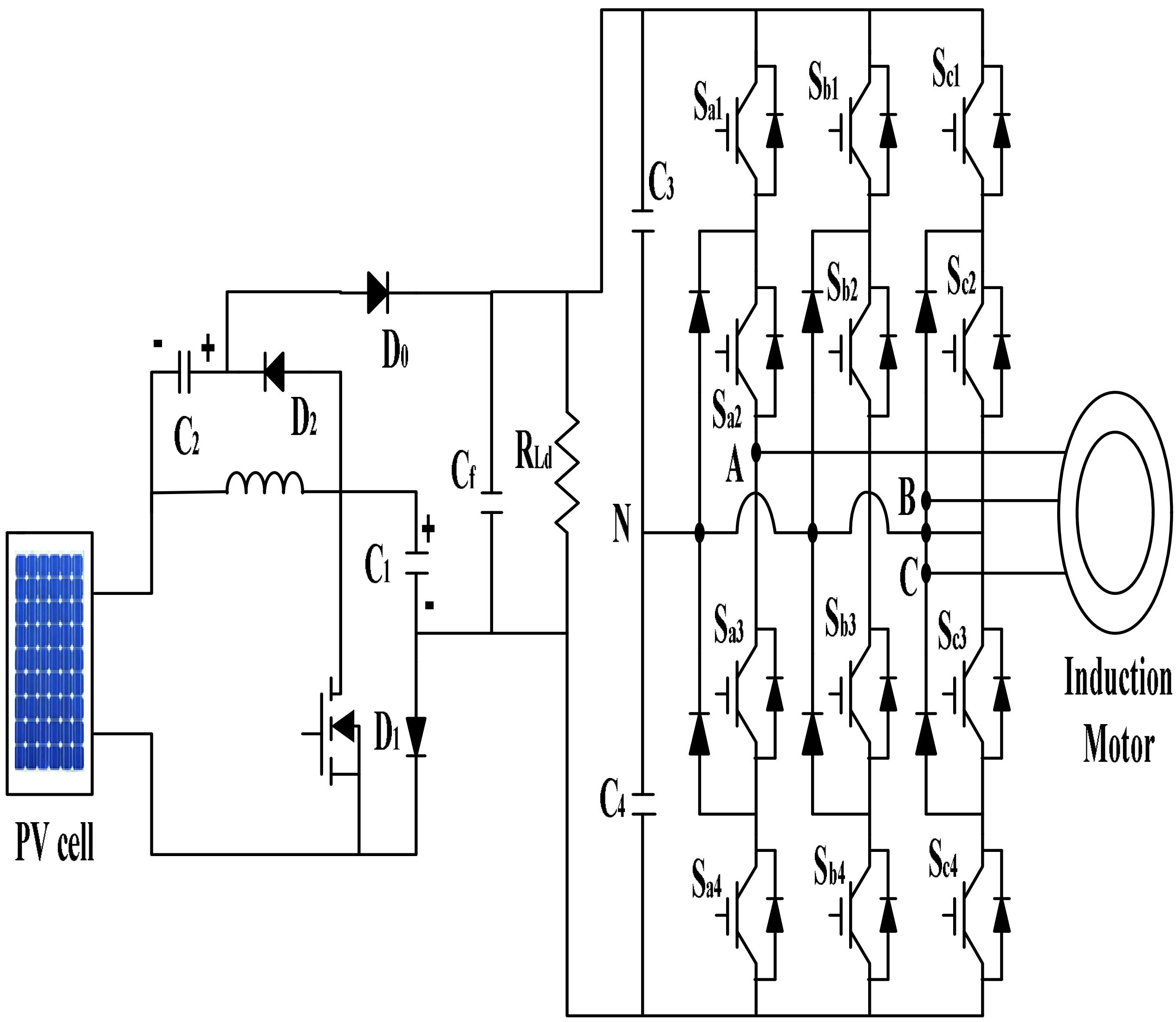

Fig 4 Non-isolated High step-up converter fed Induction motor drive

Fig 4 shows the proposed non-isolated High step-up dc-dc converter is fed with induction motor drive. This motor is broadly used because of its strong features and reasonable cost. A sinusoidal voltage is applied to the stator, which gives 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 rotate. A slip is created between these fields, when a load is applied to the motor. The frequency of the voltage is applied to the stator through power electronic switches, which allows the control of the speed of the motor. Finally the torque begins to fall when the motor reaches the steady state. The sinusoidal voltage is given by an inverter which is a diode-clamped inverter. This paper extensively focuses on standalone applications using renewable energy sources. Using this non-isolated dc-dc converter for motor drive

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operation the efficiency of the motor is also maintained. The performance of the motor characteristics are proven that this concept is efficiently used for industrial applications also for remote areas.

V. MATLAB/SIMULINK RESULTS

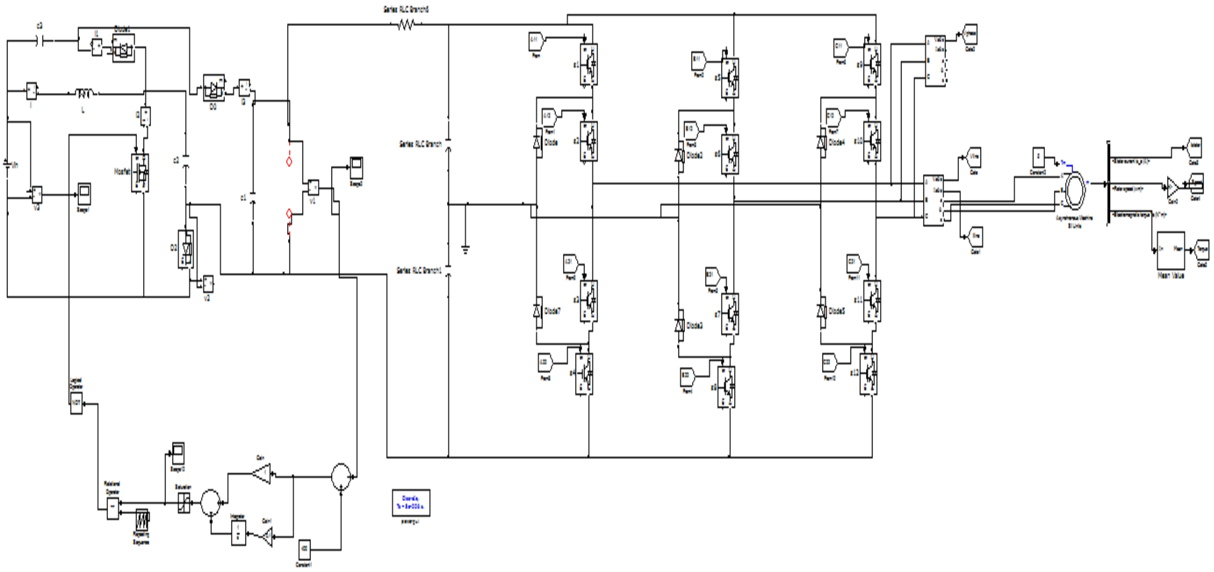

Fig 5 Matlab/Simulink model of proposed high step-up dc-dc converter fed to induction motor drive

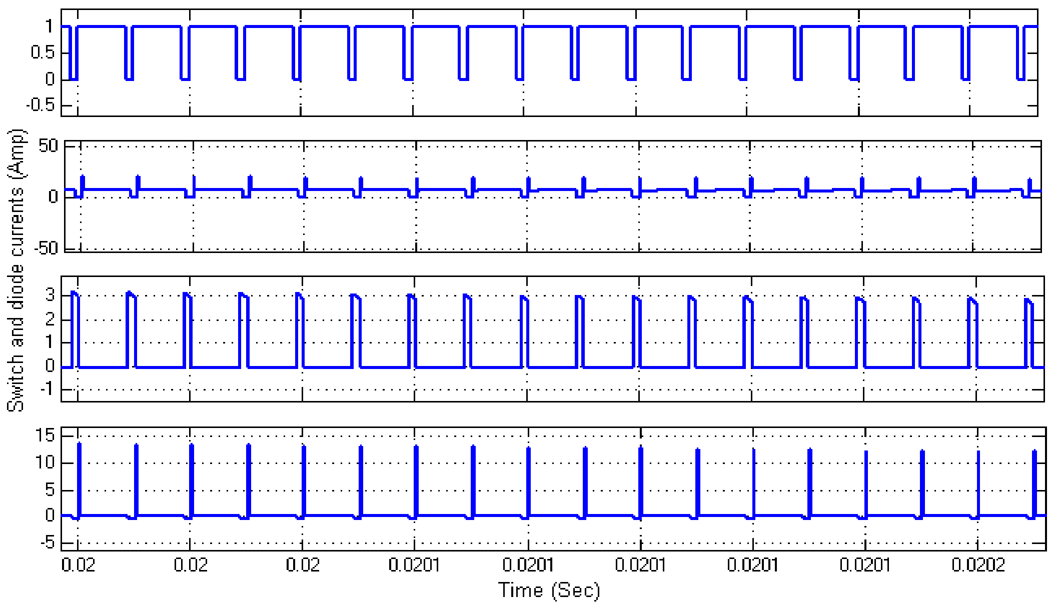

Fig 6 gate pulse, switch current, diode currents

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Fig 6 shows the gate to source voltage, switch current, input and output diode currents of the proposed high step-up converter with closed loop controller.

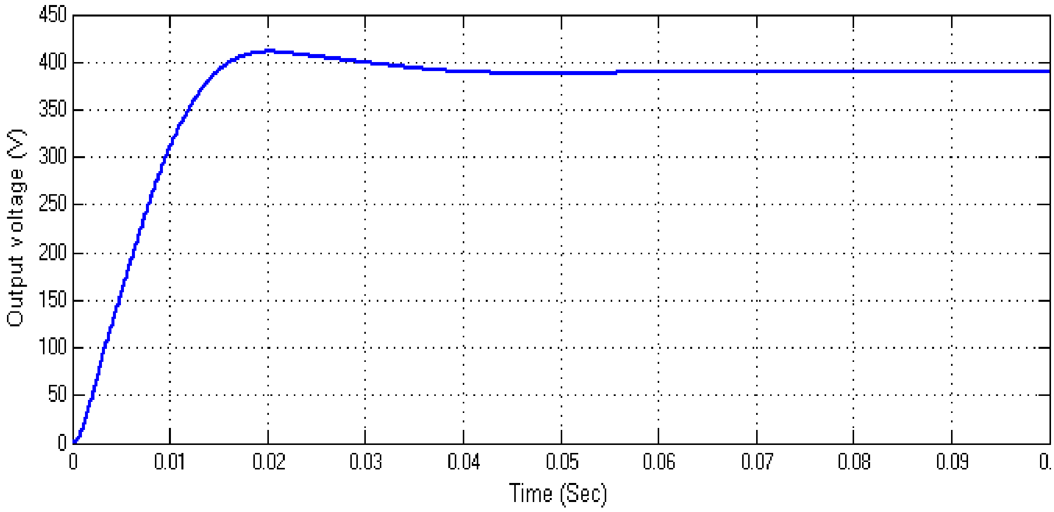

Fig 7 output voltage of converter

Fig 7 shows the output voltage of the proposed high step-up converter when operated in closed-loop controlled method. Here the output voltage is maintained constant.

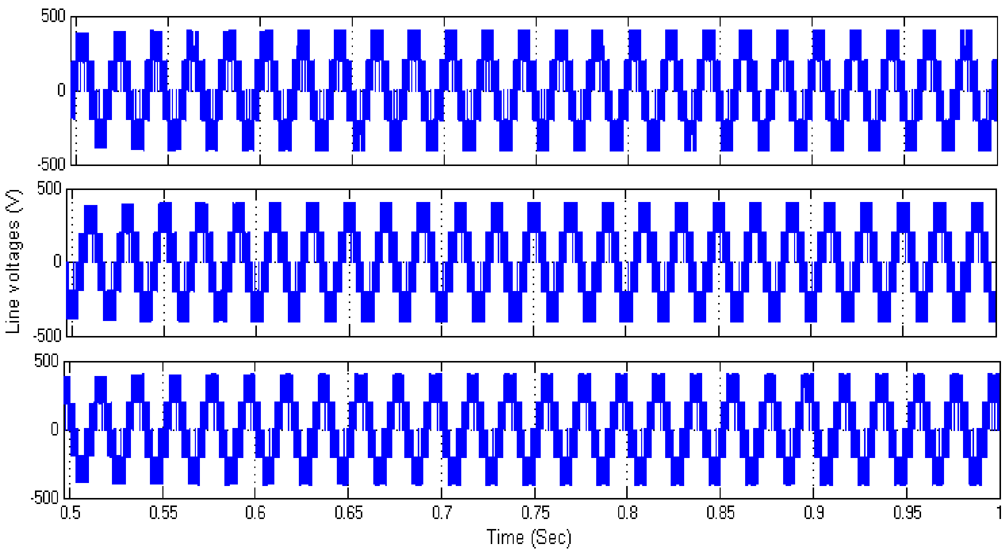

Fig 8 shows the line voltages of induction motor drive

Fig 8 shows the Line-line voltages of the proposed converter fed to induction motor system, here the line voltages are showing five levels and the voltage value is approximately 400V

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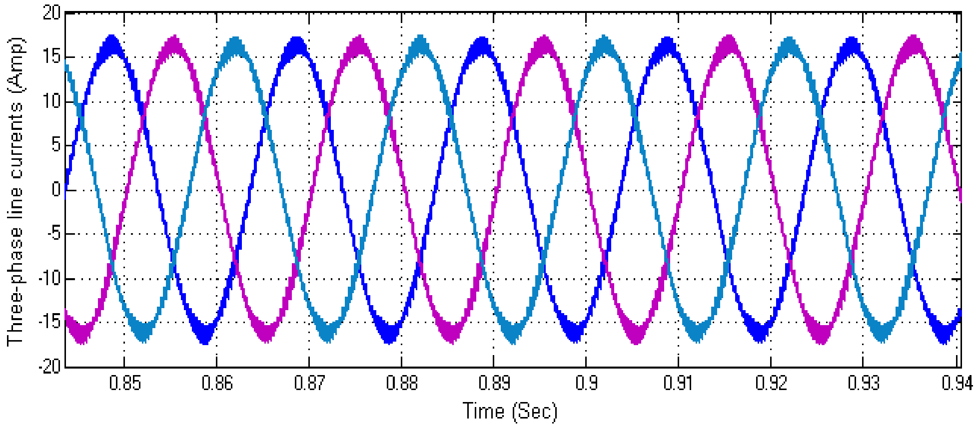

Fig 9 shows the three-phase line current of induction motor drive

Fig 9 shows the three phase line currents of the proposed converter fed to induction motor system, here the three phase line currents are showing sinusoidal response and the current value is approximately 16A

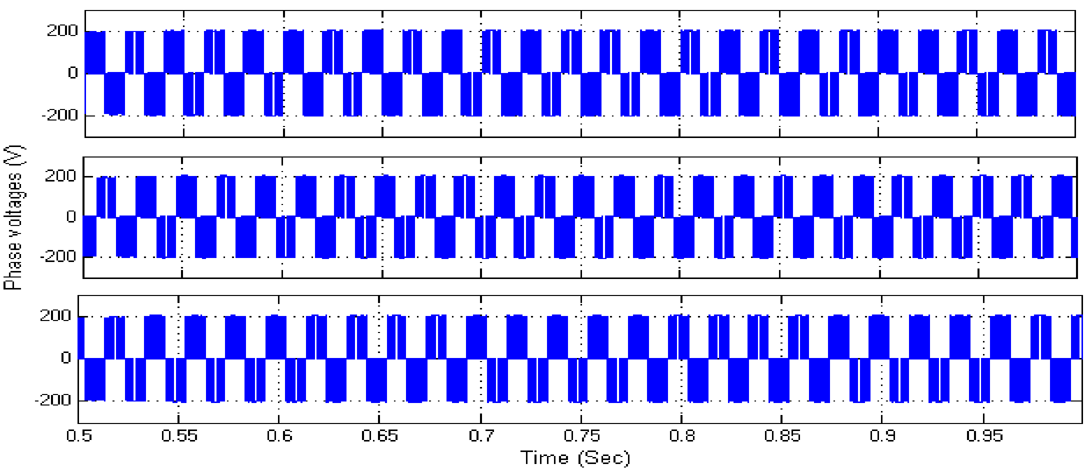

Fig 10 shows the phase voltages of induction motor drive

Fig 10 shows the phase voltages of the proposed converter fed to induction motor system, here the phase voltages are showing three levels and the voltage value is approximately 200V.

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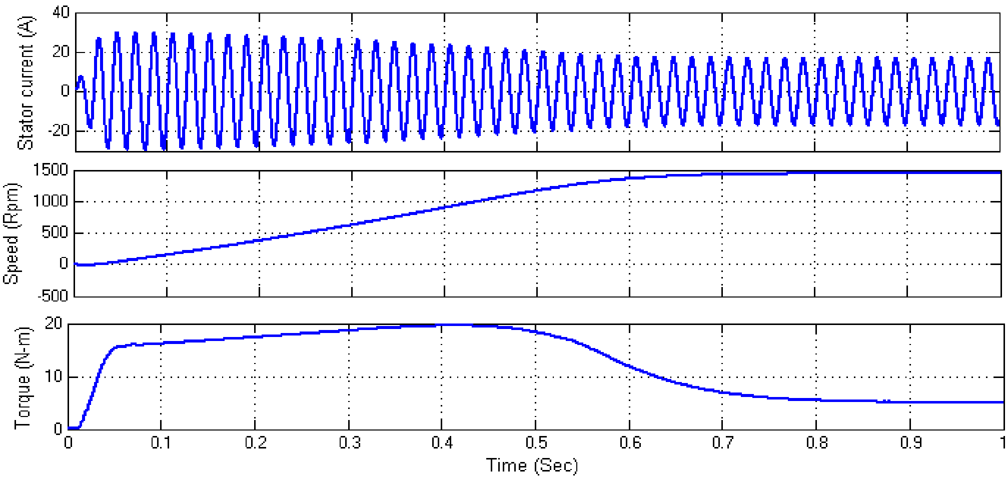

Fig 11 stator current, speed, torque characteristics of induction motor

Fig 11 shows the Stator current, Speed and Torque response of the proposed high step-up converter fed to induction motor drive system, here when the time reaches to five time constants speed comes to steady-state and torque comes to 5 N-m.

VI. CONCLUSION

Depending on the virtues of the proposed Switched capacitor converter and the switching-mode dc-dc converter a novel design of combined properties of the converters has been proposed. By operating the inductors and capacitors in switch on/off conditions output voltage is increased and is explained. The advantage of proposed concept is cost less when compared to other isolated converters and high efficiency. The proposed converter is operated under closed-loop condition and output voltage is maintained constant. Further the converter is fed to an Induction motor drive with the help of an inverter. The performance of the motor is analyzed with the help of Matlab/Simulink and results are observed.

Table-1 Simulation parameters:

S.No	Name of the parameter	Value of parameter
1	Input voltage	50 V
2	Output voltage	400 V
3	Switching frequency	100KHZ
4	Output power	5Kw
5	Output current	20A

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