ISSN (Online) 2321 – 2004
ISSN (Print) 2321 – 5526

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH IN ELECTRICAL, ELECTRONICS, INSTRUMENTATION AND CONTROL ENGINEERING
Vol. 2, Issue 2, February 2014

Induction Motor Drive With Low Cost Converter And ZVS Inverter

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Abstract: This paper proposes a new low cost converter- inverter drive system for induction motor. It proposes a Dual Inductor Converter consisting of a resonant tank, voltage doubler rectifier and a snubber circuit which act as a DC-DC boost converter. Constant duty cycle control is used in the Dual Inductor converter to improve its efficiency. The input current of the converter system is distributed through the two boost inductors making its current ripple amplitude halved at twice the PWM frequency. The output of the converter system is given to the inverter system. For the voltage source inverter, different PWM strategies are compared and the most efficient method is adopted based on its harmonic performance. The THD of PWM, SPWM and SPWM with third harmonic injection is analyzed theoretically. The system have high lifetime and is having low cost.

Index Terms: Hysteresis control, DC- DC Converter, AC motor drives, Third Harmonic Injection.

I. INTRODUCTION

A drive system is typically composed of three components: a dc-dc converter that converts low dc voltages to a required high dc voltage, an inverter that converts the high dc voltage to a single- or three-phase ac voltage, a digital controller that controls the converter inverter operation. For implementing in economic ways; we can adopt photovoltaic cell [2].

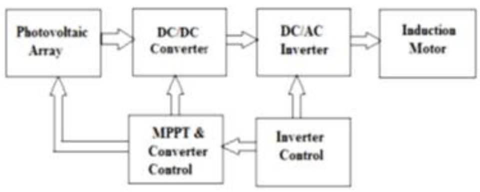

Figure 1: Simplified block diagram of the photovoltaic system.

The simplified block diagram of a photovoltaic system is shown in Fig 1. Most PV powered drive systems consist of a control unit, with or without battery as energy storage. In this paper, it proposes a system without the use of storage elements. Because of the lack of storage in the DC bus, the power of the PV array must be used immediately to accelerate the motor. The energy produced by the panel is fed to the motor through a converter with two power stages: a DC/DC TIBC stage to boost the voltage of the panels and a DC/AC three-phase inverter to convert the DC voltage to three-phase AC voltage. Voltage fed converters which were generally used is expensive due to the high voltage stress and is bulky when used in high voltage applications. So, the proposed system uses current fed converters because they need no output inductor and have flux-imbalance problems[6][7]. Generally, single inductor boost converters were used for improving the input voltage to certain extend. But, in a number of high-power applications, the performance of the boost converter can be improved by implementing boost converter with multiple switches and/or multiple boost inductors [8]-[9]. As the irradiance increases, resulting in a higher output power of the PV array, the input power in the DC bus is higher than the output power. There are different MPPT techniques for PV systems [10].

The Two Inductor Boost converter has two inductors in the primary side and a voltage doubler in the secondary side. Although, the current fed topologies are used here, it have some problems like high voltage spikes created due to the leakage inductance of the transformers, and high voltage stress on the rectifying diodes. Thus, the converters adopt resonant topologies to utilize the component parasitic characteristics and thereby achieve zero current switching (ZCS) or zero voltage switching (ZVS) condition [11]. A snubber is connected in parallel with the whole system to overcome from and problems. This paper extends the DC/DC converter to an inverting system. The inverter is based on a classic topology (three legs, two switches per leg).The theoretical and practical developments which form the basis of the new suboptimal PWM strategy have been presented, and the practical results produced have demonstrated the possibility of achieving these objectives [13].

II. PROPOSED SYSTEM

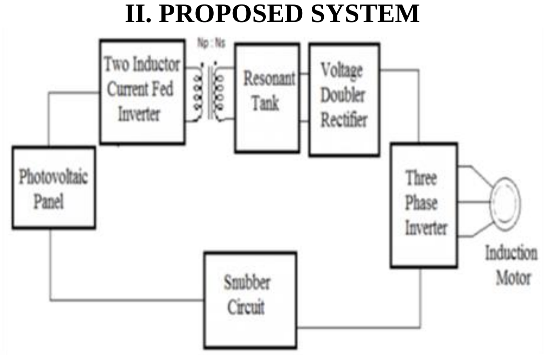

Figure 2. General block diagram of the TIBC converter

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INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH IN ELECTRICAL, ELECTRONICS, INSTRUMENTATION AND CONTROL ENGINEERING
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Fig 2 shows the general block diagram of a dual inductor converter. It mainly consists of current fed converter block, voltage doubler and snubber circuitry. Current-fed converter mainly consists of an inductor connected in series with the supply. The current source system thus obtained is normally derived from the boost converter, having an inherent high step-up voltage ratio, which helps to reduce the needed transformer turn ratio and it reduces the voltage stress to a large extend. But, it has disadvantages like high current ripples. For that, two inductors are connected in the primary side. The input current is distributed through the two boost inductors having its current ripple amplitude halved at twice the PWM frequency. Because of the low voltage characteristic of the PV panels and small input current ripple, the required DC/DC converter needs to have large voltage conversion ratio. The voltage doubler in the secondary side is used to double the input voltage to it, thereby using it for obtaining a wide output range. An isolation transformer is connected in between them. The isolation transformer is not only used to isolate the output from the input; but also, it can provide with a certain step up ratio. Increasing the turn ratio above a certain value may lead to large transformer size, high cost and stress effects. The parasitic parameters of the transformer is absorbed and neutralized by the resonant tank to provide high voltage gain and create zero-current switching (ZCS) or zero voltage switching (ZVS) condition.

Fig. 3 shows the proposed converter circuitry. The single inductor of a general boost converter is replaced by two inductors, L1 and L2. To improve electrical performance and reduce size and weight, the front end inductors in the system are magnetically coupled.

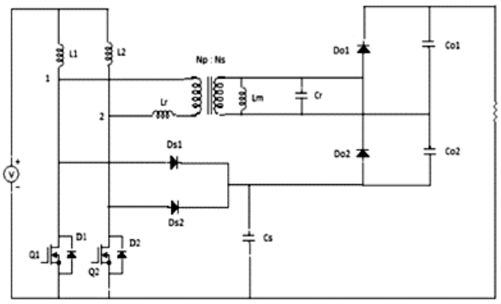

Figure 3: Proposed Two Inductor converter side circuitry

In addition, the input inductors are equal in magnitudes which make the current in the two boost inductors halved at twice the PWM frequency. The MOSFET switches Q1 and Q2 are hard switched overlapped.ie, atleast one of the switches is on at any time. The parasitic components of the resonant tank include the magnetizing inductance Lm, leakage inductance Lr and leakage capacitance Cr. In order to simplify the analysis of the proposed converter the magnetizing inductance of the transformer is very large so that the magnetizing current is negligible. The Do1, Do2, Co1and Co2 forms the voltage doubler circuit. The output capacitors Co1 and Co2 are much larger than Cr, to clamp the resonant voltage. Ds1, Ds2 and Cs form the snubber circuit. During sudden rise in voltages, energy transferred to the output capacitor is not completely transferred to the load if snubber circuit is not present. It leads to an increase in the output voltage. The topological operating stages for a half cycle includes two stages

1st stage: with both switches closed the primary winding is short circuited and the current increases linearly in the input inductors according to the specified ripple. Energy is stored in the inductors while the output filter capacitor feeds the load. The isolation transformer remains unaffected.

2nd stage: when the switch Q1 is turned-off, its current is commutated to the primary winding. The isolation transformer gets involved due to the voltage difference between node 1 and node 2. As Q2 is turned on, Ds1 will start to conduct. At this instant the current in Do2 reaches zero causing the resonance between Cr and Lm [8]-[15].

III. PROPOSED INVERTER

It uses a three phase inverter composed of six switches with each phase output connected to the middle of each leg of the inverter as shown in fig.4.

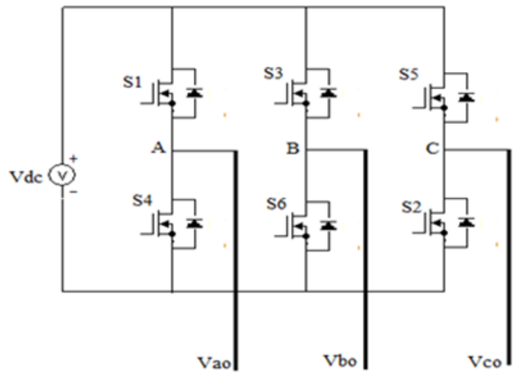

Figure 4: Three Phase Three Leg Inverter

The six step inverter is developed using PWM, SPWM and SPWM strategy with 1/6 optimal third harmonic voltage injection. For DC–DC converters, the PWM reference is a constant when the converter operates in a steady state but varies whenever the converter goes through a transient. In SPWM strategy, the peak of the sine modulating waveform is always less than the peak of the triangle carrier voltage waveform. When the sinusoidal waveform is greater than the triangular wave, the upper switch is turned on. Similarly, when the sinusoidal waveform is less than the triangular waveform, the upper switch is off and the lower switch is on. The switches are controlled in pairs ((S1; S4), (S3;S6), and (S5;S2)).

A new PWM strategy; ie, SPWM with third harmonic injection is also shown here by adding third harmonic with a peak magnitude of one sixth to the modulation waveform. It has the effect of reducing the peak value of the output waveform by a factor. The use of this PWM strategy improves the output voltage level as compared to sinusoidal PWM modulation. The sinusoidal pulse-width modulation (SPWM) technique produces a sinusoidal waveform by filtering an output pulse waveform with varying width. A high switching frequency leads to a better filtered sinusoidal output waveform. The desired

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output voltage is achieved by varying the frequency and amplitude of a reference or modulating voltage. Natural-sampled PWM is based on a defined modulation process, involving a direct comparison of a sinusoidal modulating wave and a triangular carrier (sampling) wave.

Since the inverter control is based on third harmonic injection, a wave is injected to the system other than the actual sine wave to reduce the third harmonic components in the system. Here, a sine wave of 150 Hz frequency is injected to the actual 50 Hz frequency sine wave. This wave is then compared with the carrier signal with inverter switching frequency to develop the switching pulses. This is the pulse provided to the inverter switches [2]-[13]. Fig. 5 shows the third harmonic modulation [16].

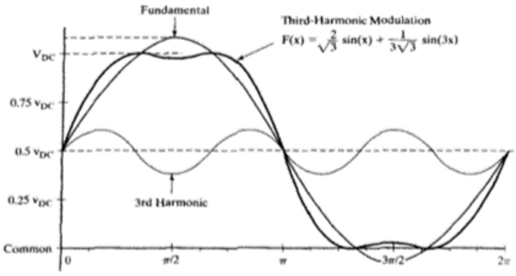

Figure 5: Third harmonic modulation

V. MATLAB/SIMULINK SIMULATION

The proposed system software is done in MATLAB/Simulink version 2013. Simulation of converter and the three phase inverter is done separately and the waveforms is analyzed. TIBC converter is controlled using hysteresis controller. An input of 26.6 volt is boosted to a constant DC 350 volt. It is fed to a three phase inverter. The inverter is controlled using PWM, SPWM and SPWM with third harmonic injection.

a)Converter Simulation and Output Waveform

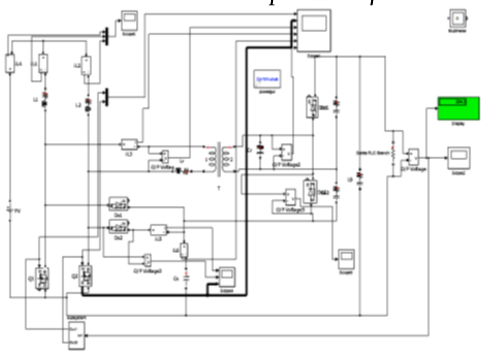

Figure 6: TIBC Converter Simulation

A dc input of 26.6 volt is given to the converter. The TIBC converter shown in fig. 6 consist of current fed inverter shown using L1 and L2. Current through L1 and L2 are shown in the fig. 7. The input current is equally divided using the two inductors thereby reducing the current ripple to half its actual value. The pulses to the two switches Q1 and Q2 is overlapping. When both the switches are turned on, the isolation transformer voltage, VT is zero and then the inductor voltages increases. When at least one switch, Q1is turned on, the voltage across the isolation transformer increases thus charging the inductor. Then the diode Ds2 will conduct It is shown in fig.8.

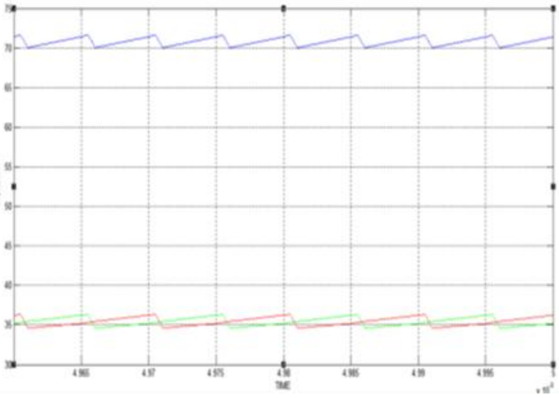

Figure 7: Currents across L1 and L2

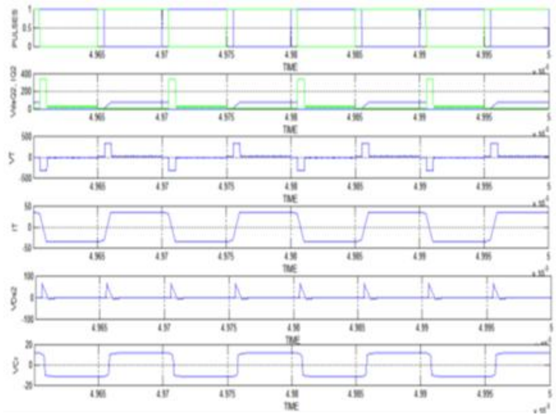

Figure 8: Voltage Q1&Q2, Snubber diode resonant capacitor & Current in the transformer

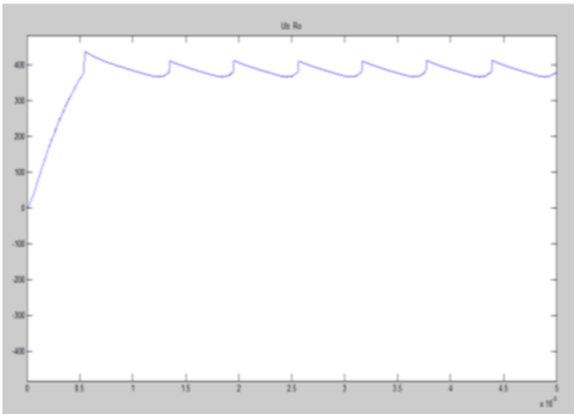

Figure 9: Output Voltage of the TIBC Converter

Voltages of the two switches Q1 and Q2, voltages at the primary and secondary of the isolation transformer, voltage of the diode, Ds1 of the snubber is obtained in fig.8. A slightly distorting dc output voltage waveform is obtained and shown in fig.9. The TIBC converter generate an output of gain 11.96 times the input voltage. Also, the dc output voltage has a ripple voltage of about 20 voltage. That is one of the disadvantage of the TIBC converter used here. As a future scope, we can extend this paper by implementing a filter at the output thereby increasing the converter efficiency.

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b) Inverter Simulation And Line Voltage

Three phase inverter used here is controlled using three methods and THD. MOSFET switches are used here. Inverter is simulated using PWM, SPWM and SPWM with 1/6 third harmonic injection and the THD of each of them is compared. Fig.10 and Fig.11 shows the inverter simulation and the output voltage waveform using PWM method. In the waveform shown, the first three parameters shows the phase voltages Van, Vbn and Vcn and the last three shows the line voltages Vab, Vbc and Vca. Fig.12 shows the THD of the system using PWM method. THD of the system is calculated as 35.12%. The measured THD o of 35 % is compared with the THD using SPWM method.

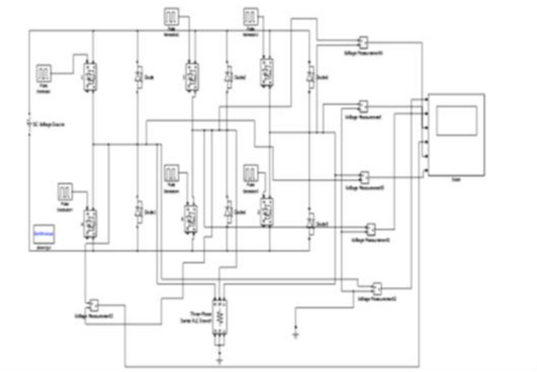

Figure 10: Three phase Inverter simulation

In SPWM method, voltage THD of 28 % is obtained. It says that SPWM method has better harmonic rejection. It is shown in Fig.14.and the output phase and line voltage of the system is shown in Fig.13. It is a three level inverter and the three voltages are 60 degree phase shifted with each other.

In SPWM with 1/6 third harmonic injection, a wave is injected to the system other than the actual sine wave to reduce the third harmonic components in the system.

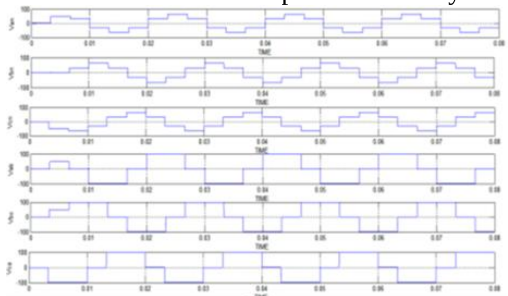

Figure 11: Inverter simulation output waveform using PWM method

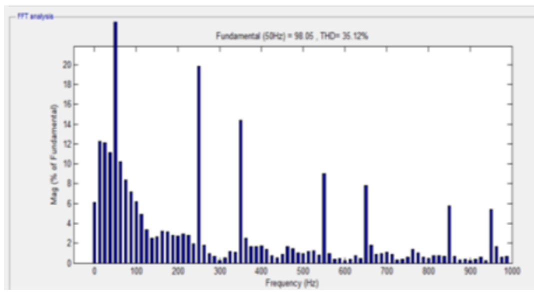

Figure 12: THD measurement using PWM method

Here, a sine wave of 150 Hz frequency is injected to the actual 50 Hz frequency sine wave. The sine wave modulating signal and the sinusoidal signal with three times the frequency of the modulating signal is added to generate a new signal which can eliminate the third harmonic in the system.

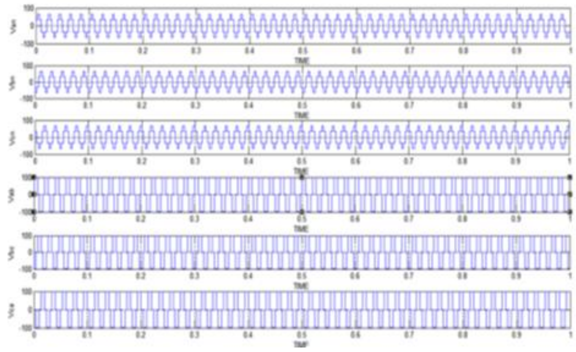

Figure 13: Output phase and line voltage using SPWM method

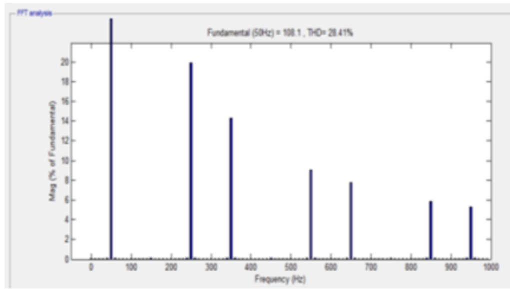

Figure 14: THD measurement of inverter using SPWM method

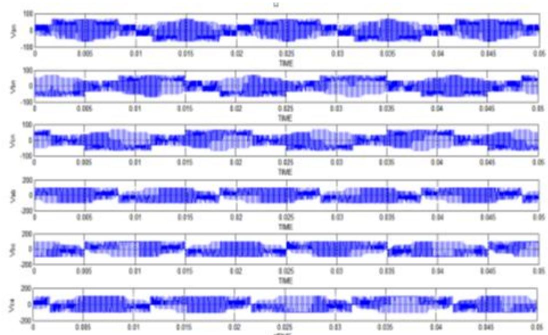

Figure 15: The output voltage using SPWM with third harmonic injection

Also, the system is injecting a sine wave with 1/6 the amplitude of the actual reference signal. This wave is then compared with the carrier signal, and pulses are generated. The output voltage of the inverter is shown in Fig.15 and the THD of the inverter using SPWM with third harmonic injection is shown in the Fig.16. It shows that the THD of the inverter using SPWM with third harmonic injection is reduced. The total THD percentage is reduced from 28% to 14.5%. So, for applications and other purposes we use SPWM with third harmonic injection. Although it has disadvantages like high cost and complexity in control, it helps in reducing the third harmonics, which is a very severe harmonic component in AC systems.

The converter output can be connected to a filter to get a ripple free dc output. This system on connection with the dc-ac inverter presented above can provide a suitable

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ISSN (Print) 2321 – 5526

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH IN ELECTRICAL, ELECTRONICS, INSTRUMENTATION AND CONTROL ENGINEERING
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ac signal to drive an induction motor drive. It can be used in water pumping and other applications.

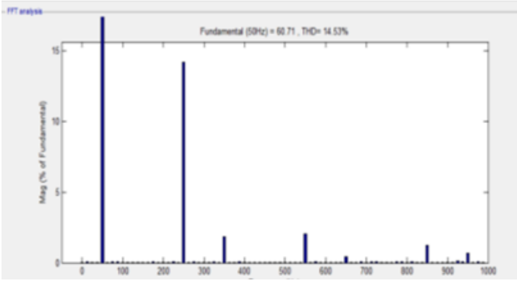

Figure 16: THD for inverter using SPWM with third harmonic injection

The inverter output from the third harmonic injection PWM strategy if connected to an induction motor, then the open loop drive system developed is very cost effective and comparatively more efficient. The experimental setup of the system is on progress.

VI. CONCLUSION

In this paper, a converter-inverter drive system using a photovoltaic array is implemented. 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 Volts is boosted to 350 volts. This paper also presented three control strategies of three phase three leg inverter. The THD and output voltages of the three systems are compared and it was proved theoretically that the SPWM with third harmonic injection generates better output. The THD of the three controls; ie, PWM, SPWM and SPWM with third harmonic injection is obtained as 35%, 28% and 14.5% respectively. An open loop induction motor is connected to the inverter thereby converting the electrical input to the mechanical output.

ACKNOWLEDGMENT

The author would like to thank the motivation provided by the University of CUSAT, and financial support from TocH Institution of Science and Technology, Ernakulam.

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