Single Phase Induction Motor Drive using Modified SEPIC Converter and Three Phase Inverter

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***Abstract*— A new idea of replacing the bridge rectifier with a modified SEPIC rectifier topology is introduced here. The proposed system uses a single phase to three phase converter structure to control the induction motor. In this circuit input current shaping is done by proposed modified SEPIC topology and the conventional inverter is replaced by six three phase inverter. The circuit proposed in this work also aims to replace the existing capacitor connected motor circuit by a variable frequency inverter drive. The harmonic distortion in conventional drive can be minimized in the proposed AC-DC-AC converter. In this drive, dsPIC30F2010 is used for pulse width modulation. Proposed driving system is simulated using MATLAB/SIMULINK. To validate the theoretical analysis, a prototype of 100W was built with an input and output voltage of 230V and 350V respectively and it worked satisfactorily.**

Keywords*— *SEPIC, Switched capacitor, DCM, PWM and THD

INTRODUCTION

Induction motors are used in many drives because they are simple and very easy to maintain. Speed of an induction motor is related to its frequency. So speed can be easily by using converters which gives variable frequency output. An inverter is a type of power converter which converts dc ac power. Thus inverter is used in the areas where ac power is required. But practical inverters give non sinusoidal output waveform.

Usually they contain harmonics. The harmonics can be eliminated with pulse width modulation. By using some modulation we can obtain the required amplitude and frequency with good quality outputs. Control of an induction motor(V/F) is become easy by using pulse width modulation. PWM is a simple method which used for controlling output of inverter. By adjusting the ON time and OFF time of inverter switches, a required ac output voltage is obtained. So PWM helps in reducing total harmonic distortion. Three phase power converters using pulse width modulation have a wide range of applications for ac machine drives. It is understood that the induction motor is going to become the main part of industrial purposes. As compared to the DC machine, it has a better power by mass ratio, simpler maintenance and low cost. However, the process of controlling of the induction is more difficult. Advantage of using a ac-dc-ac system to drive AC motor in place of simply plugging into power is that ,it allows better speed control. A available method of power converter circuit to obtain the three phase variable voltage and frequency output from single phase supply is a full bridge diode rectifier and three phase inverter system. This circuit is of simple structure and low cost. But it has more current distortion and poor power factor. whenever the power requirement in the the low power range low cost drive is relevant. The circuit proposed in this work has a modified SEPIC rectifier plus three phase inverter, with this structure source current can be controlled to be sinusoidal with unity power factor. The variable inverter drive proposed in this work used to replace existing capacitor connected motor connection. The capacitor is disconnected and the terminals of the main and auxiliary windings will fed to the inverter in this work.

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Variable frequency operation of the single phase induction motor can have many advantages, as, reduced inrush current during starting resulting in lower starting powerloss, replacement of frequent start or stop cycles of the motor by continuous operation at variable frequency, possible operate over wide input voltage range etc.

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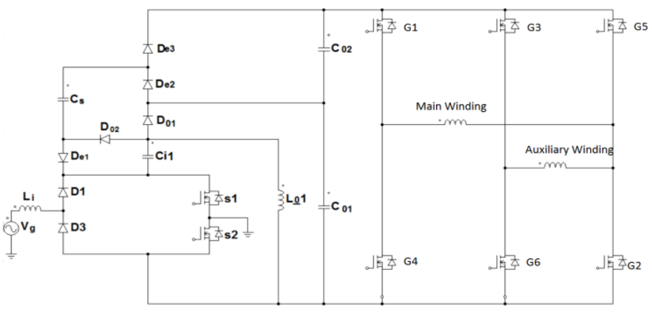

Fig -1: Motor Drive

The circuit proposed (Fig-1) in this work aims to change existing capacitor connected motor circuit by a variable frequency inverter drive. The capacitor is replaced and the terminals of the main and auxiliary windings will be fed to the inverter proposed in this paper. The additional benefit of such circuits may be the possibility to use SEPIC converter which has low input current distortion and low voltage stress on semiconductor devices. At the end port of AC/DC rectifier, high voltage is to be given to the inverter. The inverter is based on a type with three legs, where each leg consists of two switches. The control strategy used for inverter is sinusoidal pulse width modulation to improve the output voltage level compared to normal methods.

V/f Control has wide application in industrial and domestic area. The various advantages of V/f Control include wide range of speed, good running and transient performance, very low starting current requirement, wider region of stable operation, Voltage, frequencies reach rated values at base speed and acceleration can be controlled by varying the rate of change of supply frequency. Simulation of the complete system is performed in MATLAB/SIMULINK and experimental results are verified up to the converter stage.

Modified SEPIC Converter

It is a PWM rectifier using modified SEPIC topology. The design has no bridge at front end so conduction losses are very low. The proposed design gives two times gain at the output voltage. The rectifier part have following components: L_i, D_1, D_3, S_1, S_2, Ci_1, D_{o1}, L_o and C_{o1}. The absence bridge reduces the number of components and only one diode is present at each switching cycle, can result in less conduction.

Modes of Operation

Mode 1

On mode1, both S1 and S2 are ON condition, the diodes De1 and De2 are conducting, and the diodes De3, Do1 and Do2 are reversed biased. The currents flowing through the inductors Li and Lo increase linearly. The capacitor Co1supplies energy to C_S s Co1 and Co2 supplies energy to Load Ro

Mode 2

On mode2 both S1 and S2 off, hence, De3, Do1 and Do2 are conducting and De1 and De2 reverse biased. The stored energy in C_S and Li and Lo are transferred to Co1, Co2 and to Ro. CS and Co2 are connected in parallel and the currents in Li and Lo decreases in this mode.

Mode 3

On mode 3 current in Do1 is zero. In this mode, C_S and the Li and Lo charging Co1,Co2 and giving energy to the load.

Mode 4

On mode 4 currents $I_{LI\ min}$ and I_{Lo} min is become equal. So current in diode Do2 is become null. At this mode load is fed capacitors Co1 and Co2 .

Three Phase Inverter

The three phase inverter has only small change in the pulse generation. Common terminals of main and auxiliary windings is connected at the leg C. The other end of main winding is connected leg A. Other end of the auxiliary winding is connected to leg B. 180^0 out of phase waveforms are obtained at leg A and leg B . leg C has 90^0 phase difference with both A and B waveform.

4. DESIGN OF COMPONENTS

Converter is designed for input voltage, Vin = 230V and output voltage Vo = 350V .
The s gain of the rectifier is given by the ratio between the output and peak input voltages, given by

$G = Vo/Vp = D(R_o(Li + Lo)/4LiLofs)^{1/2}$…………(1)

The inductor values Li and Lo are obtained by

$Li = Vp\ D/ I_{L\ i}fs$………………………………….(2)

and

$Lo = (Li\ R_o\ V\ p^2\ D^2) / (2LiVo^2 fs - Ro\ Vp^2\ D^2)$ ….(3)

Respectively. The inductor is designed based on the ripple current specification.
The capacitance values of Cs=Co1=Co2 are given by

$Cs = Co1 = Co2 = (2Pot_{hut}) / V_0^{\ 2} - (0{,}9V_0^{\ 2})$……(4)

Simulation Models And Result

Simulation of the proposed converter is done in MATLAB/SIMULINK.

Control Strategy

Control pulses for switch are generated by PWM method. Usually it is done by comparing a saw tooth carrier and a reference value. A repeating sequence of 50kHz frequency
is compared with a constant 0.35. Whenever repeating sequence is less than the constant, it will output a high value and if constant is smaller, it will output a low value.
Here, two switches have same switching Pulse output requires.

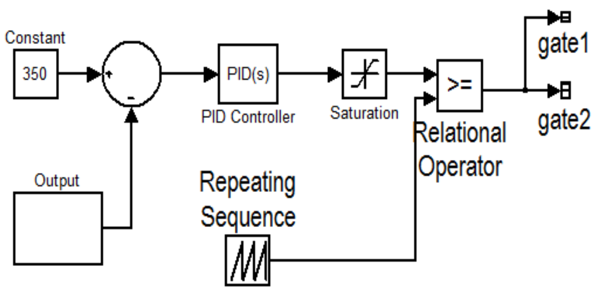

Fig -2: Control Strategy

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Simulink Model

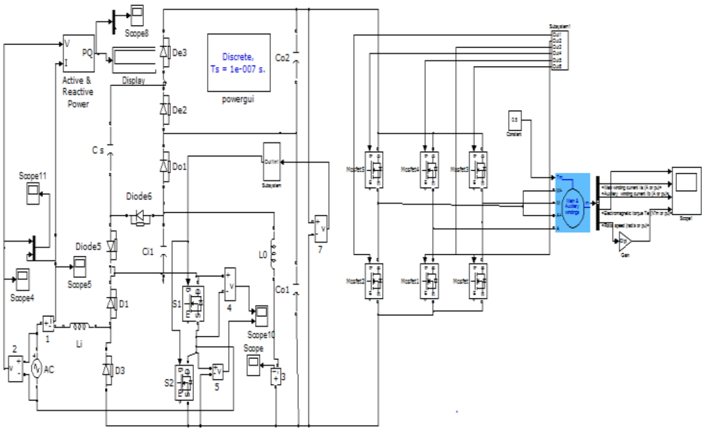


Fig -3: Simulink model

5.3 Simulation Results

The simulation results were obtained with the output voltage closed-loop and rated power. The Figure shows the simulink model of modified SEPIC converter. The converter is modeled for 100W. For an input RMS voltage of 230V, it produces an output DC voltage of 350V;

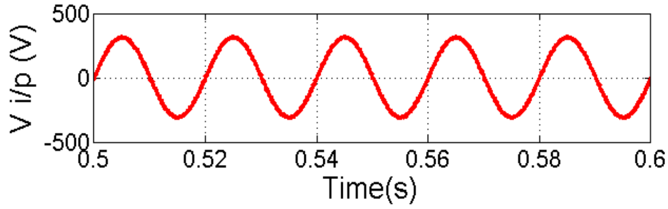


Fig -4: Input voltage

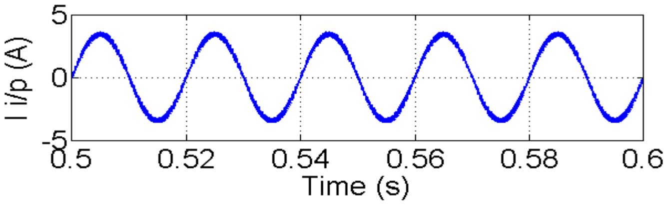
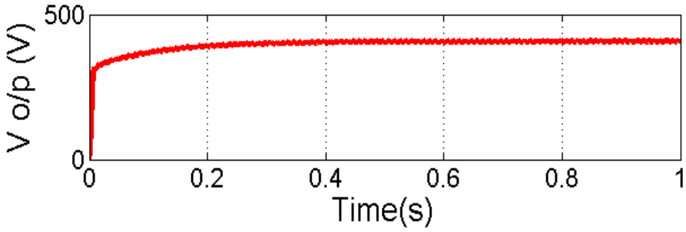


Fig -5: Input current

The results shows that the input current and input voltage are proportional and are almost in phase.



F **ig -6**: Output voltage

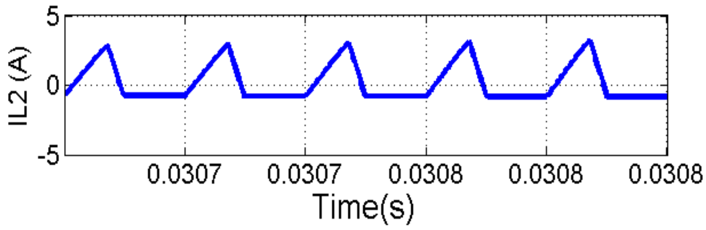


Fig -7: Inductor current

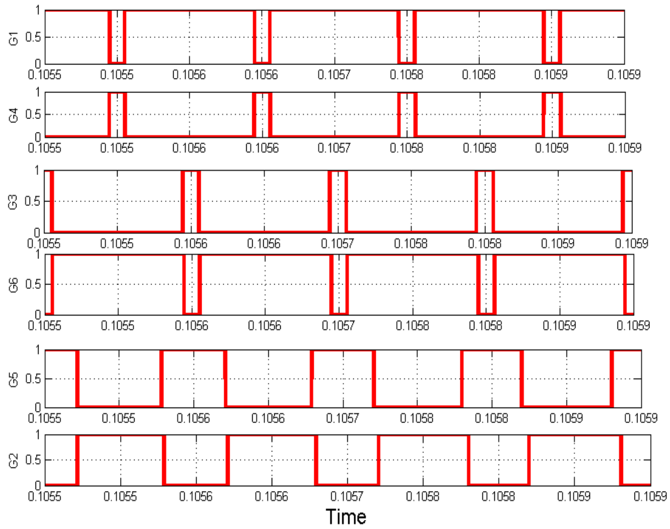


Fig -8: Inverter pulse

Simulation of proposed drive is done in MATLAB/SIMULINK. Switching frequency is choose as 20KHz for rectifier and 5 KHz for inverter.. The converter has 2 switches and both require same gate signal. For controlling this PWM rectifier PI regulators are employed.
The inverter has 3 legs of switches and the pwm pulses given to these switches are designed to make modulating waveforms of first two leg are 180^0 out of phase and modulating waveform of third leg has 90^0 phase difference between first two leg

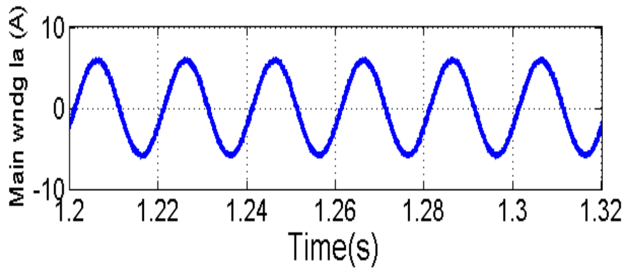


Fig -9: Main winding current

Main winding current and Auxiliary winding current are illustrated in Fig-9 and 10 respectively. 90^0phase shift between the currents can clearly be

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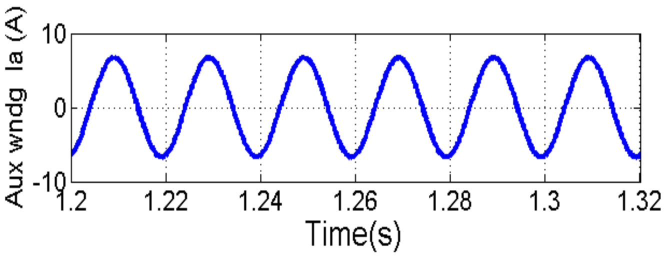

Fig -10: Auxiliary winding current

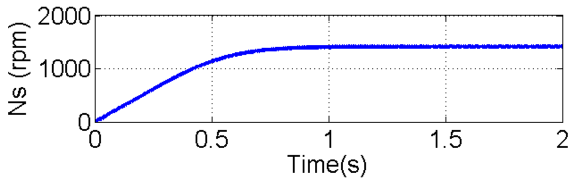

Fig -11: Speed

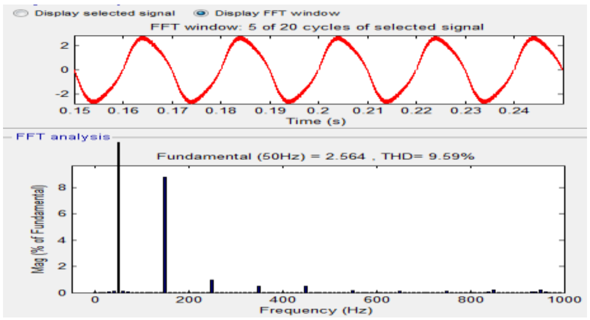

Fig -12: Total harmonic distortion

The total harmonic distortion is reduced to 9.59%. Fig-11 shows the speed vs time plot of the induction motor. The motor settles at a speed of 1450

EXPERIMENTAL SETUP AND RESULTS

Prototype is designed for an input voltage of 230V and output voltage of 350V.

Simulink Control Logic for Converter dsPIC30F2010 is programmed by simple MATLAB interfacing method. To do the interfacing MPLAB 16 bit device blocks for simulink is installed. Pickit3 programmer is used to program the microcontroller. The control logic for basic converter circuit is shown in Fig-13. Two of the PWM pins of the controller are used to give pulses to the power switches. PWM1H and PWM2H pins(23,25) are used as the PWM output pins.

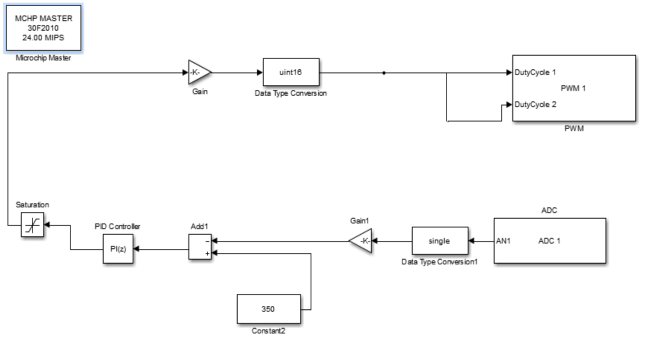

Fig -13:: Simulink control logic for converter

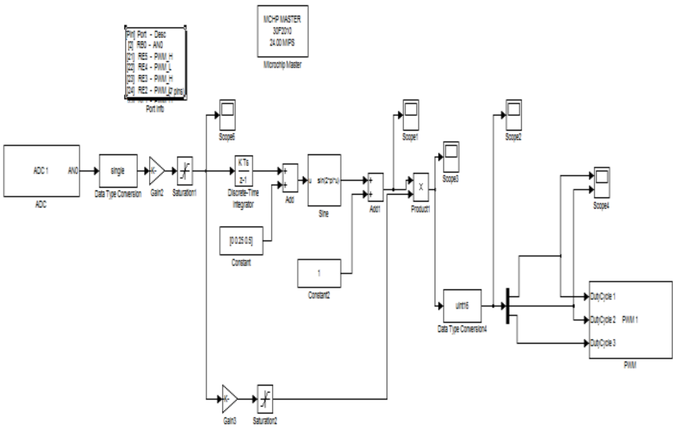

Fig -14: Simulink Control Logic for Inverter

V/f control of single phase induction motor is done using SPWM technique. Six PWM pins of the controller are used to give pulses to the power switches. PWM1H, PWM1L, PWM2H, PWM2L, PWM3H and PWM3L pins(21,26) are used as the PWM output pin.

A complete single phase induction motor using SEPIC modified converter is implemented in hardware section. The converter and inverter section are done in two seper-ate PCB's. After verifying the output from the converter using a lamp load, then it is connected to the inverter input of the second PCB. Output of inverter is measured by connecting a lamp load. And also the drive operation is verified by connecting a fan.Two dsPIC's are used for separate control of converter and inverter. In convert Single phase induction motor drive using modified SEPIC converter and three phase Inverter side, only a gate pulse is required which can be generated using simple control logic.

In inverter, SPWM is used and six gate pulses are generated from another dsPIC.

A 100W prototype is built to verify the theoretical results of the drive. The converter operation is verified by giving 230V input from the lab power supply.

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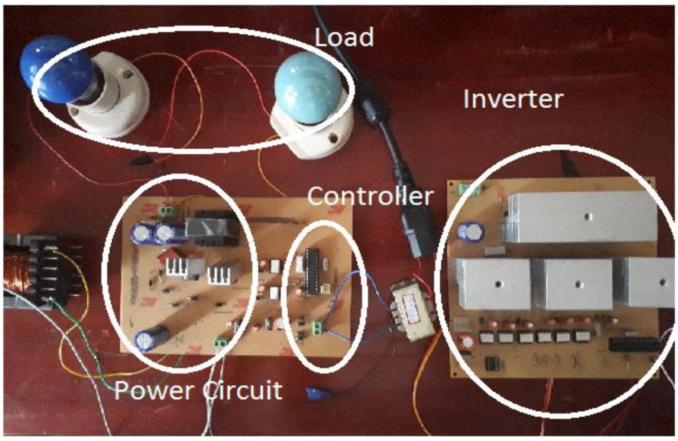

Fig -15: Experimental setup

It can be seen that both gate signals are of similar duty ratio and its value is 20%.

The output voltage obtained is shown in Fig-16, and its average value is found to be 350V.

Experimental waveforms of the input voltage and input current are presented in Fig-17 at the rated power(100W). The results show that that the input current has sinusoidal waveform and it is almost in phase with the input voltage

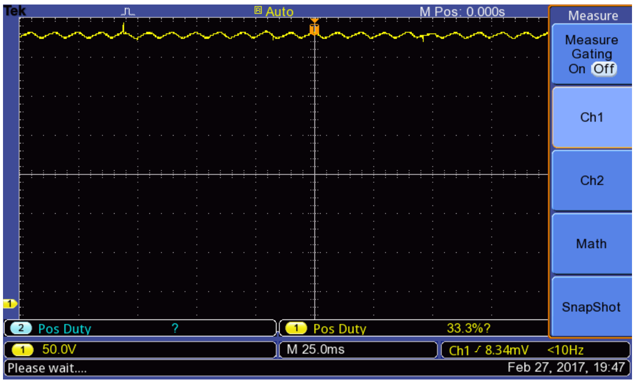

Fig -16: Output voltage

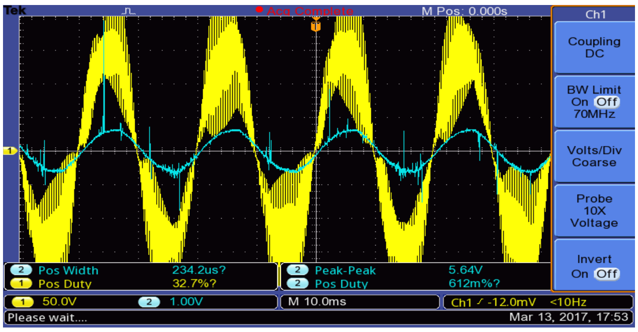

Fig -17: Input voltage and current

Drive circuit which provides the required isolation and amplification before feeding to the gate and source terminals of switches. By varying the pot connected to the analog Experimental setup with bulb is shown in Fig-18.Two bulbs are connected to both converter output and inverter output to meet the load requirement.

Fig -18: Experimental setup with bulb as the load

The capacitor in a conventional fan is removed and connected to the inverter output in order to verify the starting of induction motor in the absence of capacitor.

Experimental setup with fan is shown in Fig-19

CONCLUSION

A single phase induction motor drive using modified SEPIC rectifier and three phase inverter has been introduced. The proposed system is simulated in MATLAB/Simulink2010. The main features of the proposed drive include high efficiency and simplicity of design. The total harmonic distortion is reduced to 9.59%. To validate the theoretical analysis, A 100 W prototype was built with an input and output voltage of 230V and 350 V respectively. Experimental results of input voltage and input current show that the input current has sinusoidal waveform and almost in phase with the input voltage. The inverter's DC bus voltage (350 V) is maintained by a single phase modified SEPIC rectifier fed from a 50 Hz supply. This work replace the need of the capacitor which used in the conventional motor circuit. The proposed drive is experimentally implemented and the concept is successfully verified.

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