Advanced Research in Electrical and Electronic Engineering
p-ISSN: 2349-5804; e-ISSN: 2349-5812 Volume 4, Issue 2 April-June, 2017, pp. 39-42

http://www.krishisanskriti.org/Publication.html

Operating Three Phase Induction Motor using Single Phase Supply

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Abstract—*This paper presents a simple and low cost single phase to three phase converter topology for driving a three phase Induction motor with a single phase AC supply. The topology was derived by combining properties of the rectifier, closed loop control of the boost-converter and three-phase six switches inverter. The closed loop boost converter is used to convert a low level DC input voltage from rectifier and use to control the average model. To get high quality sinusoidal output voltage with reduced harmonics distortion, pulse width modulation (PWM) control plan is presented for firing the switches of inverter. Since the output voltage contains some harmonics therefore LC filter component is introduced. The three phase motor is connected with this generated three phase supply to test the output and to control the speed of three phase induction motor. Simulation is carried out using* ***SIMULATION SOFTWARE***

1. INTRODUCTION

The three phase induction motor has some superior characteristics to their single phase counterparts, such as higher starting torque, higher efficiency, and better power factor, economic and smaller in size. Moreover starting and inrush current in three phase motor are less. Therefore, it is desirable to replace the single phase induction motor drives in some low power industrial application.

Over the last several years, the increase in automation in farming techniques and in small rural industries has led to widespread use of three phase induction motor for fans, pumps, hammer mills, a variety of farming equipment, crop dryers, irrigation and air conditioners which requires three phase supply. But most rural lines are single phase because the cost of bringing a three phase power service at that location of operation of motor is high due to higher utility tariff and the higher infrastructure cost of three phase extension. Due to the unavailability of three phase supply some provision for single phase to three phase conversion is necessary to allow the use of these three phase motors supplied with single phase power. In that situations, phase converters are an excellent choice, whose cost is often a small fraction of that of a full three phase Service.

This paper, therefore, presents a new single phase to three phase converter topology to generate voltage balanced three phase output using bridge rectifier, dc-dc converter and three phase inverter. Analysis and simulation results illustrate the superiority of the proposed topologies.

2. IMPLEMENTATION OF PROPOSED TECHNIQUE

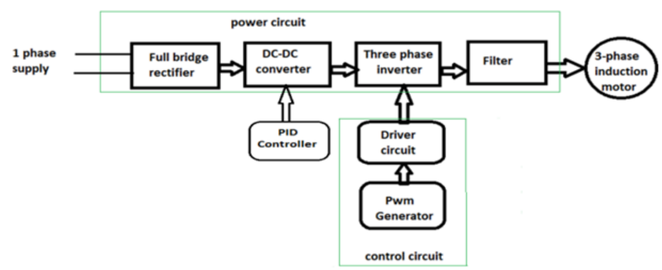

Fig. 1: The block Diagram of proposed scheme

In fig.1 The single phase bridge rectifier converts the single phase supply into a dc. It is boosted to the required value using the dc -dc converter. DC is converted to AC using three phase voltage source inverter (VSI). The output of PWM inverter is fed to the three phase inductive load.

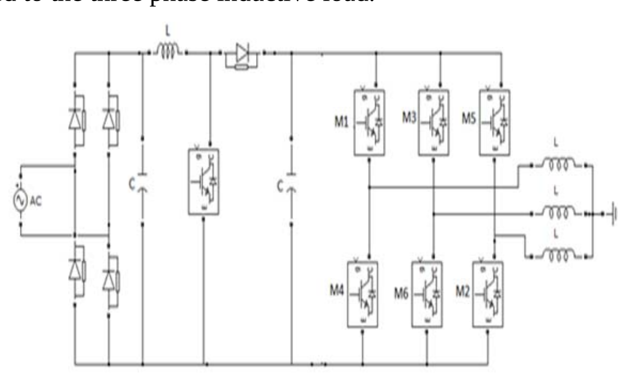

Fig. 2: Circuit diagram of proposed scheme

The circuit model of single phase rectifier with boost converter and three-phase inverter system is shown in Fig 2.

3. BASIC FUNCTION OF BOOST CONVERTER

A DC – DC boost converter is used which consists of boost inductor, diode, MOSFET used as a switch, output filter capacitance and resistive load. The converter can therefore operate in the two different modes depending on its energy storage capacity and the relative length of the switching period

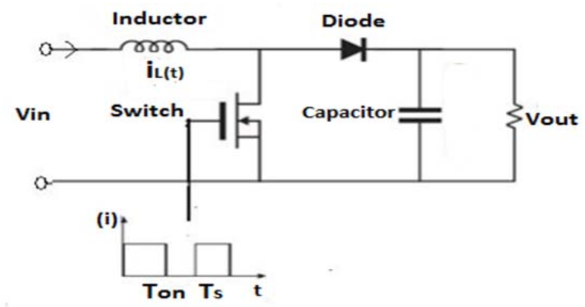

Fig. 3: Circuit Schematic of boost Converter

Mode1: When MOSFET's is switched on at t = 0 and terminates at t = T_{on}. The equivalent circuit for the model is shown in Fig. 1.The inductor current $i_L(t)$ greater than zero and ramp up linearly. The inductor voltage is V_i.

Mode2: When MOSFET's is switched off at t = T_{on} and terminates at t = T_s. The inductor current decrease until the IGBT's is turned on again during the next cycle. The voltage across the inductor in this period is V_{in}-V_{out}

4. MATHEMATICAL EXPRESSION

A. Transfer Function of Boost Converter

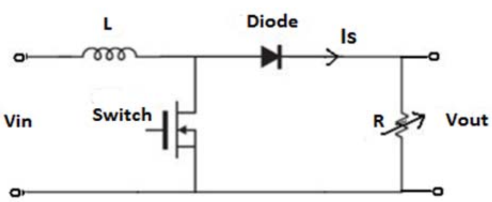

Fig. 4: Basic Circuit of Boost Converter

Basic circuit of the boost converter is shown in Fig. 4. Here I_s is the current flow through the circuit. Switch is triggered by the pulse which is generated by PWM technique. Switch remains on during T_{on} cycle and off during T_{off} cycle so triggering is depends on the duty cycle. V_{in} is the D.C. input voltage supply which is taken from the bridge rectifier which converts A.C input voltage into D.C output voltage. V_{out} is the output of the boost converter which is larger than the input $V_{in.}$

When switch turns on the current is passing through switch which increases the current level in the inductor.

At the end of T_{on} time current stored into the inductor is I_s. So,

$$V_{in} = L \times \frac{dI_s}{dt} \quad \cdots\cdots\cdots\cdots (1)$$

Using Laplace Transformation

$$V_{in}(s) = L \times S \times I_s(S) \quad \cdots\cdots (2)$$

From Fig. V_{out} can be given as

$$V_{out}(S) = I_s(S) \times R \quad \cdots\cdots\cdots (3)$$

From equation (2) & (3)

$$\frac{V_{out}(S)}{V_{in}(S)} = \frac{R}{L \times S} \quad \cdots\cdots\cdots (4)$$

Equation (4) is the Transfer function of open loop boost converter.

B. Transfer Function of Closed Loop System

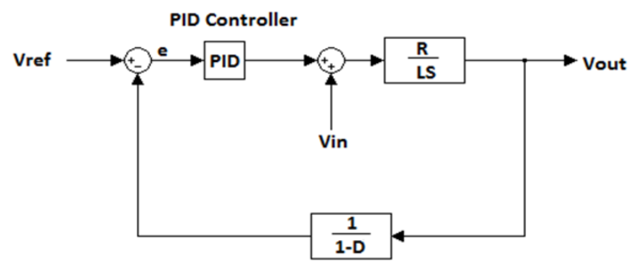

Fig. 5: Closed Loop System of Converter

In this fig.5 V_{out} is given to the Pulse Width Modulation. The output of the PWM is compared with V_{ref} which is given to the PID controller. Then it is added with V_{in} which is given to the system.

From Fig.

$$V_{out} = \left(\frac{R}{L \times S}\right) \times \left[V_{in} + \left(Kp + \frac{Ki}{S} + Kds\right) \times e\right] \cdots\cdots (5)$$

Taking $V_{ref}=0$

$$V_{out} + \left[\left(\frac{R}{L \times S}\right) \times \left(Kp + \frac{Ki}{S} + Kds\right) \times \left(\frac{1}{1-D}\right) \times V_{out}\right] = V_{in} \times \left(\frac{R}{L \times S}\right) \cdots\cdots (6)$$

$$\frac{V_{out}}{V_{in}} = \frac{\frac{R}{L \times S}}{\left[1 + \left\{\left(\frac{R}{L \times S}\right) \times \left(Kp + \frac{Ki}{S} + Kds\right) \times \left(\frac{1}{1-D}\right)\right\}\right]} \cdots\cdots (7)$$

Equation (7) is the transfer function of closed loop boost converter.

5. ZIEGLER-NICHOLS TUNING TO FIND KP , KI AND KD

The steps for tuning a PID controller are as follows:

Using only proportional feedback control:

1) Reduce the integrator and derivative gains to 0.

2) Increase *Kp* from 0 to some critical value *Kp* = *Kcr* at which sustained oscillations occur. If it does not occur then another method has to be applied.

3) Note the value *Kcr* and the corresponding period of sustained oscillation, *Pcr*

The controller gains are now specified as follows:

Controller type	K_p	T_i	T_d
P	$0.5K_{cr}$	∞	0
PI	$0.45K_{cr}$	$Pcr/1.2$	0
PID	$0.6K_{cr}$	$Pcr/2$	$Pcr/8$

Principle of operation of three phase inverter

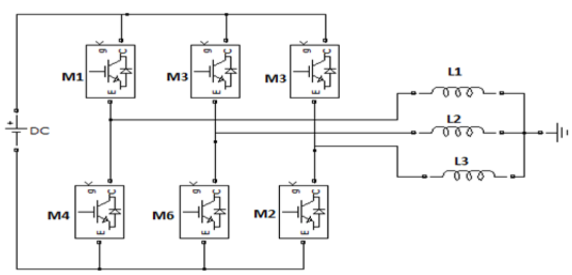

Fig. 6: The circuit diagram of inverter fed three phase inductive load

In order to generate a balanced three phase output voltages, the voltages are phase shifted by-120^0 respectively. This is done through PWM switching control of the six switches M1, M2, M3, M4, M5, M6 which are phase shifted by -120" respectively.

Table 1: Switching pattern for three phase Voltage Source Inverter

Angle	ON Switches	OFF Switches
O^0-60^0	M1 , M6	M2 , M3 , M4 , M5
60^0-120^0	M1 , M2	M3 , M4 , M5 , M6
120^0-180^0	M2 , M3	M1 , M4 , M5 , M6
180^0-240^0	M3 , M4	M1 , M2 , M5 , M6
240^0-300^0	M4 , M5	M1 , M2 , M3 , M6
300^0-360^0	M5 , M6	M1 , M2 , M3 , M4

6. LOW PASS FILTER DESIGN

In this section, the design procedure of LC low pass filter is described. This filter has the importance in the sense that it removes low order distortion at output of the inverter.

As only the harmonic content is the consideration as LC low pass filter is used which generally gives 5% distortion.

The low pass filter is used to get approximate sine wave so that resonant frequency of the LC circuit is chosen at 50 Hz (denoted by F_r) using

$$F_r = \frac{1}{2\pi\sqrt{LC}}$$

7. SIMULATION RESULT

The simulation model has been developed to convert single phase to three phase by using Simulation software. Fig. 7 shows the PWM generation block. The PWM block provides the required PWM pulses for the 6-switches of Inverter. Fig. 8 shows the complete simulation circuit diagram of the system. The 3-phase output voltage is shown in Fig. 9.

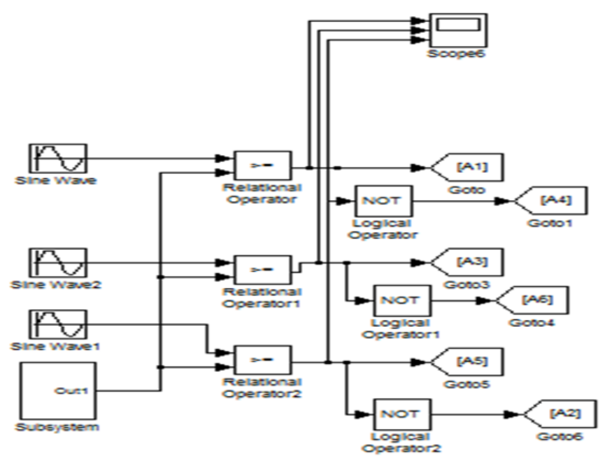

Fig. 7: Shows the PWM generation block

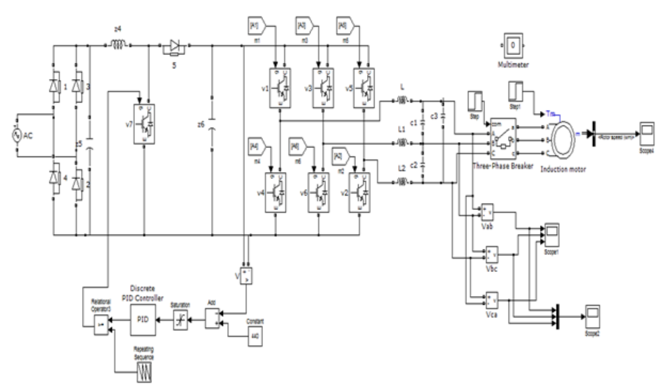

Fig. 8: The complete simulation circuit diagram

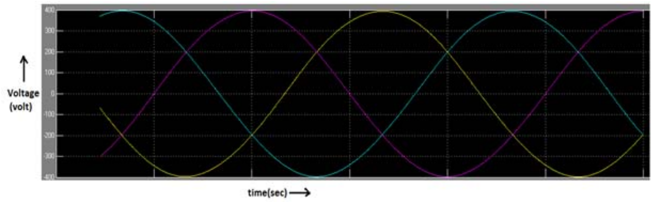

Fig. 7: Output phase voltage waveform

8. CONCLUSION

In this paper the model circuit has been simulated and waveform of output voltage has been analyzed. The waveform of inverter output voltage is not pure sinusoidal because of presence of harmonics. The THD analyzed from the FFT analysis is 0.26.These harmonics are generated in two manners .One from the power semiconductor device which are used as switching device in inverter and other from the nonlinear load (Induction motor drive). Due to nonlinear load inter harmonics also come in inverter output voltage.

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