Design of Single Phase Inverter Drive for Induction Motor

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Abstract - **Now a days the control engineering is the best choice for the control of various application in the power technology. The required hardware design and theoretical aspects of the drive is necessary for the control of the industrial application. The PWM technique is the main consideration for the control application and it is necessary to design the drive with feasible components. For the selection of the various drive components simulation is used and the appropriate base valued components are selected to get the desired result from the drive. The design introduces the basic theory of power circuit and its design specifications of buffer, base driver circuit, voltage source inverter, heat sink, snubber circuit, etc. The designed hardware is presented in single unit called drive which forms the basic representation of drive in closed loop configuration. The required signal conditioning circuits such as AC voltage sensing, speed sensing, current sensing, etc. are introduced briefly with their hardware. The software is developed in 'C' language to generate PWM firing pulses which minimizes the hardware and cost.**

keywords - **Inverter Drive, single phase drive, PC drive, PWM, Induction Motor**

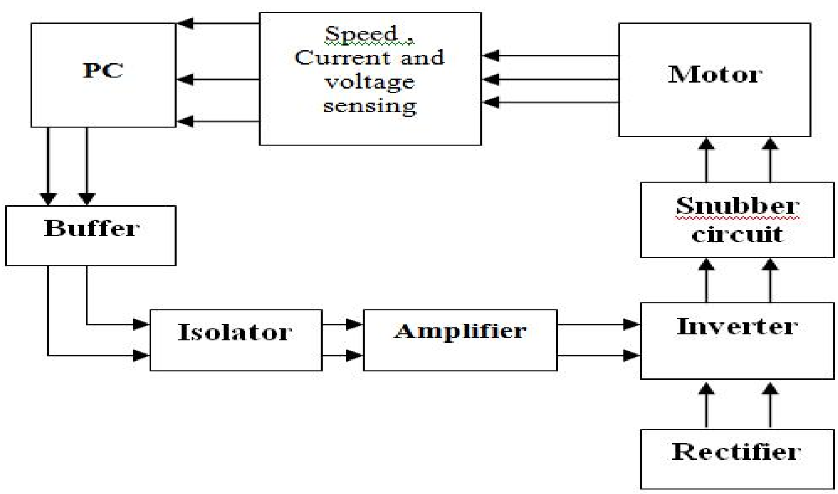
I. Introduction

General Representation of Drive

No of theories are used for the control applications. Feedback control scheme was introduced by the Jang [1] in which inverter based DC link capacitor based PWM simulation is used. The space width and the data acquisition and its parameter estimation technique is introduced [2-3]. The design of various PWM based drives and its simulation techniques is also introduced using Microcontroller and FPGA [4-9].

Fig. 1 shows the block diagram of the proposed system, which consists of various blocks such as buffer, base drive circuit, voltage source inverter, rectifier, motor, current sensing circuit, voltage sensing circuit, speed sensing circuit, etc. The system shown in Fig. 1 can work in closed loop configuration.. during closed loop operation feedback is essential and different loops are used for control. Multiple pulse width modulation is implemented by using the Computer data acquisition card. The buffer circuit is added to protect and to avoid the loading effects on computer bus. The base drive circuit consists of opto-isolator and amplifier. The opto-isolator isolates the firing circuit from the power circuit, while the driver amplify the signal which is sufficient to drive the power transistor of the voltage source inverter. The basic inverter circuit consists of four power transistors with built-in anti-parallel diodes. The BU 508D power transistor is highly desirable switch. It operates at highest possible turn-on and turn-off speeds, reducing the switching losses and maintaining the most accurate operation of the inverter.

Fig. 1 Proposed system configuration

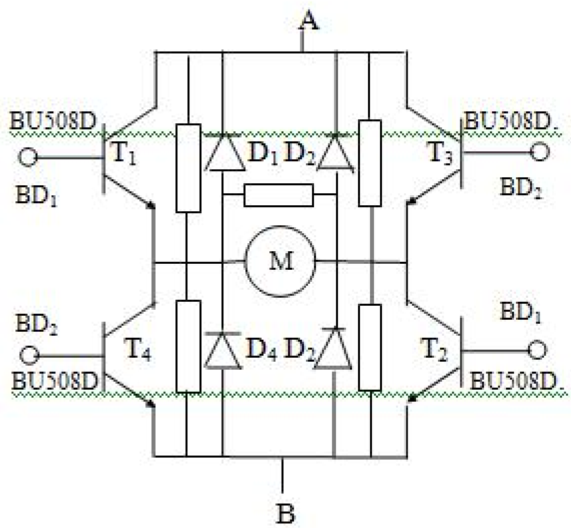


AC voltage from the source is rectified using the diode bridge and capacitor is used as a filter, the ripple present in the output of the bridge giving pure DC to the inverter. Depending upon the firing pulse width, the power supplied to the motor is varied. The speed of the motor is measured by using opto-interrupter device, which generates one pulse per revolution and these pulses are converted into proportional voltage by F to V converter. This proportional voltage is scaled into appropriate speed through software. The design of different blocks used in the system is explained in the following section one by one.

Transistor Bridge Inverter

Fig. 2 shows the single phase PWM inverter circuit with combination of power transistors and anti-parallel fast recovery diodes capable of switching 600 A at 300 V peak The capacitor bank is connected across rectifier which serves to filter the AC input voltage. The capacitor bank provides a low impedance path for the high frequency currents generated by the inverter during the PWM switching [10-15]. Each power module is driven by separate base drive circuit with their own isolated power supply. A snubber is placed across each power module to maintain the instantaneous current and voltage switching loss within the ratings of the power transistors. A snubber is a electronic circuit used to suppress undesirable transients and ringing in switched mode circuits which contains parasitic inductance and capacitive elements. The choice of transistors is made because the transistors obviate the need by current controlled method.

Fig.2 PWM voltage source inverter



Input AC voltage is fed to the bridge rectifier and the DC output is taken from the point A and B. The DC filter capacitor bank of value 750 μF / 500 V is used for the filtering action. The positive rectified output is supplied to the collector of T_1 and T_3 while ground is connected to emitter of T_2 and T_4. Output of the base drive circuit BD_1 is connected simultaneously to the bases of T_1 and T_2 while the output of the other base drive circuit BD_2 is connected simultaneously bases of T_3 and T_4. When T_1 and T_2 are conducting, the T_3 and T_4 remains cutoff and vice versa. There must be some short duration between T_1 getting off and T_3 turning on. This duration must be >= turn-off time of transistor (2 μS). When output of base drive BD_1 goes high, the transistor T_1 and T_2 conducts and current flows through A, T_1, M, T_2, B and back to A. Similarly output of base drive BD_2 goes high T_3 and T_4 conducts and current flows through A,T_3, M, T_4, B and back to A.

Power Circuit

The inverter is designed for 1 HP 250 W single-phase induction motor with power factor 0.9. While designing the power circuit the values of the components are selected in such a way that the power circuit will withstand without any damage and at the same time power dissipation, voltage rating and cost is also taken into account which should be minimum. The components selected are having slight high ratings than the actual calculated ratings.

Selection of Power Transistor

The transistor is selected on the basis of current rating and type of supply. The maximum line current drawn by the motor with 0.80 efficiency is –

$$I_{max} = \frac{\text{Wattage}}{V_D \text{ x power factor x efficiency}} \quad \text{-------------------- (1)}$$

$$I_{max} = \frac{250}{206 \text{ x } 0.9 \text{ x } 0.80}$$

$$I_{max} = 2.17 \text{ Ampere}$$

$$I_{peak} = 4.34 \text{ Amp. (Peak)} \quad \text{-------------------- (2)}$$

Assuming the safety factor of 0.7 the device current rating is

$$I_{max} = 4.34 \text{ x } 0.7$$

$$I_{max} = 3.308 \text{ Amp.} \quad \text{-------------------- (3)}$$

The maximum voltage to the diode bridge is –

$$230 + 10\% = 253 \text{ Volt.} \quad \text{-------------------- (4)}$$

The maximum output of bridge is -

$253 \times \sqrt{2} = 357.74$ V DC. -------------------- (5)

Thus taking all factors into account the requirement of minimum device rating must be 700 V.

Diode Selection

A single-phase diode bridge is designed for low power motor with capacitor filter bank. The maximum input voltage is 230 + 10% = 253 V.

The maximum output of the bridge is $(253 \times \sqrt{2}) = 357.7$ V DC. ----------- (6)

Thus the diode must withstand $357 \times 1.5 = 536.5$ V with derating.

The maximum current drawn by the filter capacitor is

$$I_c = \frac{\text{Wattage}}{V_D \times \text{power factor} \times \text{efficiency}} \quad \text{-------------------- (7)}$$

$$I_c = \frac{800}{206 \times 0.9 \times 0.8}$$

$I_c = 4.34$ Ampere

$I_c \cong 4.5$ Ampere

$$I_c\ \text{Avg.} = \frac{4.5}{2} = 2.25\ \text{A} \quad \text{-------------------- (8)}$$

Assuming the voltage drop of 5 % when the

The capacitor voltage $\Delta V = 230 \times 0.05 \times \sqrt{2}$

$\Delta V = 16.2$ Volt. -------------------- (9)

The DC current drawn at full load is I_{dc} which is 4.5 Ampere. -- ------------------(10)

The capacitor value will be a large hence charging time is assumed to be negligible.

$I_{dc} = C\, \Delta V / \Delta t$ -------------------- (11)

At $\Delta t = 2$ m Sec.

$$C = \frac{I_{dc} \times \Delta t}{\Delta V}$$

$$C = \frac{4.5 \times 2 \times 10^{-3}}{16.2} = 555\ \mu F / 500\ V.$$

II Buffer Circuit

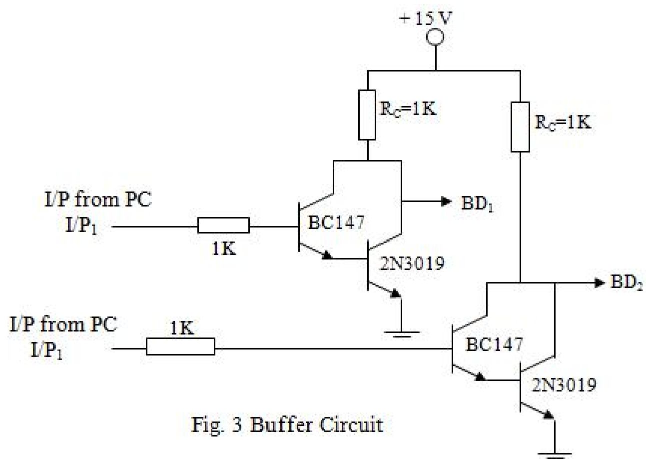


Fig. 3 Buffer Circuit

The PWM pulses are generated PC port is not sufficient to drive the opto-isolator. To over come this difficulty, buffer circuit is introduced between PC and opto-isolator. Fig. 3 shows the circuit diagram for the buffer circuit.

The signal from PC is given to inverter which drives BC147 and 2N3019 Darlington transistor pair. Output of which is given to opto-isolator.

The output of PC Port provides the base biased to the BC 147

∴ Output voltage of the inverter IC is = 5 V

The required current to turn-on BC 147 is = 5 mA

∴ Base resistance to BC 147 is = 5V / 5 mA = 1K Ω

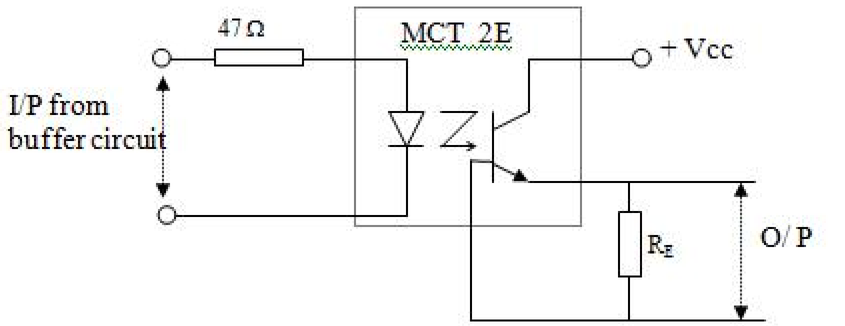
Current through BC 147 is $I_c = V_{CC} / R_c = 15$ V / 1K

$I_c = 15$mA

III Optocoupler (MCT2E):

Optocoupler is a combination of light emitting diode (LED) and a silicon phototransistor. The rise and fall time of phototransistor is very small, with typical values of turn-on time $t_{on} = 2 - 5\ \mu S$ and turn-off time, $t_{off} = 300$ nS. These turn-on and turn-off times limits the high frequency application. The phototransistor require a separate power supply and add to complexity, cost and weight of the drive circuit .Fig 4 shows the internal structure of optocoupler (MCT2E).

Fig. 4 Internal circuit of optocoupler.

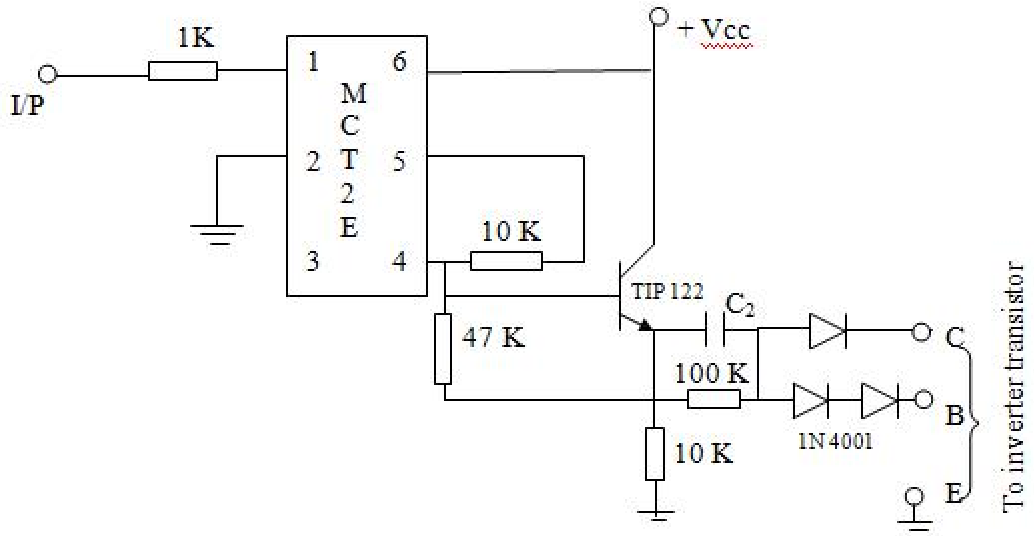


When the input is applied the light emitting diode is turn-on and light emitted by it fall on the base resistor of phototransistor. Therefore, photo transistors conducts and output is produced across emitter resistance (R_E). The emitter resistance can be calculated by using formula $R_E = (V_{CC} - V_{CE})/I_E$. The main function of optocoupler in the present application is to isolate the power circuit from the control.

Base Drive Amplifier Circuit

With the selection of values of components, the base drive circuit is designed as shown in the Fig. 5.

Fig. 5 Base Drive Amplifier Circuit



The base drive circuit is also called firing circuit. The function of base drive or firing circuit is to provide –sufficient base current to make the transistor go into quasi-saturation and reverse base current while turning off the transistor, so that turn-off time is reduced. The optocoupler MCT2E isolates the control circuit from the power circuit. This isolation provides the high speed with delay of maximum 4 μS at a frequency more than 18 KHz. The signal then drives TIP 122 to provide required base drive to the power transistor. The required voltage and current is made available by the base driver circuit. When the input signal is cut off, the transistor TIP 122 is also cut off, since no signal is available at the base of power transistor, it is switched off. The switching speed can be increased by reducing turn-on time t_{on} and turn-off time t_{off}.

IV Conclusion

The single phase drive induction motor drive has been designed using the various optimum components as per the theory. The PWM pulses are generated by using the Pc and used for testing the drive and its control applications. The simulation reduced time and provided hardware selection. Designed drive is used to control the speed of the induction motor. The control also depends on the PWM firing pulsed used for firing of the inverter.

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