Low Cost Driver Circuit of V/F Drive for Three Phase Induction Motor using Microcontroller

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Abstract— The primary function of the gate drive circuit is to convert logic level control signals into the appropriate voltage and current for efficient, reliable, switching of the IGBT module. An output driver stage consisting of small power MOSFETs or bipolar transistors convert the logic levels by alternately connecting the IGBT's gate to the appropriate on and off voltages (VON and VOFF, respectively). Most gate drive circuits also isolate the low level logic signals from the dangerous high voltage present in the power circuit. In this paper, V/f control principle is summarized and simple IGBT gate drive circuit with over-current protection is proposed with frequency control module and rectifier bridge module to implement of V/f drive for induction motor. Driver circuit test results are shown.

Key words: Driver Circuit, V/f Control, Induction motor

I. Introduction

The insulated gate bipolar transistor or IGBT is a three-terminal power semiconductor device, noted for high efficiency and fast switching. It switches electric power in many modern appliances. It is designed to rapidly turn on and off. The IGBT combines the simple gate-drive characteristics of the MOSFET with the high-current and low–saturation-voltage capability of bipolar transistors. Power MOSFETs and IGBTs are simply voltage driven switches, because their insulated gate behaves like a capacitor. Conversely, switches such as triacs, thyristors and bipolar transistors are “current” controlled, in the same way as a PN diode. The gate driver serves to turn the power device on and off respectively. In order to do so the gate driver charges the gate of the power device up to its final turn on voltage or the driver circuit discharges the gate down to its final turn off voltage[2].

In V/f Drive the complete system consists of two sections; a Power Circuit and a Control Circuit. The power circuit consists of the Three Phase Bridge Rectifier, C Filter and Three Phase PWM Inverter. On the other hand, the control circuit consists of the Micro controller, Opto couplers and Gate Drivers. An AC voltage input that is fed to a three phase diode bridge rectifier to produce DC output voltages which across a C filter will feed the three phase PWM inverter. The PWM inverter is controlled by a three phase PWM signal generated by a control circuit. The PWM inverter will then convert the DC voltage at the input to AC output voltage. The AC output voltage can be controlled in both magnitude and frequency (V/f constant). This control of voltage and frequency is required as it permits the user control the speed of an induction motor at different rates[4,11].

II. V/f Control – Principle of Operation

We will mention here only the salient points of V/f control. The base speed of the induction motor is directly proportional to the supply frequency and the number of poles of the motor. Since the number of poles is fixed by design, the best way to vary the speed of the induction motor is by varying the supply frequency. The torque developed by the induction motor is directly proportional to the ratio of the applied voltage and the frequency of supply. By varying the voltage and the frequency, but keeping V/f ratio constant, the torque developed can be kept constant throughout the speed range. This is exactly what V/f control tries to achieve.

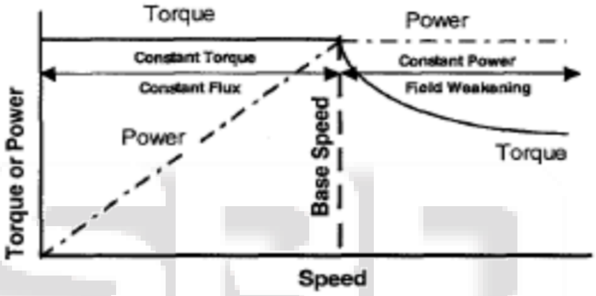

Fig. 1: Torque-speed characteristics of the induction motor with V/f control.

AC Induction motors can operate in a “Constant Flux” or “Field Weakened” mode. The Constant flux mode is often referred to as the Constant Torque range and the Field Weakened mode as the Constant Power range[1,2].

III. Basic Block Diagram of V/F Drive-Open Loop Control

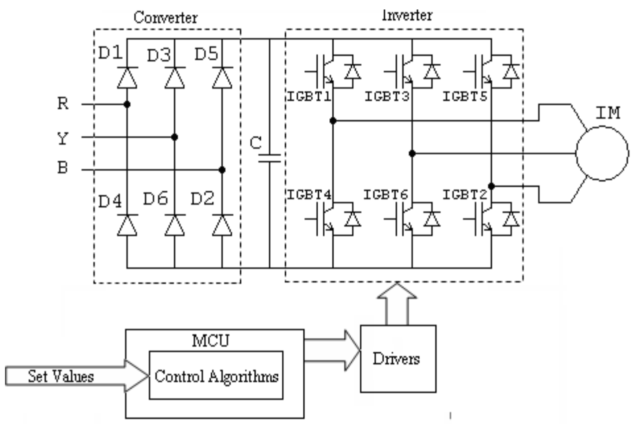

Fig. 2: Block Diagram of V/F Open Loop Control System.

Most modern VVVF drives operation requires the three basic sections as shown in Fig. 2, the rectifier, dc bus, and inverter. Converting a three-phase voltage source to DC using rectifier. After the power flows through the rectifiers it is stored on a dc bus. The dc bus contains capacitors to accept power from the rectifier, stores it, and later deliver that power through the inverter section. The inverter contains transistors that deliver power to the motor. The “Insulated Gate Bipolar Transistor” (IGBT) is a common choice in modern V/f drives. The IGBT can switch on and off several thousand times per second and precisely control the power delivered to the motor. The IGBT uses “pulse width modulation” (PWM) technique to simulate a sine wave current at the desired frequency to the motor [3,5].

IV. MOTOR CONTROL

Controlling an a.c. induction motor by the technique of sine wave-weighted pulse width modulation (PWM) switching gives the benefits of smooth torque at low speeds and also complete speed control from zero up to the nominal rated speed of the motor. To derive a varying ac voltage from power inverter PWM is required to control the duration of switches ON and OFF times. Three PWMs are required to control the upper three switches of the power inverter. The lower three switches are controlled by inverted PWM signals of the corresponding upper switch. A dead time is given between switching off the upper switch and switching on the lower switch and vice versa, to avoid shorting the DC bus. Microcontroller AT89C52 and PIC16F84 is used for PWM generation [7,10].

V. HARDWARE DESIGN

The hardware section of this project was very challenging, as the design was dealing with high voltages and currents. The project utilized many electronic components such as; Diodes, MOSFETs, Capacitors, Opto-isolators and Gate Drivers to construct the full circuit. So, in order to achieve this a full understanding of the characteristics and theory of each section had to be achieved, which assisted in completing the design and implementation of the product according to the required specifications.

A. Drive Specifications

Rated input voltage: 415V
Frequency Control Range: 20Hz to 50Hz
Horsepower = 1/4 HP
Speed = 1440 RPM
Rated Current = 0.6 A
Test Condition = no load
The complete system is divided into two sections.
Power Circuit and Control Circuit.
The power circuit consists of the three phase bridge rectifier, C Filter and Three Phase PWM Inverter. On the other hand, the control circuit consists of Microcontrollers, Opto-Couplers and Gate Drivers.[4,6]
The whole circuit is divided into four modules.

- Driver Inverter Module.
- Frequency Control Module.
- PWM Generation Module.
- Rectifier Bridge Module.

VI. DESIGN OF DRIVER INVERTER MODULE

The overall circuit contains six IGBT driver circuits for operating the six IGBTs of the three inverter circuit. Each gate driver circuit operates a single phase of the three phase power inverter legs. Controller generates pwm signals which are then applied to opto coupler to keep digital and analog section separate. Selection of opto coupler is based on frequency of pwm carrier. The main application of the gate drivers is that it converts the PWM signals produced from the microcontroller (5 V logic level signals) to a 12V level where the IGBTs can operate with [2].This driver circuit also provides over-circuit protection.

A. Features of Driver Inverter Module Components

1) Features of Transistor BC547

It is a npn bipolar junction transistor. An npn transistor is turned on when the gating is high and the switch is positively biased (collector-emitter voltage is positive). It is turned off when the gating is low.

2) Features of Transistor BC557

It is a pnp bipolar junction transistor A pnp transistor is turned on when the gating is low and the switch is negatively biased (collector-emitter voltage is negative). It is turned off when the gating is high.

3) Features of Opto coupler MCT2E

1) Gallium Arsenide Infrared Source. Optically Coupled to a Silicon npn Phototransistor
2) High Direct-Current Transfer Ratio.
3) Base Lead Provided for Conventional Transistor Biasing.
4) High-Voltage Electrical Isolation. 1.5-kV, or 3.55-kV Rating.
5) Plastic Dual-In-Line Package.
6) High-Speed Switching.

4) Features of IGBT - IRG4PH30K

- High short circuit rating optimized for motor control.
- Combines low conduction losses with high switching speed.
- Latest generation design provides tighter parameter distribution and higher efficiency than previous generations. When over current occurs voltage acrossR5 resistance increased above predetermined threshold voltage of lower BC547 and it will turn on this BC547 therefore gate pulse will directly goes to the ground and it will turn off output pulse given to gate of IGBT and provide protection against over current.

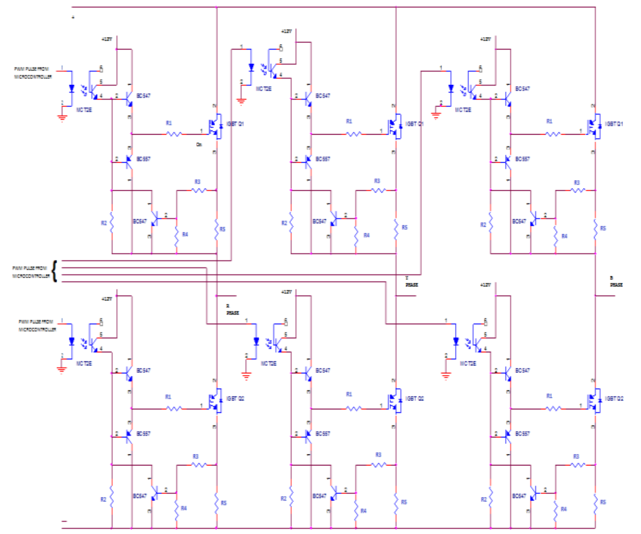

Fig. 3: Schematic of Driver Inverter Module

VII. TEST RESULT OF DRIVER CIRCUIT

IGBT have some specific requirement for its gate capacitance charging and discharging for this purpose special IGBT driver is used to drive three phase inverter from pwm pulse. Micro Controller generates pwm signals which are then applied to opto coupler MCT2E. Opto coupler is supplied from 12V D.C. It is given to collector of optically coupled transistor and collector of BC547.

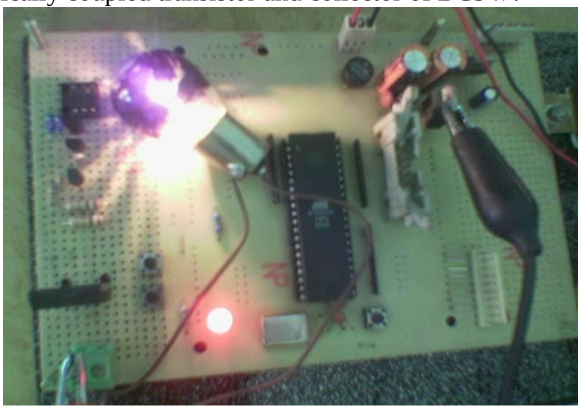

Fig. 4: Testing of Driver Circuit

A. Test Result

Drivers converts the PWM signals produced from the microcontroller (5V logic level signals) to a 12V level where the IGBTs can operate.

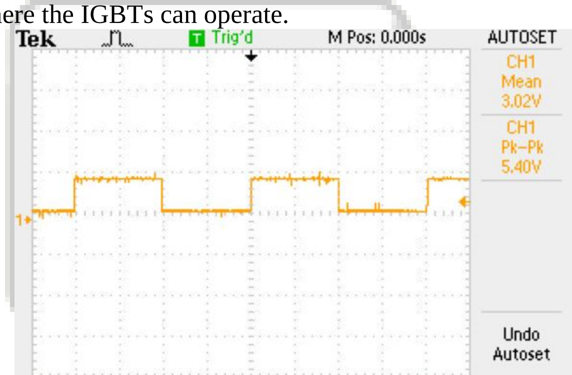

Fig. 5: Microcontroller 5V Output Pulse

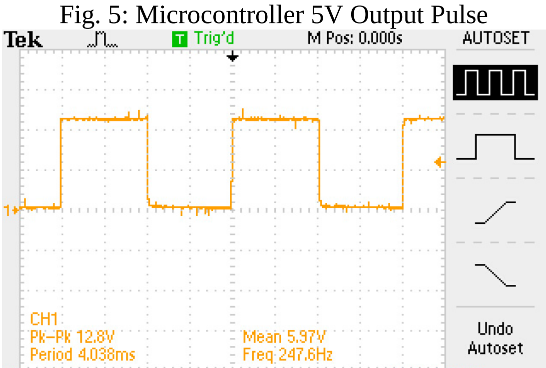

Fig. 6: 12V Output of Driver Circuit

VIII. FREQUENCY CONTROL MODULE

The Control circuit is the intelligent part of the system. It communicates with the user and send required data to set user frequency. This control circuit employs one microcontrollers. Microcontroller AT89C52 is used for frequency control. Push button keys are interfaced to set frequency control. The required user frequency is set by increased and decreased frequency in steps of one hertz through push button keys and binary equivalent of set frequency is calculated and that 8-bit data is send to microcontrollers. Set frequency and corresponding binary output is display on LCD. LEDs are provided for status of three phase output on & off [9].

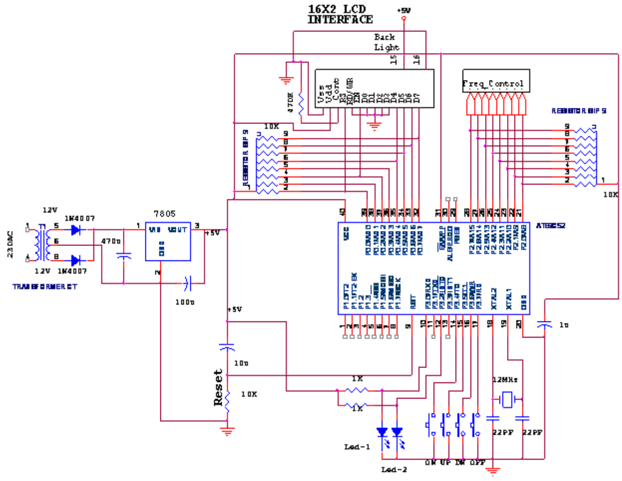

Fig. 7: Schematic of frequency control

A. Test Result of Frequency Control Module

Frequency is varying in the range of 20Hz to 50Hz and operating frequency is displayed on LCD. Equivalent count of set frequency is also displayed on LCD.

IX. RECTIFIER BRIDGE MODULE

Most modern V/F drives operation requires the three basic sections. Rectifier, dc bus, and inverter. Rectifier converts three phase AC supply to constant DC output. This DC output voltage is not smooth and it will make smooth fixed dc by capacitor for inverter stage[6].

Fig 8 shows the actual view of 600V dc supply.

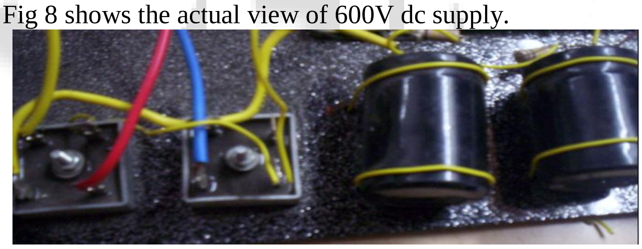

Fig. 8: Rectifier Bridge Module

When we give 3-Ø, 415V, 50Hz AC supply, it gives 600V DC supply. Series connected two capacitors are used, here each of 470 µF and 450V.

X. CONCLUSION

Designed IGBT Driver Circuit gives good results. It is very simple and easy to implement which reduces hardware complexity and also provide over current protection. In the test circuit, IGBT will turn on and off due to the input PWM signal from the driver circuit. Fundamentals of AC motor drive has been described with details of Frequency Control Module and Rectifier Bridge Module.

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