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Frequency controlled variable speed drive for Single Phase Induction Motor

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ABSTRACT

Induction motors with a single phase are commonly utilized in household goods and industrial control. Controlling the speed of these motors allows for multispeed and multifunctional operation. The variable speed drive of an induction motor utilizing the frequency control approach is the subject of this research article. It is to build a solid-state control system that is both dependable and cost-effective for usage with fractional horse power motors. The proposed variable speed drive contains a power conversion section (AC to DC and DC to AC), which employs an IRF 840 N-channel MOSFET as the switching element. To give alternating current to the motor, four IRF 840 MOSFETS are employed as H-bridge inverters. In this drive, C124 transistors and MJE 13002 transistors are used as driver circuit to drive the H-bridge inverter. In this drive, there are two power supply. The frequency control circuit and driving circuit both need a 12 V power supply. For the H-bridge inverter, a 300 V power source is employed. The frequency is controlled by a pulse width modulation SG3525A IC in this drive. For altering the speed of an induction motor, the designed variable drive circuit has a frequency range of 16 Hz to 56 Hz at constant voltage. The driving schemes of single-phase induction motors are discussed in this research study, as well as the principle actions of components utilized in variable speed drives, as well as the design calculations needed to build this drive, are supplied. Furthermore, the experimental testing of this drive when running a single-phase induction motor with a fractional horse power are presented.

Keywords- driver circuit, frequency control circuit, induction motors, switching element, variable speed drive

INTRODUCTION

Electrical drives are employed in the majority of industrial motor control applications. Some are fixed speed and some are variable speed, depending on the use. Variable speed drives have a number of drawbacks, including inefficient operation, a bigger footprint, slower speeds, and so on. Nonetheless, With the introduction of power electronics, the landscape was dramatically revolutionized, and today variable speed drives are not only smaller in size but also more efficient and reliable.

dependable, and so on. Single-phase induction motors are probably in use today in greater numbers than all other types combined. It stands to reason that the motor that is the least expensive and requires the least amount of maintenance should be used the most. This is best described by a single-phase induction motor. When connected to the main supply, the induction motor can only run at its rated speed. They do, however, have a steady motor.

A motor drive and control system with various approaches can be utilized to control the speed of these motors. The frequency of the supply, the number of motor stators, and the power input all affect the speed of an induction motor.

Solid-state control technology and how it can be utilized to regulate motors have advanced significantly in recent years. Solid state controls are usually very reliable, can give exact speeds and are becoming more economically feasible to use with fractional horse power motors.

The majority of solid-state controls use frequency modulation to control motor speed. They can change the frequency to anything higher than the standard line frequency. This means that the speed can be increased above the motor's rated capacity. They are also easy to adopt and cost-effective.

2. INDUCTION MOTOR CHARACTERISTICS WITH LOAD

Varied types of loads with different torque-speed curves occur in real-world applications. When the created motor torque equals the load torque requirement, the motor load system is considered to be stable. The motor will run at a constant speed in a steady condition. The motor's response to any disturbance gives us an indication of the motor load system's stability.

In most drives, the motor's electrical time constant is insignificant in comparison to its mechanical time constant. As a result, when operating in a transitory mode, Because the motor is assumed to be in electrical equilibrium, the steady state torque-speed curve can be applied to the transient operation as well. The torque-speed curves of the motor with two distinct loads are shown in Fig. 1. When the operation is restored after a brief interruption, the system is said to be stable. The torque-speed curves of the motor with two distinct loads are shown in Fig. 1. When the operation is restored after a brief interruption, the system is said to be stable, a deviation from it caused by a problem with the engine or the load W m is reduced as a result of the disruption. In the first scenario, the motor torque (T) is greater than the load torque at a new speed (T1). As a result, the motor will speed up and the operation will return to X.

Similarly, a W m increase in speed induced by a disturbance increases the speed by W m. The load torque (T1) will be greater than the motor torque (T), resulting in a deceleration and the point of operation being restored to X. As a result, the system is stable at point X. In the second scenario, when the speed drops, the load torque (T1) exceeds the motor torque (T), the drive slows down, and the operating point moves further from Y.

Similarly, as the speed rises, the motor torque (T) becomes greater than the load torque (T1), pushing the operating point farther from Y. As a result, the system is untrustworthy at point Y. This illustrates that, in the first example, the motor selection for driving the specified load is correct; in the second case, the choice of motor is incorrect. The selected motor is insufficient to drive the given load and must be replaced. The common existing loads are presented in the following sections, together with their torque-speed curves.

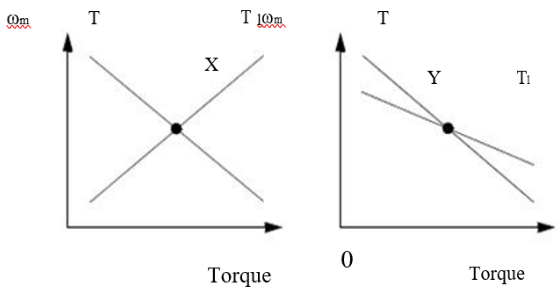
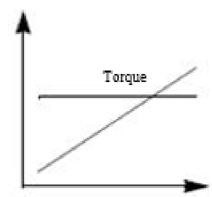


Fig. 1 The motor's torque-speed curves

2.1 Characteristics of Constant Torque and Variable Speed Loads

This type of load necessitates continuous torque independent of speed. The power, on the other hand, is proportional to the speed in a linear fashion. Screw compressors, conveyors, and feeders are examples of equipment with this characteristic. Induction motors have constant torque and variable speed loads, as seen in Fig. 2.



2.2 Characteristics of Variable Torque and Variable Speed Loads

This is the most prevalent type of torque load in industry, and it's also known as a quadratic torque load. The torque is proportional to the square of the speed, whereas the power is proportional to the cube of the speed. This is a fan or pump's typical torque-speed characteristic. Induction motors have variable torque and variable speed loads, as seen in Fig. 3.

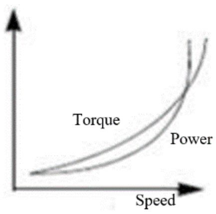


Fig. 3: Variable Torque and Speed Loads Characteristic

2.3 Characteristics of Constant Power Loads

This load is uncommon in the industry, although it does exist. While the torque varies, the power stays constant. Because torque is inversely related to speed, infinite torque at zero speed and zero torque at infinite speed are theoretically possible. In actuality, the breakaway torque required always has a finite value.

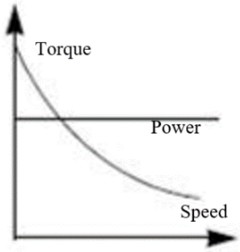


Fig. 4 Constant Power Loads Characteristic

This type of load is typical of traction drives, which require a high torque at low speeds for initial acceleration and a considerably lower torque once up to speed. The constant power loads characteristic of induction motors are shown in Figure 4.

2.4 Constant Power and Constant Torque Loads Characteristic

This is common in the paper industry. In this type of load, as speed increases, the torque is constant with the power linearly increasing. When the torque starts to no constant torque loads character decrease, the power then remains constant. Fig. 5 shows constant power load characteristic of induction motor.

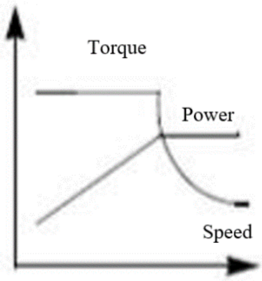


Fig. 5 Constant Power and Constant Torque Loads Characteristic

3. SPEED CONTROL OF INDUCTION MOTOR

There are two speed terms used in the motor; synchronous speed and rated speed. Synchronous speed is the speed at which a motor's magnetic field rotates. Synchronous speed is the motor's theoretical speed if there was no load on the shaft and friction in the bearings. The two factors affecting synchronous speed are the frequency of the electrical supply and the number of magnetic poles in the stator. Synchronous speed is calculated by Equation (1).

$$\text{Synchronous Speed} = 120 \times \text{frequency/Number Poles} \quad (1)$$

Where;
Frequency = Electrical frequency of the power supply in Hz
Number of Poles = Number of electrical poles in the motor stator

Since the frequency of the power supply is usually fixed (typically 50Hz), the number of magnetic poles is the principal design factor affecting motor speed. The rotor of an induction motor at synchronous speed, but lags this speed slightly. This lag is expressed as a percentage of the synchronous speed called the slip as in shown in Equation (2).

$$\text{Slip} = (\text{Synchro Speed-Rated Speed/Synchro Speed}) \quad (2)$$

4. SPEED CONTROL OF SINGLE-PHASE INDUCTION MOTOR USING FREQUENCY CONTROL METHOD

The 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. It is design for wide application in for the streamlining and simplification of manufacturing processes as well as the improvement of product quality in industrial fields. The frequency control method is often used to control and modify the speed of a single-phase induction motor with a variable speed drive. Using the variable resistance, it may change the required speed by altering the frequency. Integrated circuits are used to create low-cost, high-performance speed control circuits.

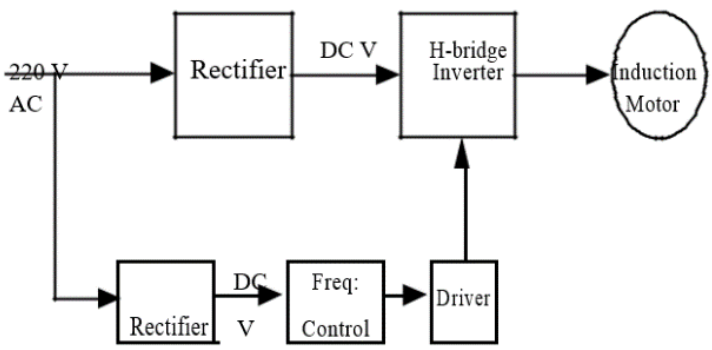


Fig. 6 Block Diagram for Using an Inverter to Control the Speed of a Single-phase Induction Motor

5. POWER MOSFET-BASED H-BRIDGE INVERTER

The operations of this inverter are;

T_1-T_2 ON: Both create short circuits across

Both are faulty because they form short circuits across the DC source.

T_3-T_4 ON: Both create short circuits across

the DC source and are invalid.

T_1-T_4 ON: Applies positive voltage (Vs) to

the load. The positive current (I_L) passes through T_1-T_4 and the negative current ($-I_L$) is through D_1-D_4.

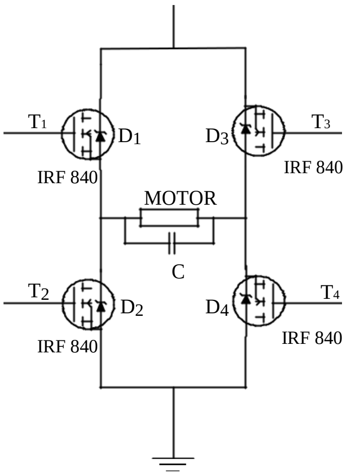


Fig. 7 H-bridge Inverter Configuration

T_2-T_3 ON: Applies negative voltage (-Vs) across the load. The positive current (I_L) flows through D_2- D_3 and returns energy to the DC source. The negative current ($-I_L$) flows through T_2-T_3 and draws energy from the supply. T_1-T_3 ON: Applies zero volts across the load. The positive current's path is T_1-T_3 and the negative current's path is D_1 - T_3. T_2 - T_4 ON: Applies zero volts across the load. The positive current's path is through D_2 - D_4 and the negative current's path is T_2 - T_4. Fig 7 shows the configuration of H-bridge inverter.

This inverter has four switches.

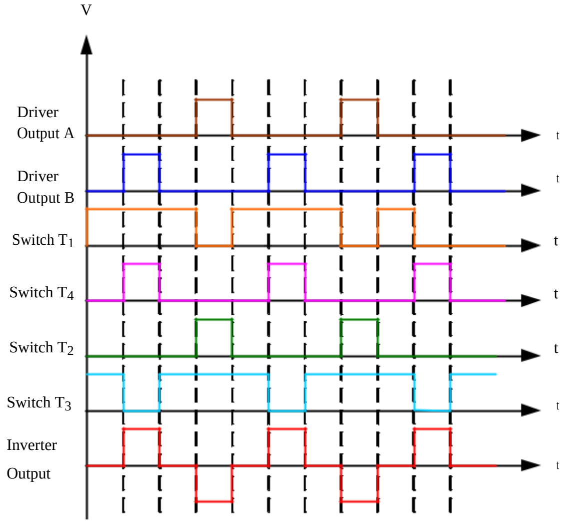


Fig. 8 Frequency Control System Timing Diagram

Across the load, the H-bridge can generate (positive voltage Vs), (zero voltage VL). Voltage dips across transistors and diodes produce deviations from this figure. PWM control circuit, driver circuit, and H-bridge inverter circuit are the three parts of the frequency control system. The pulses are generated using a PWM control circuit with a variable resistor and fed to two driver circuits. The driver circuit divides the PWM control circuit's four pulses into two. The H-bridge inverter is then operated by the pulses of the driving circuit. In this manner, the motor receives alternating current from the H-bridge inverter. Figure 8 depicts the frequency control system's timing diagram.

6. PERFORMANCE TEST AND RESULTS

Two independent power supplies are used in this variable speed drive. The H-bridge inverter was powered by a 300 V DC power supply, whereas the SG 3525A Pulse Width Modulator was powered by a DC 12 V regulator power supply (7812 IC), as well as transistors that switch on and off (C 124 and MJE 12002). The input voltage of the H-Bridge inverter is 300 DC volts from the diode bridge rectifier. Figure 9 shows the 300 DC voltage testing of the rectifier output. It was measured in 10ms/div on the X axis and 10 20 V/div on the Y axis.

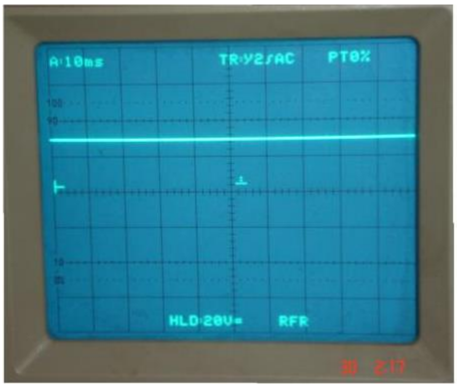


Fig. 9 Result of Diode Bridge Rectifier

The P.W.M IC (SG3525A) test results are displayed in Fig. 10. This is the driver transistor's input pulse. These results were obtained using a regulator with a range of 20 to 150 k. The X axis is 10 ms/div, while the Y axis is 10 1V/div in these tests.

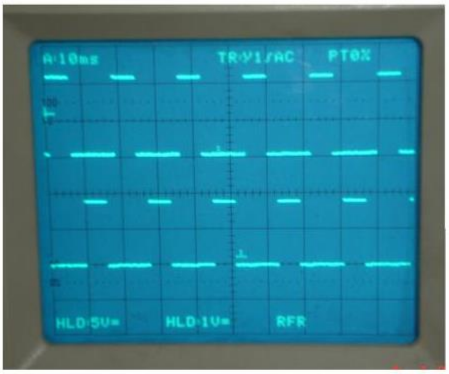


Fig. 10 Result of P.W.M IC Control Circuit (R_T = 20 kΩ)

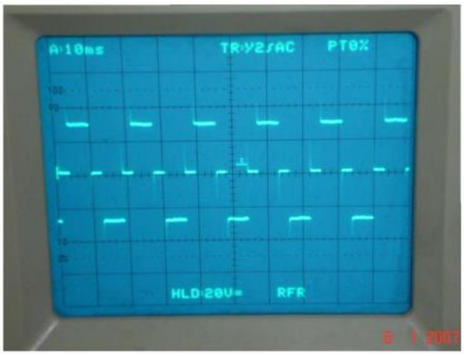


Fig. 11 Result of H-bridge Inverter Output (R_T = 20 kΩ)

Figure 11 shows the output of the inverter. The Y axis is 10 ms/div and the X axis is 10 20 V/div in this test. These tests were carried out on a variable speed drive with no load.

Figure 12 shows the variable speed drive's inverter output results when driving a fractional horse power single-phase induction motor. The estimated and test results of the suggested variable speed drive circuit are shown in Table 1.

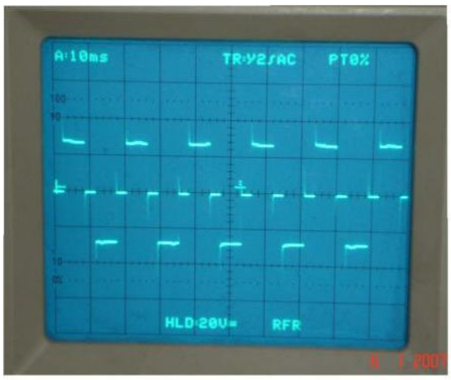


Fig. 12 Result of H-bridge Inverter output (R_T = 20 kΩ)

Table 1: Variable speed drive results calculated and tested

Regulator (kΩ)	Calculated Results		Test Results	
	Freq (Hz)	Speed (rpm)	Freq (Hz)	Speed (rpm)
150	17	510	16	480
100	24	720	23	690
80	30	880	28	840
60	35	1050	33	990
40	46	1380	42	1260
20	66	1980	56	1680

7. CONCLUSION

The speed control system can be separated into four elements in this drive: the rectifier, PWM control circuit, driving circuit, and H-bridge inverter. The primary goal of this project is to create a small open-loop sinusoidal PWM inverter for controlling the speed of a single-phase induction motor. The H-bridge inverter, which is made up of four IRF 840, was used to keep the hardware of this tiny inverter to a bare minimum.

The experimental results show that a variable frequency can successfully drive a single-phase induction motor, and that the motor's speed can be simply modified using the suggested variable speed drive with frequency control approach.

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