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Four Quadrant Operation of Induction Motor Using H-Bridge in Harsh and Noxious Environment Field with Dust, Voltage Fluctuation and Major Load Variations

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Abstract

The investigation and findings show that the H Bridge variable frequency drive is the optimum choice for resolving intrinsic motor problems and energy conservation. Variable frequency drives outperform other strategies like soft starters because they offer numerous benefits over other techniques, including greater versatility and control over the motor's starting and stopping capabilities. Dynamic torque control, overload protection, and power reduction during idle are other essential aspects of variable frequency drives. Conserving energy to the greatest extent possible is one strategy to avoid energy shortages. It has been reported that 75% of the electrical energy generated globally is used by motors. It has been noted that the main problem with motors is that they use a lot of current to start. As a result, high inrush current produces excessive heat, reducing the lifespan of electrical equipment and using more electricity. Reducing the initial inrush current to a manageable level is advised. By using an induction motor and the H Bridge, this current can be decreased. H Bridge uses a technique known as variable speed drive, which is often referred to as variable torque drive, to control the speed and torque of AC induction motors. Pulse width modulation is used to monitor the motor's voltage and torque in this occurrence. Although there are several methods to reduce the motor's current, such as by employing soft starts, variable torque drives are more advantageous. The strong starting torque and flexible speed control of DC motors make them useful in a range of applications. However, because of the cost and commutation, there are a few significant problems. As a result, the PWM-powered H bridge inverter extends the life of machinery and provides electricity to electrical appliances in response to demand. The fact that it is an energy-saving gadget, however, is by far its greatest advantage. This is especially important in a country like India, where the energy crisis has halted economic growth.

Keywords: *Energy Saving, Four Quadrant, H-Bridge, PWM*

1.0 Introduction

When employing a DC motor, there are four different operating modes or quadrants as shown in Figure 1. In the first and third quadrants of operation, the DC motor is in the motor forward and motor backward modes, respectively, with a provided voltage greater than the back emf and a distinct current flow channel[1,2].

The motor operates in the second and fourth quadrants when its back emf value is greater than the voltage provided[3,4]. This is the mode of operation for forward and reverse braking, respectively, and the direction of current flow is again reversed[5,6].

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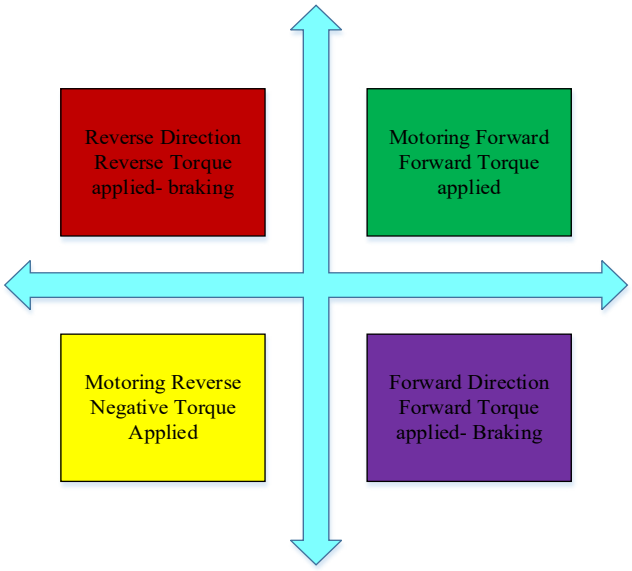


Figure 1. Four quadrant operation of DC motor.

2.0 Proposed Model

Motors are employed everywhere, whether in industry or homes[7,8]. The most potent, all-encompassing resource for powering any engine is electricity[9,10]. Homes and factories are the two places where AC induction motors are most often and widely employed[11,12]. However, the issue pertaining to AC induction motors must be resolved and they must function extremely well[13,14]. Although several devices are utilized to prevent the aforementioned issues, variable frequency drives are the most effective equipment[15,16]. Motors can be operated at different loads by lowering their speed thanks to the variable frequency drive, which regulates both the motor's frequency and speed[17,18]. The frequency and speed of motor action are directly correlated with one another[19,20]. Modifying the frequency of the AC voltage allows the motor speed to be changed to a desired value[21,22].

$$N_s = \frac{120\,f}{P} \tag{1}$$

N = Speed of motor (RPM).

F = Electrical Frequency of motor (Hz).

P = Number of poles of motor.

These variable frequency drives are crucial for HVAC applications because they reduce energy waste significantly when a motor draws a high beginning current and consumes a significant amount of power before reaching its rated speed[23,24].

This current may be decreased with the use of the variable frequency drive, which significantly reduces energy consumption. Variable frequency drives have many uses in a wide range of equipment, including fans, pumps, air conditioners, microwave ovens, tower cooling systems, and ship propulsion systems[25,26].

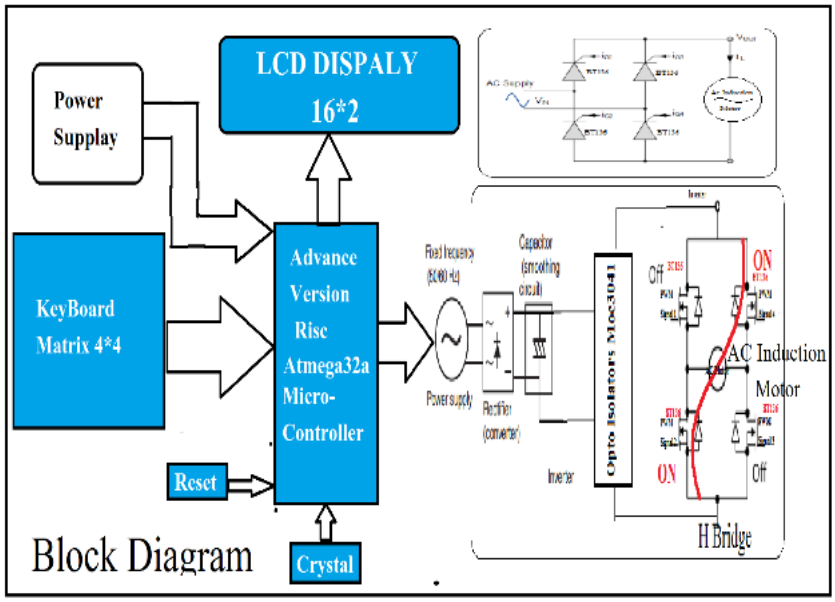


Figure 2. Controlling AC induction motor H bridge speed and torque.

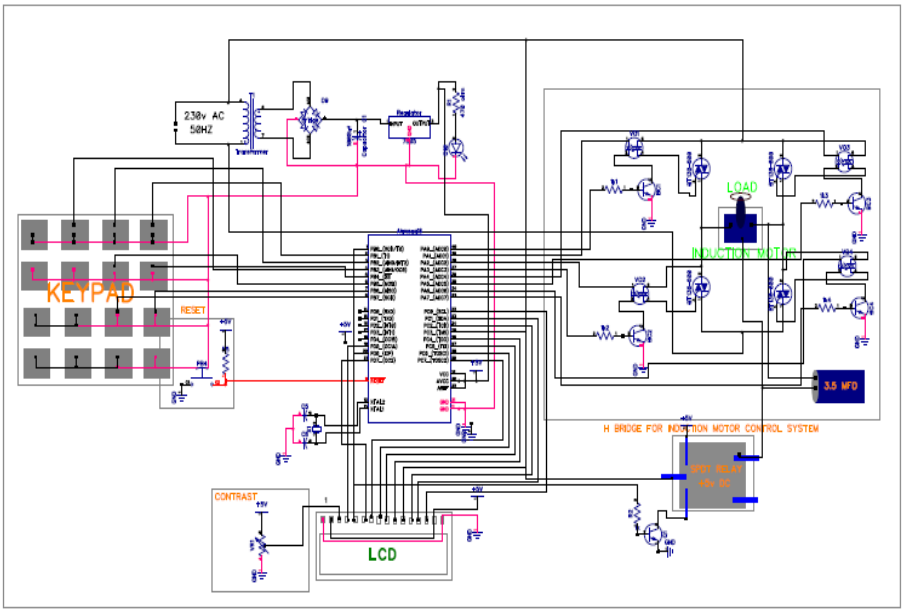


Figure 3. Pin schematic for an induction motor operating in four quadrants utilizing an H-bridge.

It has been shown that 10% of the energy used by AC motors is lost if the motor is not operating at maximum efficiency, and an additional 12% and 15% are wasted. The customer is therefore very motivated to eliminate this energy loss, and the only way to do so is by adopting tools like variable frequency drives[27,28].

Thus it offers the wonderful benefit of energy conservation. Three main components comprise variable frequency drive. These are as follows:

- AC to TRIAC Converter
- TRIAC Bus
- Invertor :- TRIAC to AC convertor

When specified AC voltages are input into an AC to TRIAC rectifier, the AC voltages are transformed to TRIAC voltages, which are directed even more toward the TRIAC bus. Voltages from the AC to the TRIAC converter are stored on the TRIAC bus[29,30].

This is made composed of chokes and capacitors to smooth the power supply and eliminate TRIAC voltage ripples, which smooth the waveform[31,32]. The invertor, which is the final and most important part, converts TRIAC to AC by roughly simulating a sine waveform, the pulse of which is then adjusted to control voltages and motor frequency, as seen in Figure 2. Variable Frequency Drive (VFD) relies heavily on PWM, the primary method for controlling motor speed[33,34].

Figure 3 shows the pin diagram for an induction motor operating in four quadrants utilizing an H-bridge.

3.0 Results and Discussion

3.1 Microcontroller-based PWM

The fundamental method that is most frequently used to regulate motor speed and frequency is pulse width modulation. Using a microcontroller, this is possible. Using PWM, we chose a frequency range of 5Hz to 50Hz for this study. The fundamental idea behind PWM is that a microcontroller generates a sine wave, which is then superimposed over a triangle wave[35].

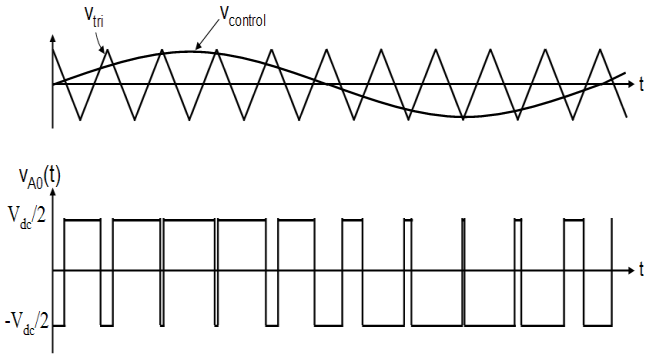


Figure 4. PWM representation.

A square wave is produced as a consequence, which is supplied into the inverter part. The duty cycles of the pulse may be adjusted to alter the square wave's width. Duty cycles, in essence, indicate how long a pulse waveform is on and off. As a result, by alternating the waveform between two distinct levels, the appropriate duty cycle of a sine wave may be approximated for the square wave. In Figure 4, a PWM representation is displayed.

3.2 Software and Hardware-based PWM

Using Proteus, the aforementioned approach was coded using a microcontroller and then emulated. The following is a picture of the depiction.

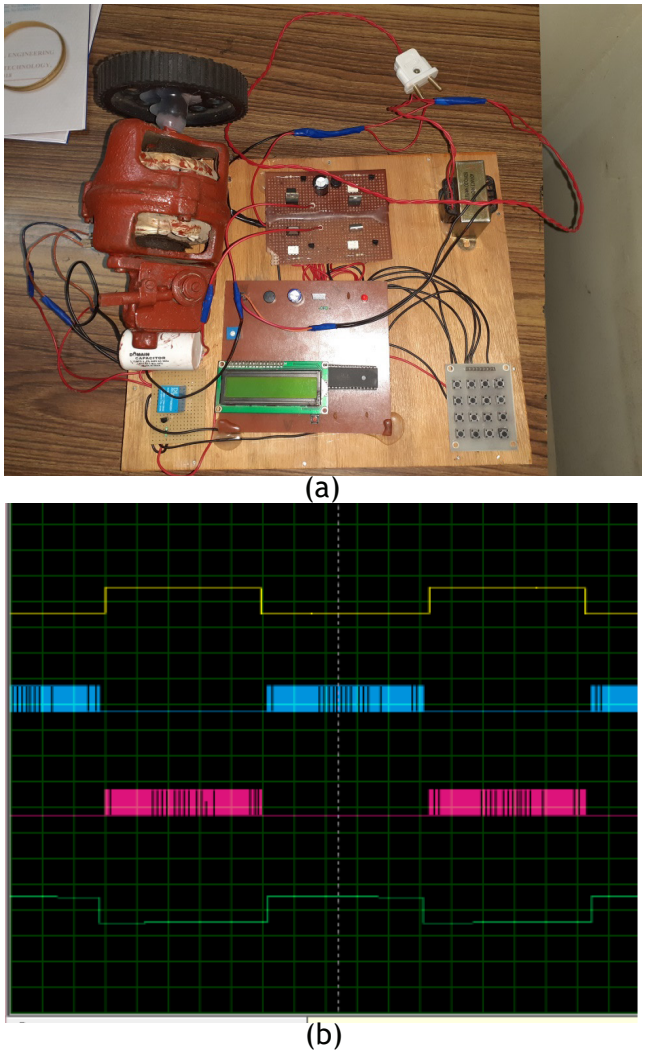


Figure 5. **(a)** Experimental Set up For H Bridge Induction Motor. **(b)** Software-based PWM representation additionally, the controller was used to achieve this.

Oscilloscope findings were compared with software after hardware and results were examined. Figure 5a shows the experimental set-up of an induction motor with a microcontroller and switches to change the direction of the motor it is also useful for motoring and braking operation. Figure 5(b) depicts the software simulation result.

3.3 H Bridge

Generally speaking, an H-bridge is a very straightforward circuit with four switching elements and a load positioned in the middle in the shape of an H, as seen in Figure 6.

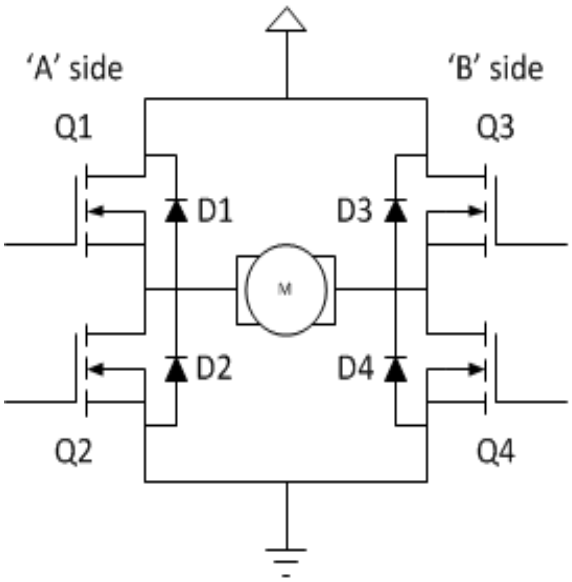


Figure 6. H bridge block diagram.

Typically, bi-polar or FET transistors—or, in some high-voltage applications, IGBTs—are used as the switching components (Q1, Q4). There are other integrated solutions, although, for the purposes of this study, it is often irrelevant whether or not the switching elements are integrated with their control circuits. D1, and D4, also known as catch diodes, are typically Schottky type diodes.

3.4 Static Operation

The fundamental method of operation for an H-bridge is as follows: when Q1 and Q4 are activated, the motor's

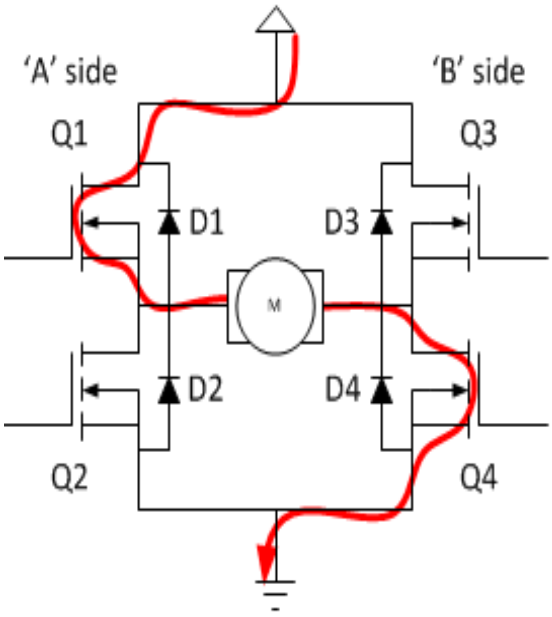


Figure 7. Forward motoring.

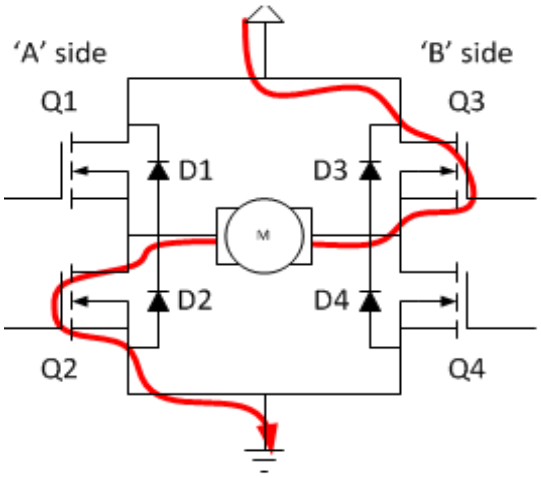


Figure 8. Reverse motoring.

left lead is linked to the power source and its right lead is connected to the ground. The motor shaft starts to rotate as seen in Figure 7 as electricity runs through it, energizing it to move forward.

The bridge is grounded at the bottom and has a power source (such as a battery) connected to its top. Only three sensations are available to the side-A switches due to this limitation imposed by the four potential states.

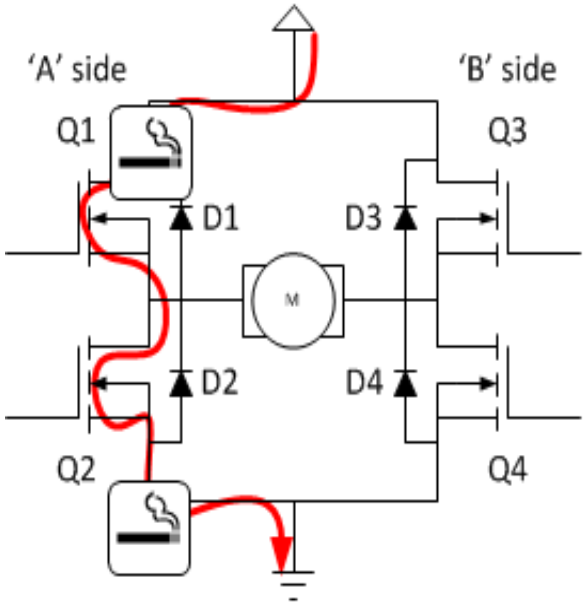


Figure 9. Restricted mode.

As seen in Figure 8, if Q2 and Q3 are turned on, the opposite will happen, causing the motor to be activated in the opposite direction and the shaft to start spinning backwards.

Never are Q1 and Q2 (or Q3 and Q4) closed simultaneously in a bridge. It could short-circuit your power supply by establishing a very low-resistance channel between power and ground. "Shoot-through" is the term for this circumstance, which is an almost foolproof method of quickly demolishing a bridge or circuit. Figure 9 illustrates the induction motor's restricted mode.

4.0 Conclusion

The aforementioned analysis and findings demonstrate that the H Bridge variable frequency drive is the most effective means of resolving intrinsic motor problems, and it is also the most suitable drive for addressing energy conservation. Alternative methods such as soft starters are not as effective as variable frequency drives due to the latter's numerous advantages, such as giving control over the starting and stopping of the motor and increasing the motor's action diversity.

Other important characteristics of variable frequency drives are dynamic torque control, overload protection,

and power reduction when not needed. We might argue that this gadget is really helpful in a nation like India where energy conservation is critical. In addition, VFDs have to be utilized in conjunction with HVAC systems in commercial buildings and residential appliances. The expense of this equipment is its sole downside. It requires upkeep and is quite expensive. However, it is impossible to dispute the significance of the H Bridge in variable frequency drives.

5.0 Future Extension

It appears quite unlikely that H Bridge will alter in the future given its current configuration. But, anything is possible given how quickly technology is developing and how frequently individuals are submitting new findings.

We can encounter any gadget thanks to emerging technologies like FPGAs, DSP advancements, genetic algorithms, fuzzy logic, creative PWM approaches, and revolutions in the field of power electronics. Moreover, VFDs may be made smaller with NANO technology. Energy savings would be attainable at tiny levels as well since this little version of the H Bridge would be particularly beneficial in small devices.

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