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Implementation of V/f Control Scheme for Single-phase Induction Motor using Arduino

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ABSTRACT

In this paper V/f control scheme is discussed and implemented for the speed control of single-phase Induction motor. Atmega328 controller based Arduino Uno board is used for the implementation of V/f control algorithm. Single-phase MOSFET/IGBT based full-bridge SPWM controlled Inverter is implemented in hardware for the testing of speed control of induction motor. SPWM is generated based on lookup table entered in Arduino board. SPWM gate pulses and AC output of an Inverter is also shown in this paper.

KEYWORDS: SPWM, MOSFET, IGBT, Inverter

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INTRODUCTION

There is different method of speed control of single phase induction motor and to control the speed of single phase induction motor generally using V/F control strategy. Out of the a number of methods of speed control of an induction such as pole changing, frequency variation, variable rotor resistance, variable stator voltage, constant V/f control, slip recovery method etc., the constant V/f speed control method is the majority generally used. In this method, the V/f ratio is kept constant which in turn maintains the magnetizing flux constant so that the maximum torque remains unchanged. Thus, the motor is totally utilized in this method. This paper include with hardware of V/f speed control of single-phase induction motor .The performance of the volt per hertz strategy were evaluated. In constant V/f control, by use PWM inverter, we can vary the supply voltage as well as the supply frequency such that the V/f ratio remains constant so that the flux remains constant too. So, we can get different operating zone for various speeds and torques and also we can get different synchronous speed with almost same maximum torque. Thus the motor is fully utilized and also we have a good variety of speed control. It is effortless, cost-effective to easier to design in open loop. But the drawbacks of open loop is it doesn't correct the change in output also it doesn't reach the steady state quickly.

SPEED CONTROL METHODS OF INDUCTION MOTOR

The Speed of Induction Motor is changed from Both Stator and Rotor Side[1].

Speed control of induction motor from stator side are further classified as:

- Changing the number of stator poles
- Adding rheostat in the stator circuit
- Controlling supply voltage
- v/f control or frequency control

Speed control of induction motor from rotor side:

- Adding external resistance on rotor side
- Cascade control method
- Injecting slip frequency emf into rotor side

V/f Control is the most popular and has found widespread use in industrial and domestic applications because of its ease-of implementation. However, it has inferior dynamic performance compared to vector control. Thus in areas where precision is required, V/f Control are not used.

The various advantages of V/f Control are as follows:

- It provides good range of speed.

- It gives good running and transient performance.
- It has low starting current requirement. It has a wider stable operating region.
- Voltage and frequencies reach rated values at base speed.
- The acceleration can be controlled by controlling the rate of change of supply frequency.
- It is cheap and easy to implement.

V/F CONTROL OF INDUCTION MOTOR

Synchronous speed can be controlled by varying the supply frequency. Voltage induced in the stator is $E1 \propto \Phi f$ where Φ is the air-gap flux and f is the supply frequency. As we can neglect the stator voltage drop we obtain terminal voltage $V1 \propto \Phi f$. Thus reducing the frequency without changing the supply voltage will lead to an increase in the air-gap flux which is undesirable[3]. Hence whenever frequency is varied in order to control speed, the terminal voltage is also varied so as to maintain the V/f ratio constant. Thus by maintaining a constant V/f ratio, the maximum torque of the motor becomes constant for changing speed.

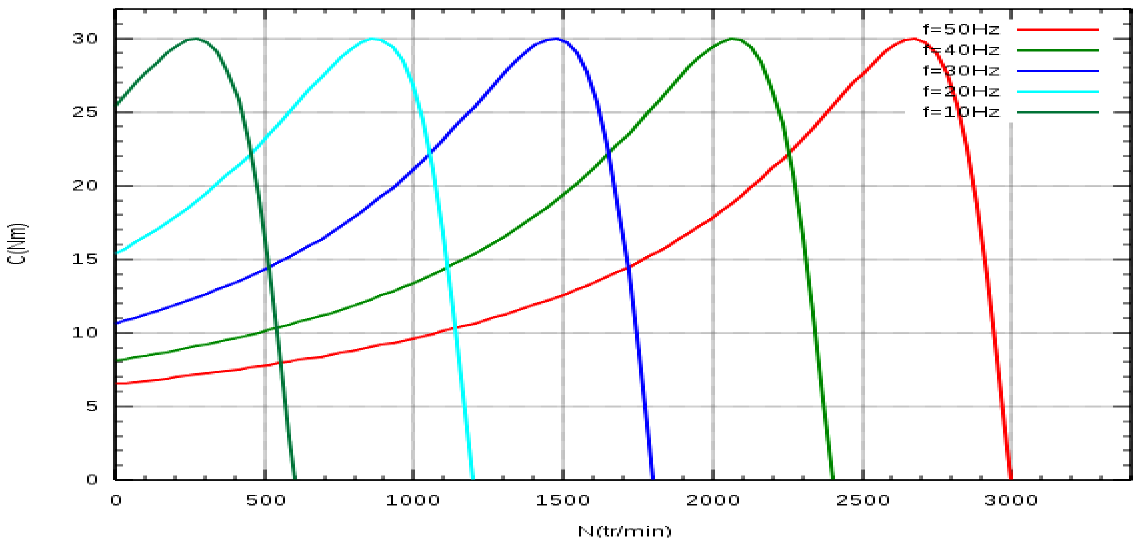

Fig. 1 Torque-speed curves with V/f ratio constant

Fig. 1 shows the relation between the voltage and torque versus frequency. It demonstrates torque voltage and frequency being increased up to the base speed. At base speed, the voltage and frequency reach the rated values as listed in the nameplate. The motor can be driven beyond base speed by increasing the frequency further. However, the voltage applied cannot be increased beyond the rated voltage. Therefore, only the frequency can be increased, which results in the field weakening and the torque available being reduced. Above base speed, the factors governing torque become complex, since friction and windage losses increase significantly at higher speeds. Hence, the torque curve becomes nonlinear with respect to speed or frequency.

V/F CONTROL SCHEME IMPLEMENTATION ON ARDUINO

The Arduino Software (IDE) allows you to write programs and upload them to your board. Arduino is an open-source electronics platform based on easy-to-use hardware and software.

Features of the Arduino UNO:

- Microcontroller: ATmega328
- Operating Voltage: 5V
- Digital I/O Pins: 14 (of which 6 provide PWM output)
- Analog Input Pins: 6
- DC Current per I/O Pin: 40 mA
- DC Current for 3.3V Pin: 50 mA
- Flash Memory: 32 KB of which 0.5 KB used by bootloader
- SRAM: 2 KB (ATmega328)
- EEPROM: 1 KB (ATmega328)
- Clock Speed: 16 MHz

In Arduino IDE first PWM output pins frequency is set to 4 kHz. Then Look up table is implemented at modulation index of 1 for generation of SPWM. Onboard A0 channel is used to change the modulation index and output power frequency from 10 Hz to 50 Hz. Fig.2 (a) shows the SPWM output at Switching frequency of 4 kHz and power frequency of 50 Hz. Fig.2 (b) shows the output of SPWM with simple RC low pass filter circuit for exact power frequency verification. It is Sinusoidal 50 Hz.

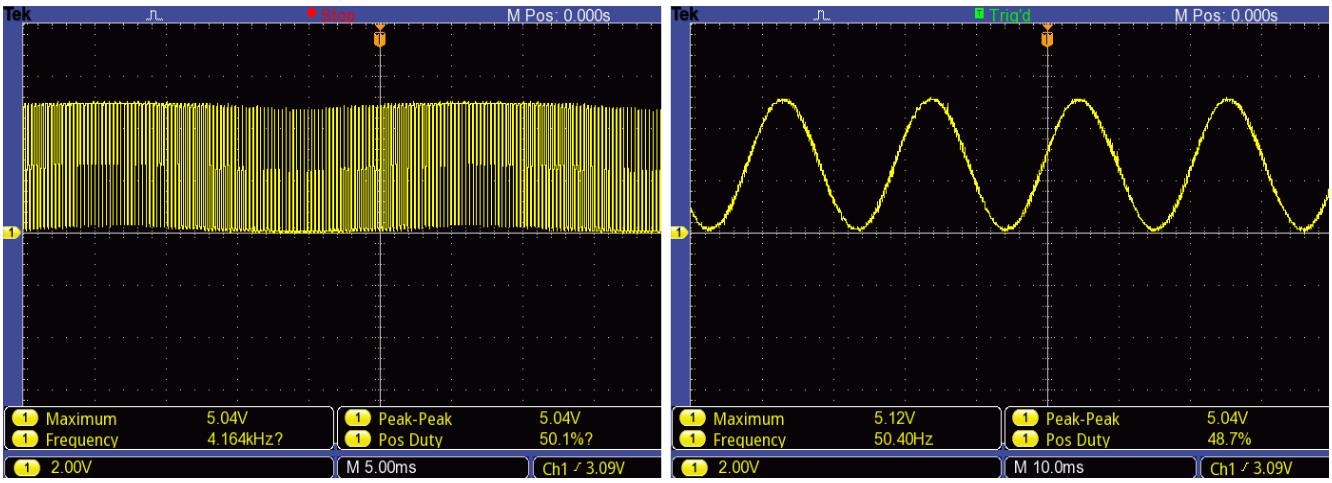

Fig.2 (a) SPWM Output from Arduino PWM pin. (b) SPWM output with Low pass RC filter.

HARDWARE IMPLEMENTATION AND RESULTS

In hardware three circuits are required to implement.

(1) Isolated DC Power supplies (which required for isolated Gate Pulses in Full bridge Inverter)

(2) Control circuit with MOSFET driver circuit (Using Arduino Board and TLP-250)

(3) Power circuit (which includes full-H bridge Inverter)

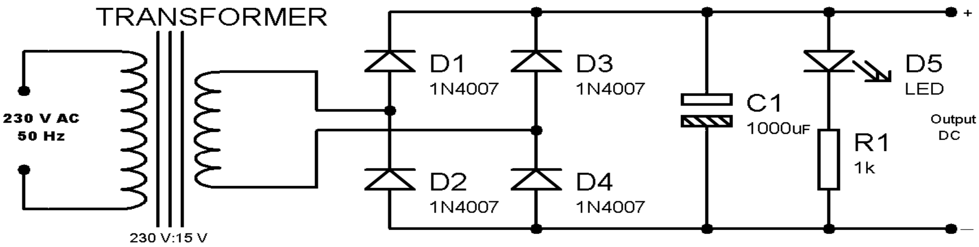

Fig.3 Circuit diagram of Isolated DC Power Supplies

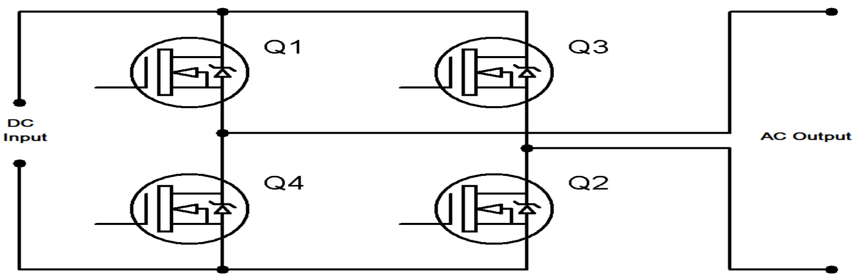

Fig.4 Circuit diagram of Single-phase Full Bridge Inverter

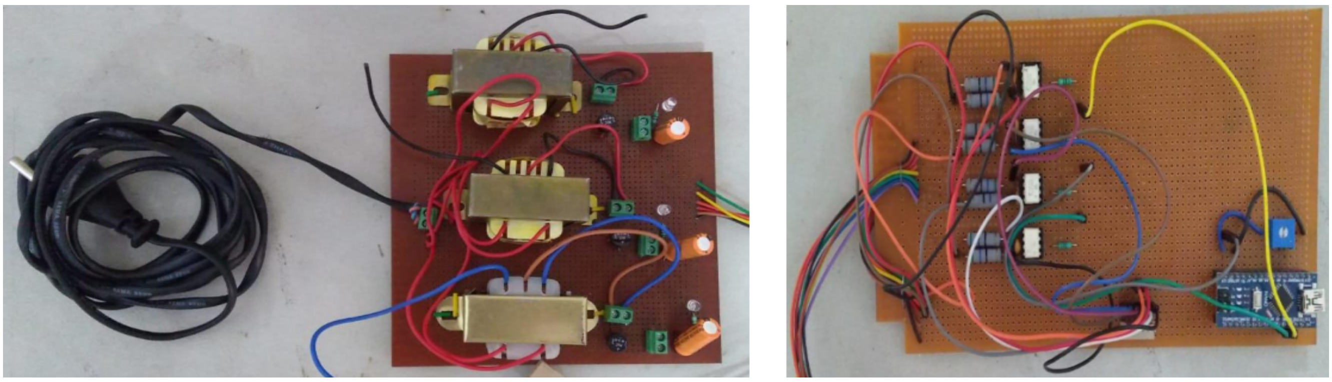

Fig.5(a) Implemented Hardware circuit of Isolated DC Power Supplies (b) Control circuit and MOSFET Driver card

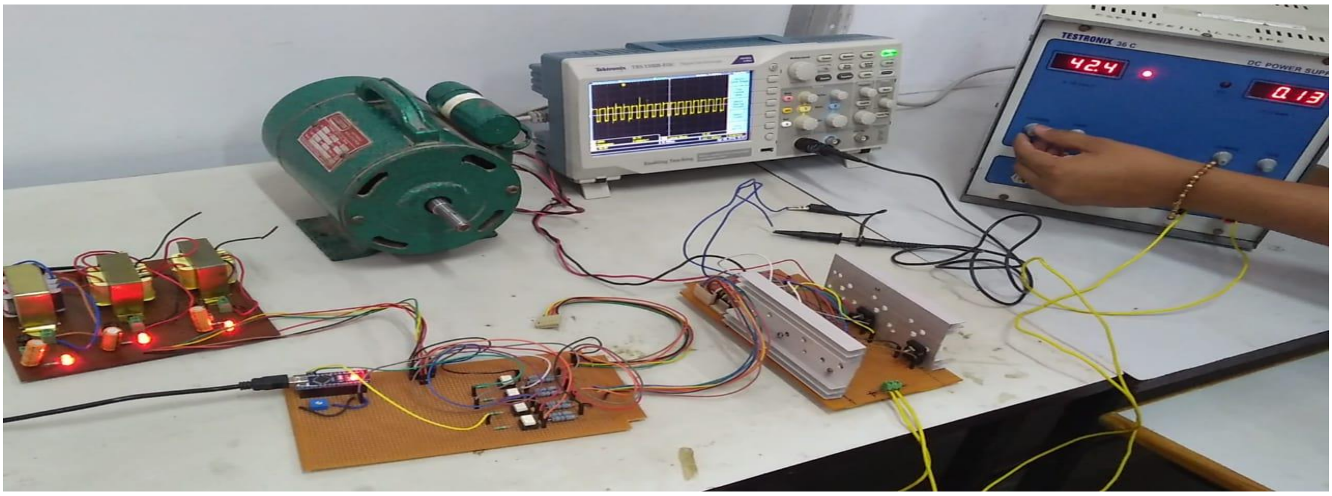

Fig.6 Hardware setup for Testing of V/F control of Induction motor

Fig.3 and Fig.4 shows complete circuit diagram for isolated DC Power supplies and Power circuit of bridge Inverter. Fig.5 and Fig.6 shows hardware implemented for testing of complete setup.

CONCLUSION

Here V/f control of Induction motor is implemented in prototype hardware circuit and speed of induction motor can be varied very smoothly with constant max. torque. Using this method full speed range of Induction motor can be controlled from 0 % to 100 %. We can also over speed motor but at reduced maximum torque. Motor speed can be varied using simple potentiometer.

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