IJCSE International Journal of Computer Sciences and Engineering Open Access
Research Paper Vol.-6, Issue-12, Dec. 2018 E-ISSN: 2347-2693

Analysis of Open Loop V/F Control of Three Level Cascaded H- Bridge Inverter Fed Induction Motor Drive

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Available online at: www.ijcseonline.org

Accepted: 07/Dec/2018, Published: 31/Dec/2018

Abstract— Open loop V/f control of cascaded H-Bridge inverter fed induction motor drive is simulated in PSIM environment. Cascaded H-Bridge three level inverter is used to obtain good quality of output voltage. This method can be implemented by change in the supply voltage and frequency applied to the three phase induction motor at constant ratio. . The proposed system is an effective replacement for the conventional method which produces high switching losses. Phase shifted SPWM control scheme has been used for Cascaded H-Bridge multilevel inverter. Simulation results are presented in this paper to validate the effectiveness of the proposed scheme.

Keywords— Cascaded H-Bridge Multilevel Inverter, Multicarrier PWM technique, THD

I. INTRODUCTION

Recently development of multilevel inverter fed AC drive is popular for speed control of high power induction motor. Variable AC drive provides improved performance and energy efficiency. However, until recently, the provision of a continuously variable speed has been considered too expensive for all but special applications for which the compromise of constant speed was not acceptable e.g. elevators, mill drives, machine tools [1]. For many industrial applications an exact speed control is not needed, because of a great inertia of the mechanical system, a fast response to change in the reference, or due to fact that a precise control of the motor developed torque is not necessary. The concept of multilevel inverter control has opened a new possibility that induction motors can be controlled to achieve dynamic performance [2]. The Cascaded H-Bridge method can be applied to higher level converters. As the number of level increases, the synthesized output waveform adds more steps, producing a staircase waveform [3]. In these applications the main objective is to maintain the speed at a fixed reference value, and the use of constant V/F control method offers good results [8]. Recently power electronics and control systems have matured to allow these components to be used for motor control in place of mechanical gears. These electronics not only control the motor's speed, but can improve the motor's dynamic and steady state characteristics. Adjustable speed ac machine system is equipped with an adjustable frequency drive that is a power electronics device for speed control of an electric motor. It controls the speed of the electric motor by converting the fixed voltage and frequency to adjustable values on the machine side. High power induction motor drives using conventional three phase converters have the disadvantages of poor voltage and current qualities. The presence of significant amount of harmonics makes the motor to suffer from severe torque pulsations, especially at low speed. To improve these values, the switching frequency has to be raised which causes additional switching losses.

In this paper, a three phase three level Cascaded H-Bridge multilevel inverter fed induction motor drive is designed and implemented. The proposed inverter can reduce the harmonic contents by using phase-shifted SPWM technique. V/f is an efficient method for speed control in open loop. In this scheme, the speed of induction machine is controlled by the adjustable magnitude of stator voltages and its frequency in such a way that the air gap flux is always maintained at the desired value at the steady state. Here the speed of an induction motor is precisely controlled by using three level cascaded H-bridge multilevel inverter, with improved performance in terms of switching losses and THD.

II. POWER TOPOLOGY

In the conventional technique, normal PWM method is used, so that the voltage and current is of poor quality and the switching frequency causes more amount of switching losses. These drawbacks are rectified using three phase cascaded h-bridge multilevel inverter. The voltage and current qualities are better and the switching losses are reduced when compared to the conventional technique. Also the THD is found to be better.

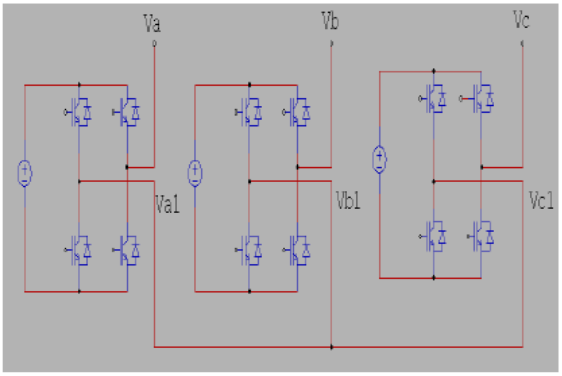

Fig.1. Power Topology of Three level Cascaded H-bridge Inverter

The three phase three level cascaded h-bridge voltage source inverter is shown in fig.1. Each dc source is connected to an inverter. Each inverter level can generate three different voltage outputs, +Vdc, 0, and –Vdc using various combinations of the four switches. It contains 12 unidirectional active switches and three separate dc sources. The most attractive features of multilevel inverters are as follows [2].

- They can generate output voltages with extremely low distortion and lower dv/dt.
- They draw input current with very low distortion.
- They generate smaller common-mode (CM) voltage, thus reducing the reducing the stress in the motor bearings.
- They can operate with a lower switching frequency.

III. MODULATION SCHEME

This paper mainly focuses on multicarrier PWM method. This method is simple and more flexible than SVM methods. The multicarrier PWM method uses several triangular carrier signals, keeping only one modulating sinusoidal signal. If an n-level inverter is employed, n-1 carriers will be needed. The carriers have the same frequency *f*cr and the same peak to peak amplitude Vcr. The modulating signal is a sinusoidal of frequency *f*m and amplitude Vm. In this proposed scheme phase sifted modulation scheme is used. For three level triangular carriers required M-1=2 where m= voltage level. There is a phase shift between two adjacent carrier waves, given by [7].

Øcr =360°/ (m–1)

Here Øcr =360°/ 2

Øcr =180°

The principle of the phase shifted modulation for a three-level CHB inverter, where two triangular carriers are required with a **180°** phase displacement between two carriers. Of the three phase sinusoidal modulating waves, only the phase a modulating wave Va is plotted for simplicity. Comparison of carrier and modulating waves and gate pulses for upper switches are shown in fig. 2.

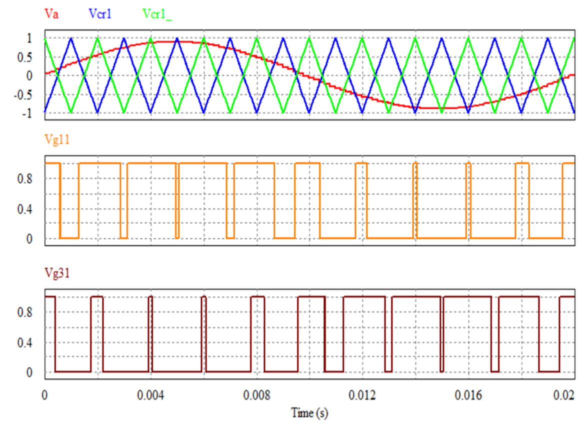

Fig.2. Simulated waveforms of carrier and modulating waves. Gate Pulses of upper switches for phase shifted modulation

IV. CONSTANT VOLT/HERTZ OPERATION

In this type of control, the motor is fed with variable frequency signals generated by the PWM control from an inverter. Here the V/f ratio is maintained constant in order get constant torque over the entire operating range. Since only magnitudes of the input variable-frequency and voltage are controlled, this is known as "Scalar Control". Generally, the drives with such a control are without any feedback devices.

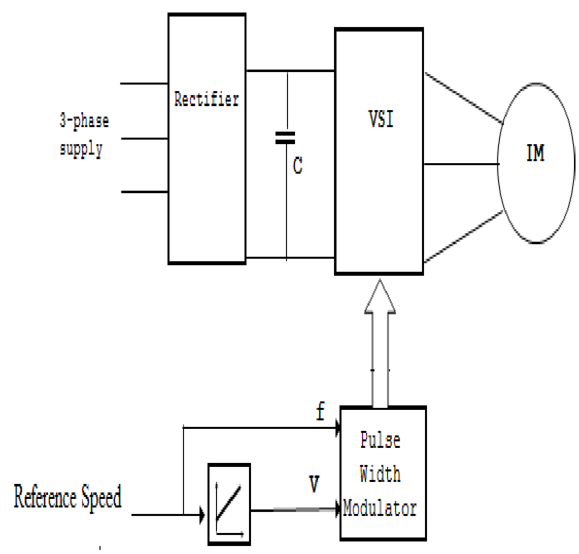

Fig.3 Open-loop V/f control

Hence a control of this type offers low cost and is an easy to implement solution. Fig. 3 shows the open-loop V/f control of three phase induction motor. The voltage and frequency being increased up to the base speed. At base speed, the voltage and frequency reach the rated values. We can drive the motor beyond base speed by increasing the frequency further. But 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 wind age losses increase significantly at higher speeds. Hence, the torque curve becomes nonlinear with respect to speed or frequency.

V. SIMULATION RESULTS AND DISCUSSION

Output line voltage waveforms for 50 Hz frequency are shown in fig. 4.

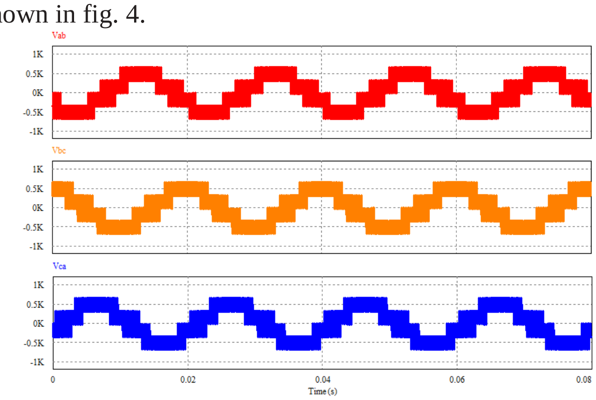

Fig. 4 line voltage for 50 Hz Frequency

Speed- Torque curves for 50 Hz frequency are shown in fig. 4. The frequency spectrum with THD for line voltage is shown in fig. 5. In fig. 6 The spectrum shows that the harmonic content present in the line voltage for three- level inverter is very low compare to two level inverter.

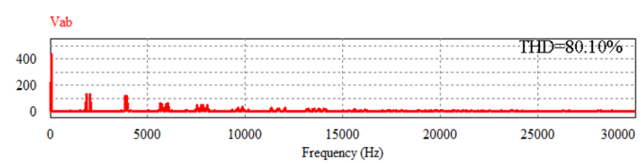

Fig. 5 frequency spectrum for two level inverter

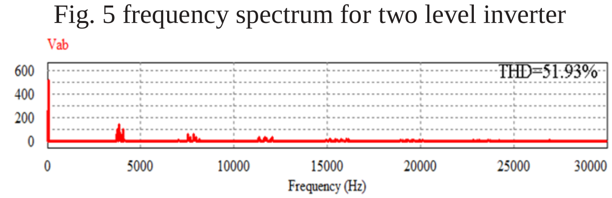

Fig. 6 frequency spectrum for three level inverter

The frequency of reference signal determines the inverter output frequency, and its peak amplitude controls the modulation index. The variation in modulation index changes the rms output voltage of the multilevel inverter. By varying the reference signal frequency as well as modulation index, the speed of an induction motor gets controlled.

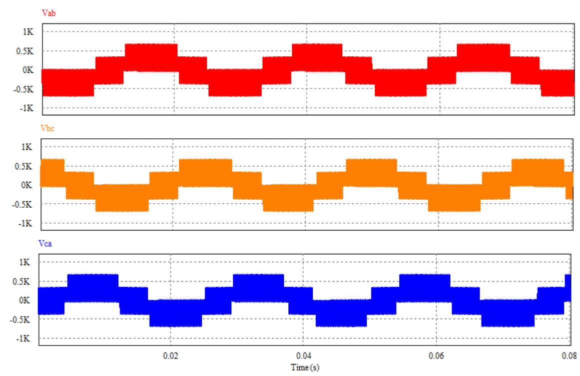

Fig 7 line voltage for 40 Hz Frequency

The speed- torque curves conclude that the voltage and frequency applied to the motor gets decreased, and then the speed of an induction motor also gets decreases simultaneously.

VI. CONCLUSION

Three-level cascaded H-bridge multilevel inverter has been presented for drive applications. The phase shifted carrier SPWM technique is simulated for producing low harmonic contents in the output voltage; hence the high quality output voltage was obtained. The THD and frequency spectrum of line voltage is compared with two level inverter. It is concluded that three level inverter performances is better than two level inverter. The open loop speed control was achieved by maintaining V/f ratio at constant value. The simulation results show that the proposed system effectively controls the motor speed and enhances the drive performance through reduction in total harmonic distortion (THD).

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