

Design of Adjustable Speed Drive Incorporating SPWM Technique

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ABSTRACT: Adjustable Speed Drive is an equipment that adjusts speed by external controller. Here, by comparing sine wave and carrier wave spwm is generated. SPWM inverter produced ac, drives the single phase induction motor. The control signal is PI controlled and speed is adjusted by changing the load as per requirement. To remove the harmonics produced by SPWM inverter filter is designed.

KEYWORDS: SPWM inverter, filter, PI controller.

I. INTRODUCTION

As fuel is getting diminished so energy savings have been a big factor nowadays. So for saving energy with increased motor longevity Adjustable Speed Drive is largely used nowadays. Here a SPWM inverter is designed and DC voltage is given to it, DC is converted to ac and a single phase induction motor is driven by this ac o/p and speed of this motor is adjusted by closed loop speed control method.

In proper speed control we need to vary both the motor voltage and frequency to control slip. For single phase induction motors with just one phase we get a pulsating voltage only. So single phase motors artificially create a second phase to create the rotation. This second phase can be created in many ways- using auxiliary windings and phase shift capacitors. So this idea of proper speed control does not really work.

The work in this paper is divided in two stages. 1) SPWM inverter design 2) PI control. An inverter is a circuit which converts a DC power into an AC power at desired output voltage and frequency. The AC output voltage could be fixed or variable voltage and frequency. This conversion can be achieved either by controlled turn on and turnoff devices (e.g. BJT, MOSFET, IGBT, and MCT etc.) or by forced commutated thyristors, depending on application. [1]

SPWM inverter design is done by using IGBT. Here, sine wave is compared to triangular wave and gate pulse is generated. During positive half cycle if IGBT 0 is always OFF and if IGBT 1 is ON, then IGBT 2 is getting pulse and IGBT 3 is getting pulse through a NOT Gate. Similarly, for the negative half cycle, if IGBT 2 is always OFF and IGBT 3 is ON, then IGBT 0 is getting pulse and IGBT 1 is getting pulse through a NOT Gate. Thus we got the Unipolar SPWM output.

IGBT has greater turn off time, high input impedance, high power gain.

In presence of nonlinearity and parameter variation PI control gives best results. But it gives overshoot during tracking mode and load disturbance rejection. This is mainly due to the fact that the complexity of the system does not allow the gain of the PI controller to exceed a certain low value and at the starting mode the high value of the error is amplified across a PI controller causing annoyance high variations in command torque. Whenever the gains of the controlled exceed a certain value, the variation in the command torque become very high and will destabilize the

International Journal of Innovative Research in Science, Engineering and Technology

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Vol. 6, Issue 6, June 2017

system. In order to overcome this problem we propose a limiter ahead PI controller.[2] Now the speed error has come within saturation limits.

paper is organized as follows- section II describes related work. In Section III proposed method, in section IV simulation and in Section V experimental results are given. Section VI presents conclusion. Section VII presents future scope and in section VIII references are given.

II. RELATED WORK

Speed control is very useful part of our daily life. For large motors adjusting speed is essential. So, adjustable speed drive has a wide application now a days.

My invention is done by PI controller. But to get success in a work we have to study about the other researches on related topic. So a literature survey is always important. I learn about this topic from "Controlling 3-Phase Induction Motors Using VFD And PLC".

Here, the work is done by diode bridge converter, VFD-M programming. Using PLC motor is running in forward direction and stops in reverse rotation.

For PLC here a speed potentiometer, a forward/reverse direction selector, a run/jog switch, a start/stop push button is used.

I learn the control method idea - voltage and frequency ratio constant to make the slip constant, vector control, direct torque control etc.

I studied some patents; like- Controller for pulse width modulation circuit using AC sine wave from DC input signal and also some papers on filter design.

My idea of PI control arises because- a PI controller is a feedback control loop which calculates the error signal and from "PI controller" I learn it is important to point out the complexity of the electronic components within the circuit path.

III. PROPOSED METHOD

My project is to design a spwm inverter with reduced harmonics and drive a single phase induction motor and adjusting the speed by a closed loop control of PI controller.

SPWM are of two types- (i) Bipolar, (ii) Unipolar.

- Bipolar technique is a 4-quadrant technique. So, its generating mode's back emf is greater than motoring mode.
- Motor current is always flowing through the single shunt resistor, regardless of which state the PWM signal is in, with bipolar PWMs, if the pulse width for one of the PWM states is too short, we can simply flip to the other PWM state, where the shunt signal will be correspondingly longer. So we are always guaranteed to have at least one interval within each PWM cycle (regardless of the duty-cycle value) where the shunt signal width is wide enough to easily facilitate an accurate reading of the motor current.[8]

But, it contains more harmonics than unipolar.

For unipolar SPWM-

- THD performance is better.
- Filter requirement is less.

But due to the presence of zero state it opens a leakage current path.

Here, unipolar SPWM inverter is designed.

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● BLOCK DIAGRAM-

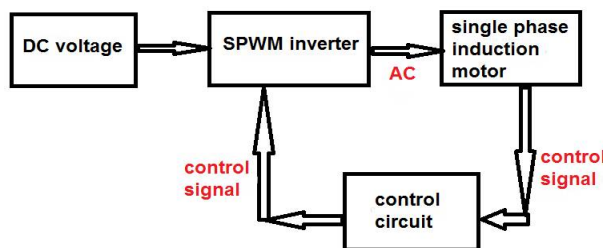


Fig:1

The total work done is based on a planning. The planning is -
One sine wave and one triangular wave (carrier wave) is compared and thus the pulse width is generated. Here by comparing two sine waves pulses are generated.

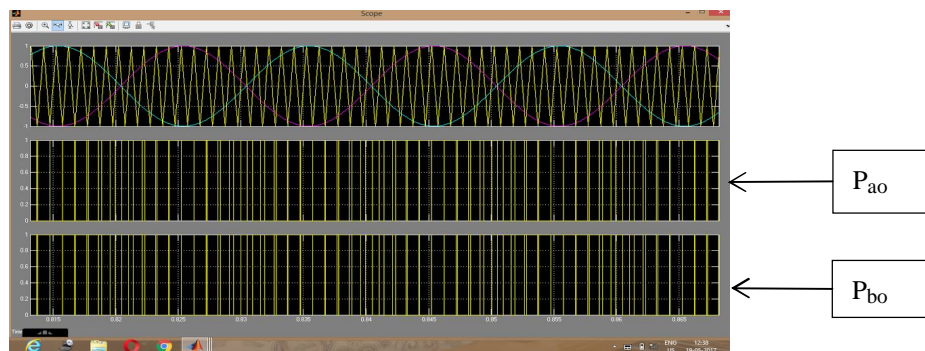


Fig:2

$$P_{ab} = P_{ao} - P_{bo}$$

Now, the generated pulses are applied to gate terminals and during positive half cycle if IGBT 0 is always OFF and if IGBT 1 is ON, then IGBT 2 is getting pulse and IGBT 3 is getting pulse through a NOT Gate. Similarly, for the negative half cycle, if IGBT 2 is always OFF and IGBT 3 is ON, then IGBT 0 is getting pulse and IGBT 1 is getting pulse through a NOT Gate. Thus we got the Unipolar SPWM output.

SPWM inverter is chosen because

1. Power loss is low.
2. No voltage drop across the switch. [3]

Now, this voltage is filtered to reduce harmonics.

● FILTER DESIGN-

Filter design is the process to eliminate harmonics, which are produced from SPWM inverter. Here, we are using LC filter.

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Vol. 6, Issue 6, June 2017

$$f = \frac{1}{2 * \pi * \text{sqrt}(L * C)}$$

Fig:3

1. LC filter is loss less.
2. Ripple is less.

This voltage is applied to single phase induction motor, then the speed output is compared to a reference speed and then it is PI controlled. To avoid the problem of high command torque and destabilization a limiter is given. Finally the speed is adjusted and as the name suggests adjustable speed drive is done.

IV. SIMULATION

Simulation is a process of creating and analyzing a physical model to predict its performance. Here, simulation blocks are used from simulation library and connection is done. The data is given and finally implementation is done. The idea of the project is implemented and the main circuit diagram is given-

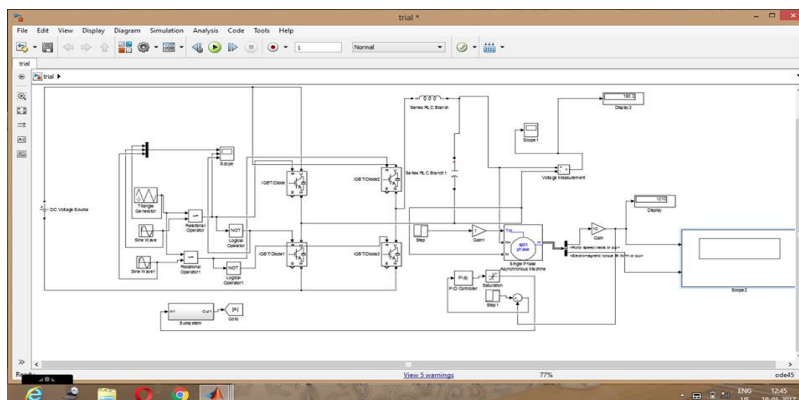


Fig:4 MAIN CIRCUIT DIAGRAM

Here, a SPWM Inverter is designed and DC voltage is given to it, DC is converted to ac and a single phase induction motor is driven by this ac o/p and speed of this motor is adjusted by closed loop speed control method. The output of the inverter is fed to motor and then speed is controlled by PI controller is shown.

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Vol. 6, Issue 6, June 2017

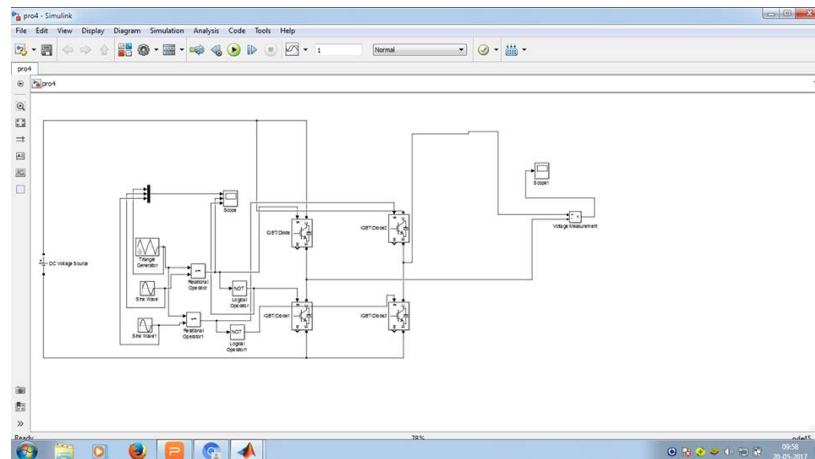


Fig:5 SPWM INVERTER

Here, sine wave is compared to triangular wave(carrier wavv) and gate pulse is generated. During positive half cycle if IGBT 0 is always OFF and if IGBT 1 is ON, then IGBT 2 is getting pulse and IGBT 3 is getting pulse through a NOT Gate. Similarly, for the negative half cycle, if IGBT 2 is always OFF and IGBT 3 is ON, then IGBT 0 is getting pulse and IGBT 1 is getting pulse through a NOT Gate. Thus we got the Unipolar SPWM output.

V. EXPERIMENTAL RESULTS

The experiment shows the results- (i) SPWM inverter output without using filter, (ii) SPWM inverter output with using filter, (iii) motor output. The turn on-off switching pulse is obtained from Matlab simulation.

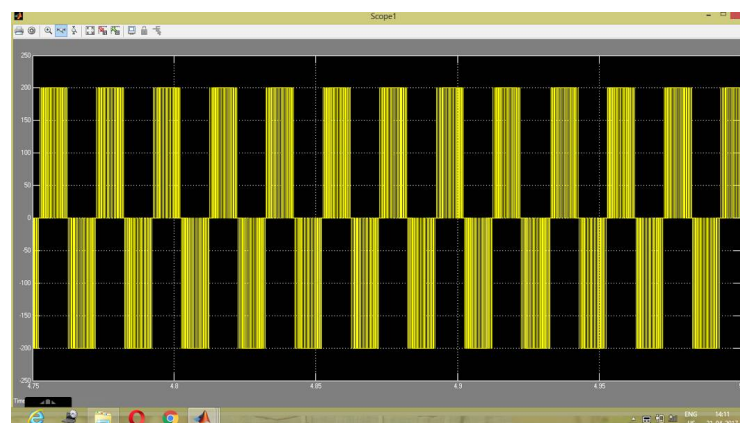


Fig:6 UNIPOLAR SPWM OUTPUT WITHOUT FILTER

The peak output voltage is 200v. The Matlab Simulink simulation is used to design the SPWM generator and constructed the single phase inverter. The simulation result is used as an indicator to design the hardware part. But we get square waves which is full of harmonics, which is not desired. The modulation index is determined by formula $m = (f_d / f_m)$. Max. frequency deviation of carrier (f_d) and Max. modulating frequency (f_m) and $m =$ modulation index.

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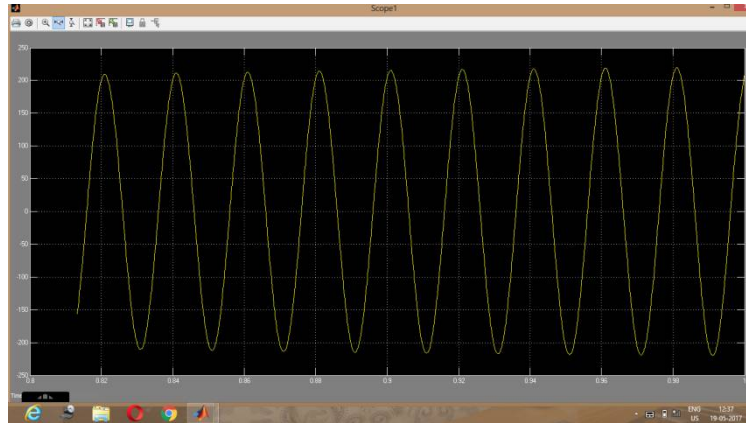


Fig:7 UNIPOLAR SPWM OUTPUT WITH FILTER

The harmonics present in SPWM output is eliminated by LC filter. After filtering we get the simulation result as given. The peak voltage is near 200v. This output is given to single phase induction motor for getting better response. For better approach harmonic trap filters can be used.

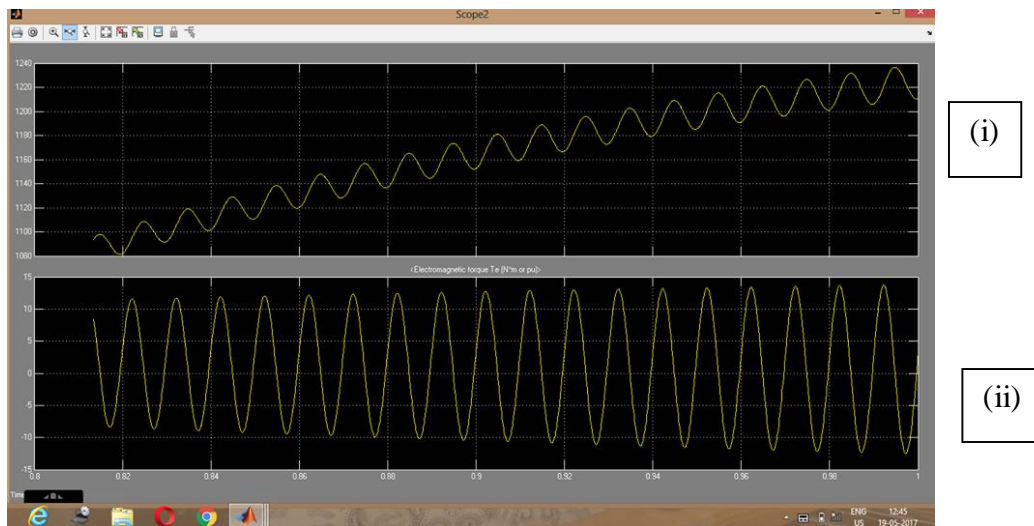


Fig:8 MOTOR OUTPUT

(i) speed & (ii) electromagnetic torque

Here, we can see after changing the load speed is remaining constant. As, torque is proportional to voltage square so when T_m is changed voltage is also changed, and after PI control frequency is changed, so voltage and frequency ratio is remaining constant, so speed is constant. Thus we have got the speed and electromagnetic torque as shown.

VI. CONCLUSION

This report introduced adjustable speed drive system of a single phase induction motor. We presented SPWM inverter and control its speed. When we are changing the load, the voltage and frequency are changed, but voltage upon

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Vol. 6, Issue 6, June 2017

frequency ratio is constant so speed is remaining constant. Thus we have adjusted the speed and we have designed adjustable speed drive system incorporating SPWM Technique.

Load(N-m)	Speed(Rpm)
1	1210
100	1210
1000	1210

Table:1

When we are changing the load, speed is remaining constant and this is shown in the given table.

But, while doing the project we got some error,
Loss of voltage- 17.26%
actual voltage- 230V
practical value- 190.3V
harmonics are present.

IEEE says harmonic content as "a measure of the presence of harmonics in a voltage or current waveform expressed as a percentage of the amplitude of the fundamental frequency at each harmonic frequency. The total harmonic content is expressed as the square root of the sum of the squares of each of the harmonic amplitudes." [5] For harmonic reduction tuned banks will be needed to eliminate all harmonics away from the system. For better approach PLC, fuzzy logic can be used.

VII. FUTURE SCOPE

Research is endless. My project could be further researched upon and extended by considering various other advanced simulation tools, both in the hardware and in the software.

The developed control strategy is not only simple but also reliable and may be easy to implement in real-time applications using dSPACE, Data acquisition cards, TMSDSP cards, NI cardsetc. For control of various parameters and can also be combined with fuzzy, ANNs and rough sets for other applications.[6]

VFDs are now widely used in industry, and even in residential applications.

VFDs can be used to save energy by controlling the speed of motors in several applications, use of VFDs can also be used for savings from better machinery, lower costs, better process control, and so higher productivity, quality etc is obtained.

Demand for VFDs is highest in the Asia Pacific region, owing to presence of a large number of oil and gas companies. The Middle East, especially GCC, produces the bulk of oil and gas, employing hundreds of thousands of motors. The regional VFD manufacturing industry is quite strong, and western corporations are targeting the region, owing to its immense potential.[7]

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