Speed Control of 3-Phase Squirrel Cage Induction Motor by 3-Phase AC Voltage Controller Using SPWM Technique

V. V. Srikanth [1] Reddi Ganesh [2] P. S. V. Kishore [3]
[1] [2] Vignan's institute of information technology/electrical and electronics department, Visakhapatnam, India
[3] Addis Ababa university/ electrical and electronics department, Addis Ababa, Ethiopia.

Abstract

The objective of this paper is to investigate the effect of SPWM technique on 3-phase ac voltage controller for speed control of induction motor drive. SPWM for closed loop control of induction motor drive fed by ac voltage controller is designed and considered for evaluation. AC voltage controller makes use of line commutation and as such no complex commutation circuitry is required in this controller. The main application of this model is winders, fan drives, domestic pumps, industrial heating and lighting control. Simulation is carried out by using MATLAB 2009b and programming for firing of SCR is done by using KEIL.

Keywords*: AC voltage controllers, Squirrel Cage Induction motor, Silicon Controlled Rectifier and Microcontroller, SPWM*

Introduction

For the industrial development of a nation the choice of machines is considered as utmost importance since the early industrial era in many developing machines the machine control is more complicated than other quantities like loading factors or faults etc. All most all of these machines employed are induction machines because of their added advantages of ruggedness, low cost, weight, volume and inertia, high efficiency and ability to operate in dirty and explosive environments, easy to control when compared with DC motors even for its disadvantage of lagging power factor. But with the advent of power electronics transformed the scene completely and today we have variable drive systems which are not only smaller in size but also very efficient and higher reliable. Induction motors are able to be control even for variable speeds and in the narrow range also. In other words power electronic components find their use in low as well as high power applications [1]. AC drive systems use the AC motor as the driven element either in induction or synchronous type. Since most of the motors in industries are only of induction type, developed on this field took place rapidly [2].

We are selecting 3-phase AC voltage controller along with SPWM technique for the speed control of induction motor, ac controllers are thyristor based devices, which convert fixed alternating voltage without a change in frequency. By changing the firing angle of SCR the output voltage of AC voltage controller changes. Since frequency remains constant in AC voltage controller, flux changes in the IM motor with the change of output voltage in the AC voltage controller and hence torque of IM changes. Since torque is proportional to speed, speed will be controlled. However the speed variation in narrow range cannot be eliminated by variac technology. This can be eliminated by power electronic converters. With the introduction of these modern techniques high efficiency & flexibility in control can be achieved. Compact size and less maintenance are the other features of this technique. Thus these features make this method more advantages than others.

This paper presents the closed loop simulation of IM with SPWM technique for speed control of 3-phase induction motor by using SCR based AC voltage controllers with line commutation technique [8].

Block Diagram

The block schematic diagram of single closed loop control is shown in fig. Feedback control of speed and current is employed to regulate the speed and to maintain the current within safe limits.

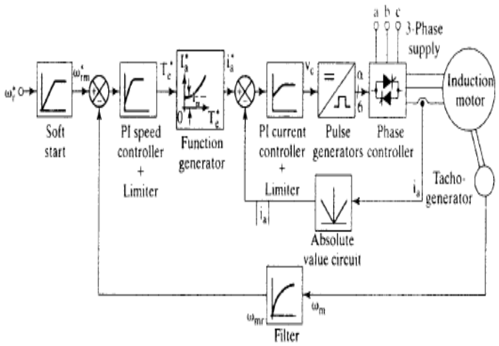


Fig1: closed loop speed control of IM for variable stator voltage control

The inner current-feedback loop is for the purpose of current limiting. The outer speed loop enforces the desired speed in the motor drive. The speed command is processed through a soft start/stop controller to limit the acceleration and deceleration of the drive system.

The speed error is processed, usually through a PI controller, and resulting torque command is limited and transformed into stator-current command. The current command is compared with actual current, and the error is processed through a limiter. This limiter ensures that the control signal v_c to phase controller to a safe level [5].

Speed control of IM:

Variable Stator Voltage method

Since torque varies as square of the voltage applied to its stator terminals. Thus by varying the applied voltage, the electromagnetic torque developed by the motor can be varied. This method is generally used for small squirrel-cage motors where cost is an important criterion and efficiency is not. However, this method has rather limited range of speed control [5].

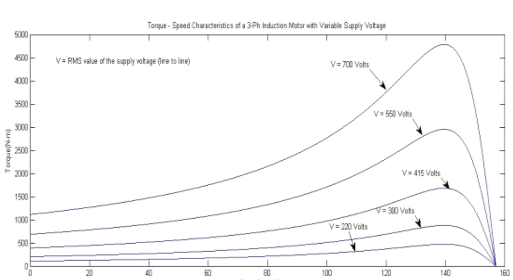


Fig2: speed-torque characteristics

The speed-torque characteristics of variable stator voltage are shown above. As the supply voltage is decreased, the value of maximum torque also decreases. However it still occurs at the same slip as earlier. Even the starting torque and the overall torque reduce. Thus the machine is highly underutilized. Thus this method of speed control has very limited applications.

3-Phase AC Voltage Controller:

In phase control the Thyristors are used as switches to connect the load circuit to the input ac supply, for a part of every input cycle. That is the ac supply voltage is chopped using Thyristors during a part of each input cycle. The thyristor switch is turned on for a part of every half cycle, so that input supply voltage appears across the load and then turned off during the remaining part of input half cycle to disconnect the ac supply from the load. By controlling the phase angle or the trigger angle 'α' (delay angle), the output RMS voltage across the load can be controlled. The trigger delay angle 'α' is defined as the phase angle (the value of wt) at which the thyristor turns on and the load current begins to flow. Thyristor ac voltage controllers use ac line commutation or ac phase commutation.

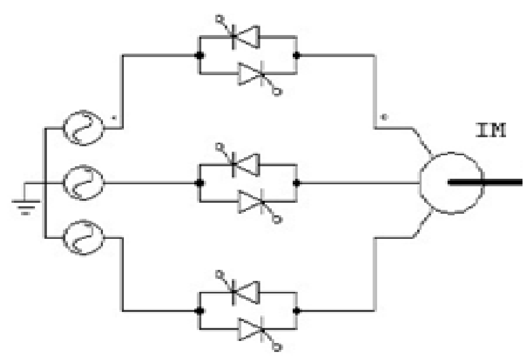


Fig3: 3-phase AC voltage controller with motor load

Depending on the firing angle a, there may be three operating modes.

a) mode-1.
b) mode-2.
c) mode-3.

Mode-1: $0 \le \alpha \le 60^{o}$

There are periods when three SCRs are conducting, one in each phase for either direction or periods when just two SCRs conduct. Per phase RMS output voltage.

$$V_0 = \sqrt{6}V_s\left[\frac{1}{\Pi}\left(\frac{\Pi}{6} - \frac{\alpha}{4} + \frac{\sin 2\alpha}{8}\right)\right]^{1/2}$$

Mode-2: $60^0 \le \alpha \le 90^0$

Two SCRs, one in each phase, always conduct. Per phase RMS output voltage in mode2.

$$V_0 = \sqrt{6}V_s\left[\frac{1}{\Pi}\left(\frac{\Pi}{12} + \frac{3\sin 2\alpha}{16} + \frac{\sqrt{3}\cos 2\alpha}{16}\right)\right]^{1/2}$$

Mode3: $90^0 \le \alpha \le 150^0$ When none or two SCRs conduct. Per phase RMS output voltage in mode3.

$$V_0 = \sqrt{6}V_s\left[\frac{1}{\Pi}\left(\frac{5\Pi}{24} - \frac{\alpha}{4} + \frac{\sin 2\alpha}{16} + \frac{\sqrt{3}\cos 2\alpha}{16}\right)\right]^{1/2}$$

For $\alpha \ge 150^0$ there is no period when two SCRs are conducting and the output voltage is zero at $\alpha \equiv 150^0$. Thus, the range of the firing angle control is $0^0 \le \alpha \le 150^0$.

SPWM method:

In this method of modulation, by comparing a sinusoidal reference signal with a triangular carrier wave of frequency f_c, the gating signals are generated. The number of pulses per half cycle depends on the carrier frequency. This pulses can directly applied to gating circuit of SCR which controls the RMS output voltage of AC voltage controller circuit [5].

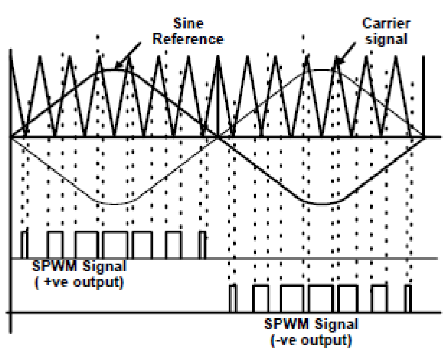


Fig4: SPWM technique

Simulation results

The simulation of ac voltage controller fed induction motor drive is done in MATLAB/Simulink toolbox.

Open Loop:

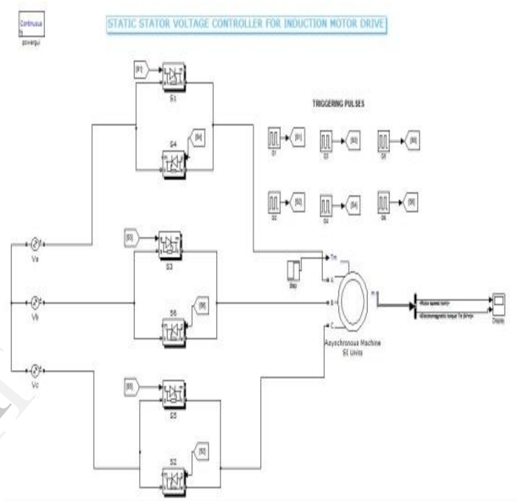


Fig5: Simulation Simulink model of proposed open loop speed control of IM

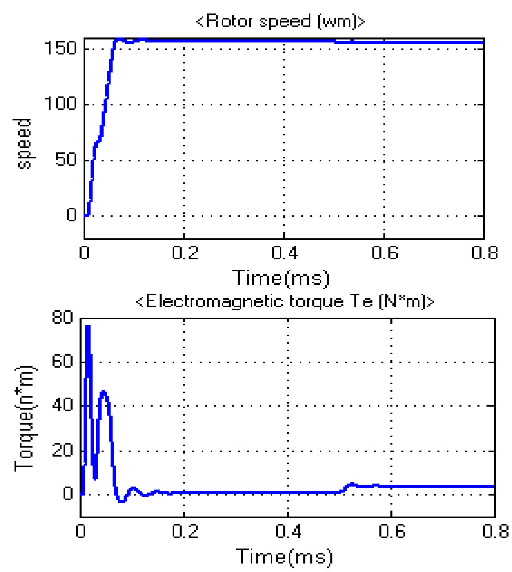


Fig6: simulation results for speed and torque

Closed Loop:

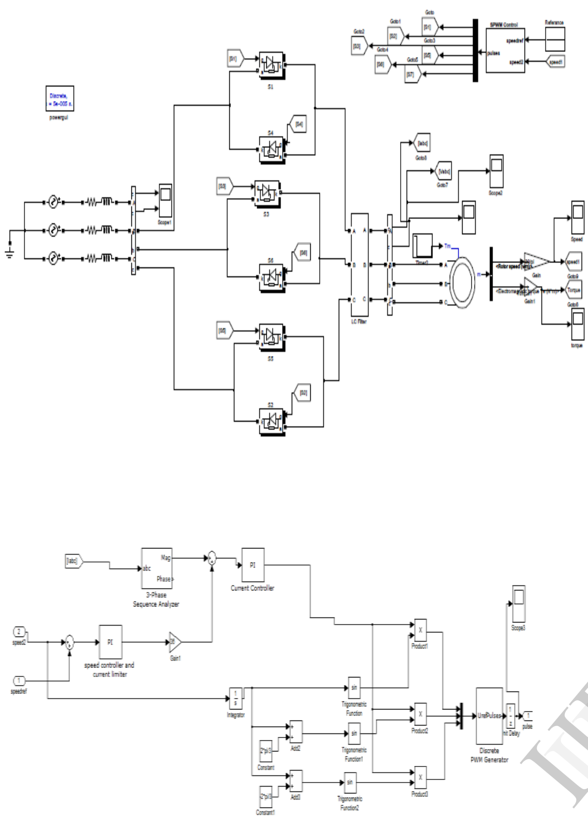


Fig7: Simulation Simulink model of proposed closed loop speed control of IM

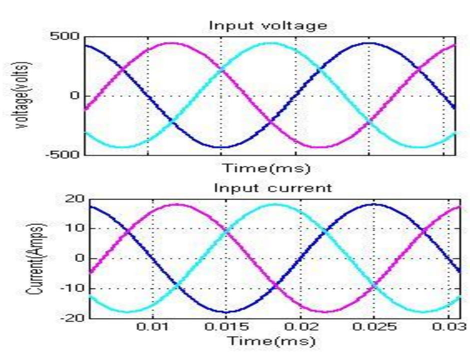


Fig8: simulation results of input voltage and current

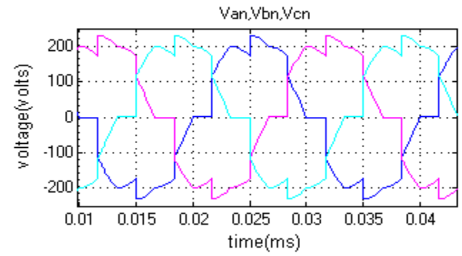
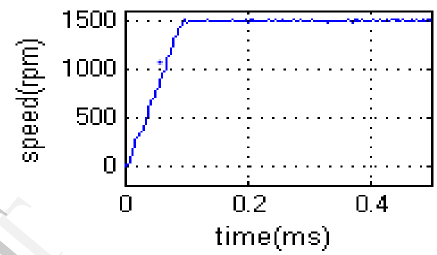


Fig9: Instantaneous output voltage of ac voltage controller



Experimental setup

Block Diagram

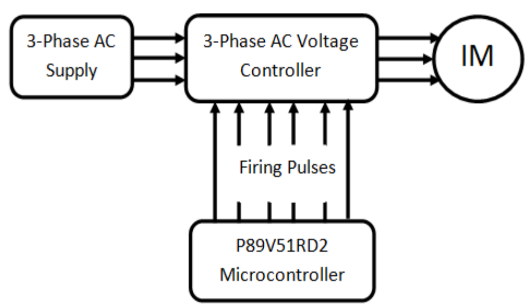


Fig12: Block Diagram for Hardware implementation

This proposed design has been fully tested and verified by driving incandescent lamps. Firing pulses generated from microcontroller are given to gate circuit of thyristors. Opto-isolator is used to isolate the microcontroller from ac voltage controller. From the above test results the speed of 0.5HP 3-phase SQIM can be varied in a narrow range from 1370rpm to 1470rpm

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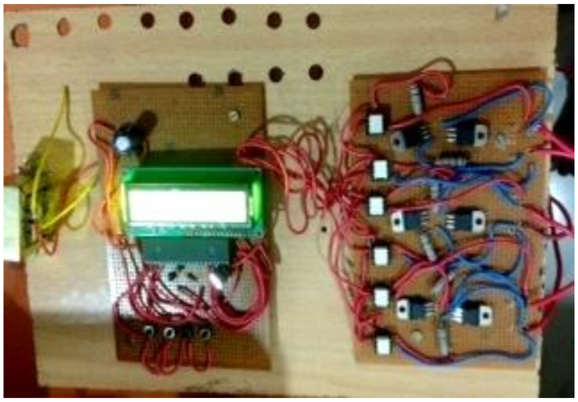

Fig13: experimental setup

Test results for open loop:

S.NO	AC VOLTAGE (V_{RMS})	SPEED (RPM)
1.	0	0
2.	25	925
3.	75	1250
4.	100	1390
5.	200	1460
6.	300	1470
7.	415	1470

Stator-voltage-control method offers limited speed range. However this introduces pronounced harmonic contents and input supply power factor for the voltage controller is quite low. These are used for low-power drives like fans, blowers and centrifugal pumps requiring low starting torque.

Parameters of Induction motor:

Induction motor parameters	value
Line voltage	415V
Supply frequency (f)	50 Hz
Stator resistance (Rs)	0.435ohm
Stator inductance (Ls)	4mH
Rotor resistance (Rr)	0.861ohm
Rotor inductance (Lr)	1mH
Mutual inductance(Lm)	69.31mH
Number of pole (p)	4
speed	1500rpm

Conclusion

This paper presents modelling and simulation of 3-ac voltage controller for speed control of IM. With the help of SPWM technique speed control of induction motor is very effective and harmonic free. The disadvantages in SPWM technique can be eliminated with the help space vector modulation. Speed control of IM is achieved with help of controlling the firing angle of ac voltage controller and for closed loop reference speed can be achieved with SPWM technique.

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