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MATLAB Simulation of Single-Phase SCR Controller for Single Phase Induction Motor.

O. Oladepo and G.A. Adegboyega

Department of Electrical and Electronic Engineering,
The Federal University of Technology, Akure, Nigeria.
E-mail: ooladepo@yahoo.com

Abstract

Thyristors are now widely used in many power electronics and motors drives applications. This is due to their several advantages such as relatively small size, low losses, market availability, and low cost. In this paper, a stator voltage control of single-phase induction motor using thyristors is analyzed and simulated. The stator voltage has been controlled by phase angle control of single-phase supply. The delay angles and their corresponding resistor values before the thyristor fires had been analysed. Firing requirements and limits of control have also been studied. An electronic circuit is designed on multisim software with BT 151 thyristor to control the speed of AC induction motor and simulated. The simulation results have been found in correlation with the one obtained from the simulated matlab program using MATLAB 7.

Keywords: Voltage Controller, Induction Motor, Speed Control, Thyristor.

Introduction

In the last decades, the production of power electronics switches has been plentiful and diverse. Some of these switches are thyristors, Gate-turn-off thyristor (GTO's), bipolar power transistors, Metal Oxide Semiconductor Field-Effect Transistor (MOSFET's) [1, 2]. Even with these devices, the basic thyristor still constitutes a robust, simple and economical device that has many applications.

Thyristors are widely used for control of power in both AC and DC systems. This is due to their several advantages such as relatively small size, low losses and fast switching. Apart from many other uses, such a controller is used to control the single phase AC power in induction heating, light control, reactive power control and starting as well as speed control of AC motors.

Single phase AC voltage controller has been used with R-L load [1, 2] for various circuit configurations. This technique can be modified to be used with induction motor by reducing the equivalent circuit of induction motor to be just R and L [3]. Single phase AC voltage controller used with single-phase induction motor is shown in Fig.1.

Using of single phase AC voltage control in speed control of induction motor has disadvantages such as low efficiency due to extra rotor copper losses. Although it has these disadvantages, but generally, this scheme has some advantages on other aspects, including low cost in installation, ease to maintain and reliable which make this scheme popular option in industry. This scheme has been used in many industrial applications as in driving an overhead travelling crane, an elevator speed control system [5], and starting and stopping means for induction motor [4-7].

In reference [4] a signal from the rotor voltage and current are used to control the speed and torque respectively. But the main disadvantage of this technique is not applicable for squirrel cage induction motor; moreover the control of current without any reference to the power factor leads to a rather nonlinear torque/speed characteristic. In reference [5] a tachometer generator connected to three-phase squirrel-cage induction motor to generate a speed signal representing the actual speed of the induction motor and to compare it with command speed signal to produce a suitable firing signal. In reference [6] and [7] the single phase AC controller with cycle skipping method was used to control, start, and stop the three-phase induction motor.

System Modeling

In this paper modelling of induction motor has been carried out by reducing its equivalent circuit to be *R-L* load. Then, MATLAB program has been used to obtain all performance parameters in terms of its firing angle. A modern computer simulation using Multisim software has been used to validate the MATLAB simulation results.

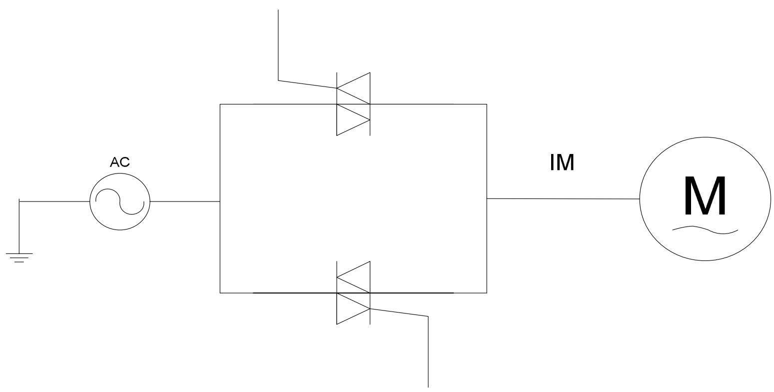

Figure 1: Single Phase AC Voltage Controller for 1-ph Induction Motor.

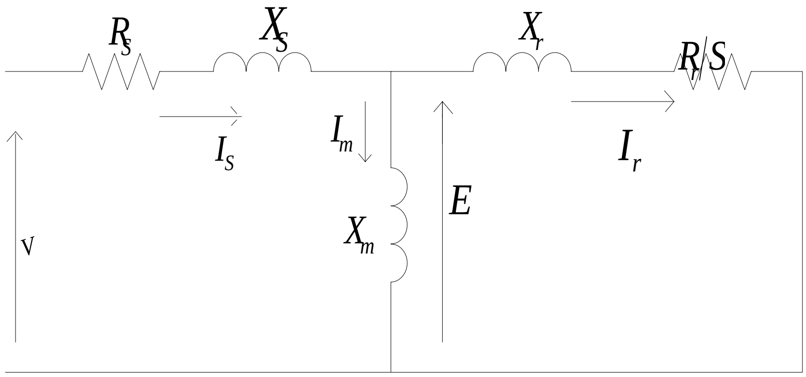

Figure 2: Equivalent Circuit of an Induction Motor.

The simplified equivalent circuit of an induction motor is as shown in Fig.2. The total impedance can be express as shown in equation (1). This equation can be reduced to be just R and L elements in terms of slip as shown in equations (2) and (3) respectively.

$$Z = Z_S + \frac{Z_m * Z_r}{Z_m + Z_r} \tag{1}$$

$$R = \frac{R_S + \left(X_m^2 * R_r\right)}{S} * \left(\frac{R_r/2}{X_m + X_r}\right)^2 \tag{2}$$

$$X_L = X_S + \left(\frac{X_m R_r^2}{S^2} + X_m X_r \left(X_m + X_r\right)\right) * \left(\frac{R_r/2}{X_m + X_r}\right)^2 \tag{3}$$

Once the total impedance of the motor is found, it could be represented by phase control circuit. After that the mathematical analysis has been used to determine the supply current and all other performance parameters in the induction motor by using MATLAB computer program.

Multisim Computer Simulation

An electronic circuit was designed on software base on the calculated delay angles, firing angles and the values of resistor (both variable and fixed) to trigger the silicon control rectifier into conduction.

The 30^o conduction angle required that the firing pulse be delayed 150^0 or 6.92ms. (The period of ½ cycle at 50HZ is 8.33ms.) To obtain time delay.

$$6.92ms = 0.8RC$$

$$RC = 8.68ms$$

$$if\ C = 0.10\mu F$$

$$then, R = \frac{8.68 \times 10^{-3}}{0.1 \times 10^{-6}} = 86{,}000\Omega$$

To obtain the minimum R (150° conduction angle), the delay is 30° or

$$(30/180) \times 8.33 = 1.39ms$$

$$1.39ms = 0.8RC$$

$$RC = 1.74ms$$

$$R = \frac{1.74 \times 10^{-3}}{0.1 \times 10^{-6}} = 17{,}400\Omega$$

Using practical values, a 100k potentiometer with up to 17k minimum (residual) resistance with BT 151 and Traic (2N6071) as composed in the circuit in figure 2.

Table 1: Delay Angles, Resistors and Output Voltage Computed

Delay angle (α)/°	Resistor (R)/Ω	Output voltage (Vout)/v to thyristor	Input voltage (Vin)/v to RC network
30	17400	63.2	75.2
60	34750	31.7	44.8
90	52100	21.1	29.9
120	86300	12.7	18.0
150	86800	12.7	18.0

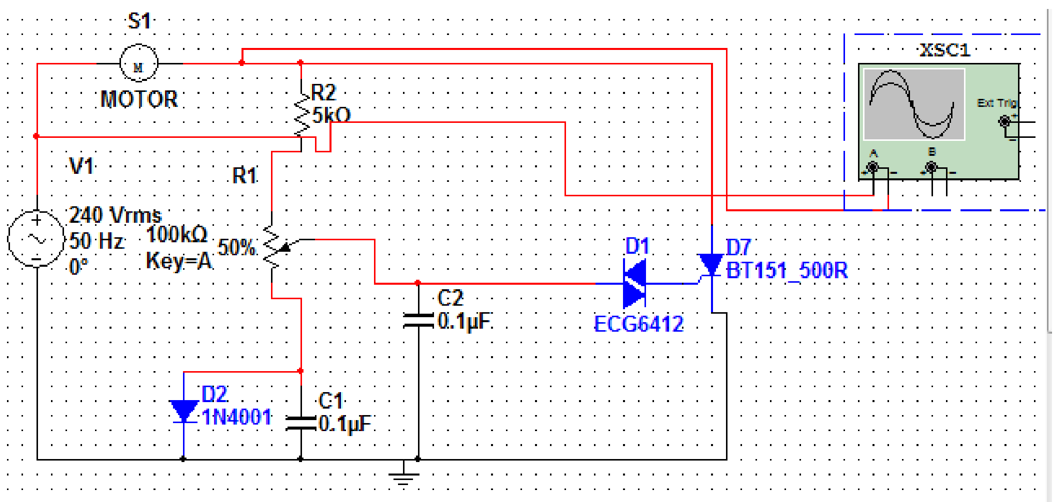

Figure 3: Control Circuit on Multisim Software.

The Nameplate Motor Data used in this Simulation is shown in Table 2:

Table 2: The AC Motor Parameter.

Rated voltage	220V	Stator inductance	10mH
Rated current	2.5A	Rotor inductance	10mH
Stator resistance	1.0Ω	Rated speed	1000rpm
Rotor resistance	1.5Ω	Insulation class	
Frequency	50Hz		

Simulation Results

The modelled circuit was simulated and the results were obtained. The input waveform obtained from the alternating current (AC) signal 220V single phase power line is shown in the figure 4.

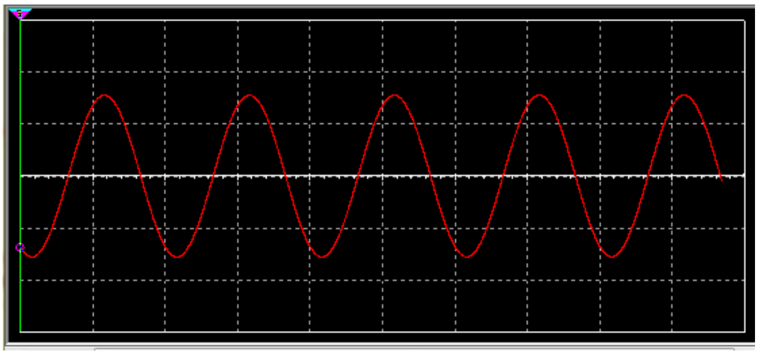

Figure 4: Input AC signal waveform (200V/Div, 10ms/Div).

The above signal is fed into the relaxation oscillation circuit to generate an 'on' and 'off' signal which turns the thyristor 'on' and 'off' at a preset value of potentiometer. The square wave signal is shown in the figure 5.

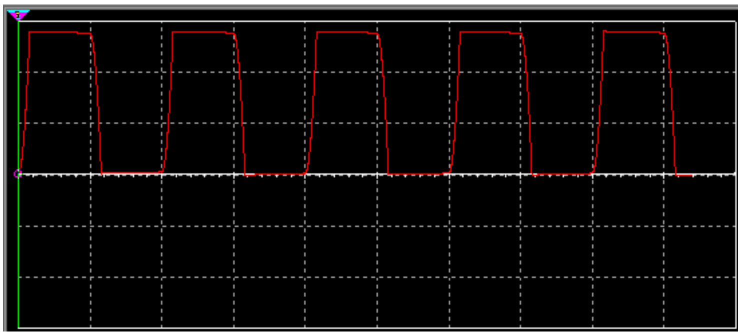

Figure 5: Output waveform from the RC Network Circuit. (1V/Div,10ms).

The action of the thyristor or triac is controlled by a diac which is switched on by a charge on the capacitor under the control of potentiometer R. The resistance of the diac is virtually infinite as long as the voltage across it remains within the breakover voltage limits, -VBO to +VBO. During each half cycle of the mains sinewave, the capacitor charges until the voltage across it exceeds the diac breakover voltage. The diac then switches on and capacitor discharges itself into the gate of the triac and switches it on. The above simulation results shows that the input supplies to the RC network circuit is sinusoidal waveform, the signal then transform into square wave to operate the silicon controlled rectifier. Therefore, the RC integrator circuit acts as delay circuit. The firing angle α is varied by the adjusting the potentiometer at the input terminal of the diac. Figure 6 shows the waveform at the firing angle of 30^0 (the conduction angle of 150^0).

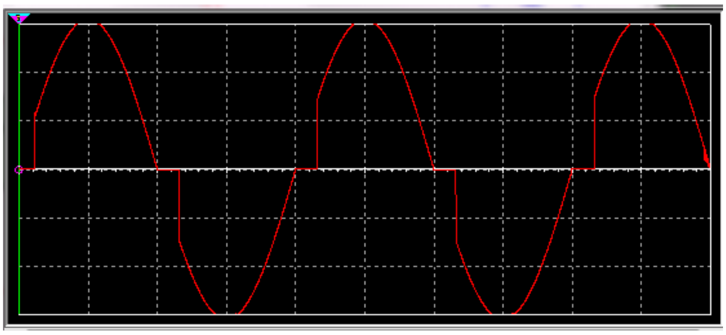

Figure 6: Output Waveform at 30^0 Firing Angle.

The above waveform shows that as the firing angle is been varied by adjusting the value of the potentiometer, the conduction angle is also varied and thereby the output voltage supplied to the load is been controlled. The values of potentiometer when α is varied were obtained and illustrated as shown in figure 7.

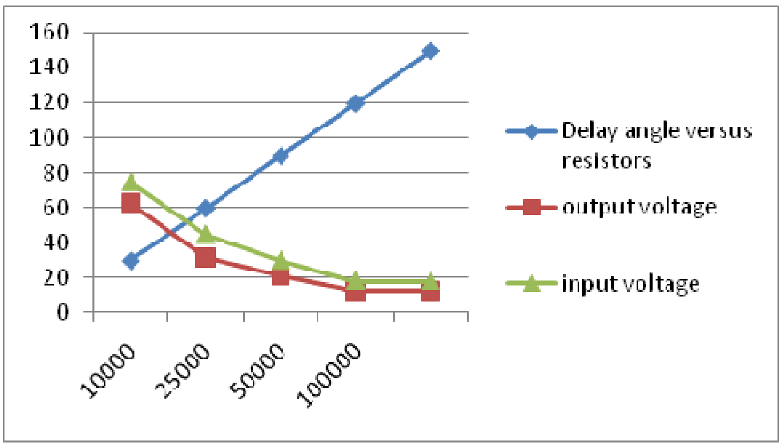

Figure 7: Phase Voltage Variation for Different Firing Angle

From the above table, when the potentiometer value is increased, the delay angle will increase and the width of the positive and negative half cycle will become smaller. Therefore, the motor speed is reduced.

The matlab simulation and the output waveform at 30^0 delay angle obtained were shown below having a good correlation with output from the Multisim software.

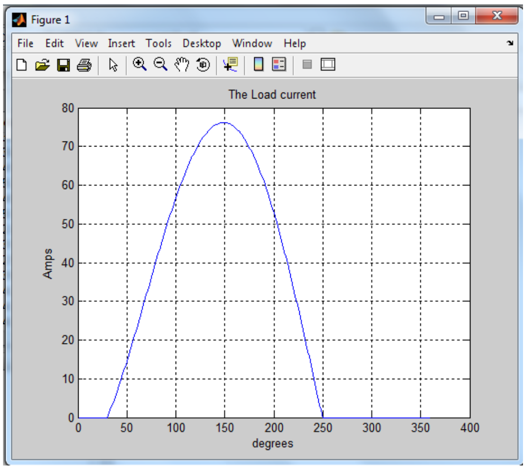

Figure 8a: waveform of the load current

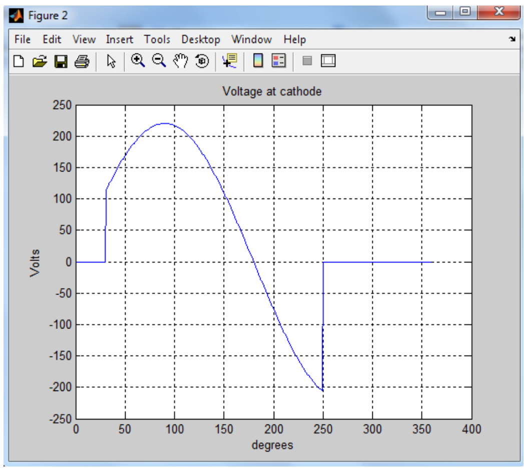

Figure 8a: waveform of the load current

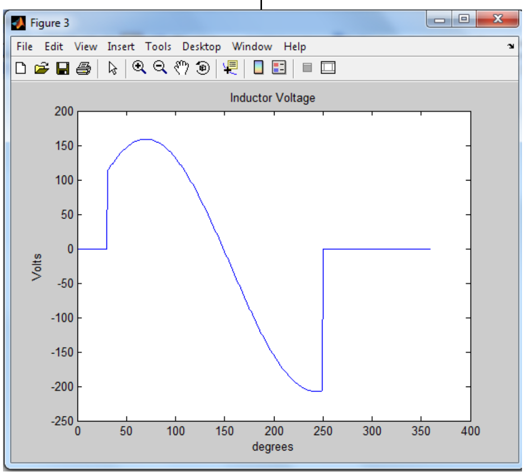

Figure 8c: Waveform of Inductor Voltage.

Conclusion

This paper presents a modeling and simulation of single phase AC voltage controller for single-phase induction motor. The simulation results from multisim software have been found in correlation with their counterpart from MATLAB 7. The speed control of the induction motor is achieved by controlling the firing angle. The relation between the speed of the motor and the firing angle depends on the mode of operation and the phase voltage supplied. Most of the National electrical energy is been consumed by the Electrical motors both at the domestic and industrial premises, therefore the implementation of this power electronic control provides a larger percentage of energy conservation.

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