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MONITORING THE VARIATION OF SPEED FOR SINGLE PHASE INDUCTION MOTOR USING ANTI PARALLEL BACK TO BACK CONNECTED SILICON CONTROLLED RECTIFIER

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Abstract- *Silicon Controlled Rectifier (SCR) is one of the most powerful power electronics devices which are used in various appliances in our daily life. These rectifiers are also called phase controlled rectifiers or thyristors and are widely used for its lower on-conduction losses, easily availability, lower switching losses, higher efficiency and a large percentage of cost-effectiveness. The efficiency of these rectifiers are almost 90% and are used extensively in industrial and household applications, mostly in variable-speed drives from minimum horse-power motor to maximum horse power motor. In this research paper, such kind of speed drives are explained as it is described here how to vary the speed of single phase induction motor using anti-parallel back to back connected thyristor. The anti-parallel back to back thyristors are connected in the stator side of the induction motor. The voltage control method are applied here for controlling speed because the output voltage of thyristors is varied by controlling the firing angle of it and it can be turned on by applying a short pulse into it's gate . A zero crossing detection circuit are designed for detecting the starting of the input voltage. Then the microcontroller is programmed for generating firing angles in a particular sequence that are shown in the paper. The firing angles are fed to the gate of the thyristors for conduction. Depending on the conduction angle and firing angle, the output voltage, torque and speed are varied which is our goal in this research work. Moreover, the relationship among the voltage, speed and firing angle are also evaluated and graphically represented.*

Keywords*:* Antiparallel back to back connected SCR, Single phase induction motor, variation of gate pulses, firing angle, speed control**.**

1. INTRODUCTION

Speed control of induction motor is required as it is widely used in various industries and household applications. Induction motors are used world-wide because of its simplicity, ruggedness and low cost. The difference between single phase and three phase induction motor is that single phase induction motor isn't self-starting. Single phase induction motordoesn't have any revolving magnetic flux. For making it self-starting, an extra winding known as auxiliary winding is provided with the main winding. The two windings are 90° electrically apart and are connected in parallel across the single phase supply.Split-phase and capacitor-start motor are the examples of two valuable single phase induction motor.Various methods are adopted for controlling the speed of induction motor such as voltage control, voltage/frequency control adding rheostat in statorand changing the pole of the induction motor.

Depending on the methods various techniques are applied for speed control, various techniques are applied for speed control, the recent voltage control method that has been discovered for controlling speed is connecting anti-parallel back to back connected thyristor in the stator side of the induction motor.

Different sequences of pulses in various firing angle are given to the gate of thyristors. By varying the firing angle, the output voltage changes and that's why speed also changes because speed and voltage have proportionality. Speed control of induction motors is quite difficult because of its decreasing efficiency and lower power factor. Inductive nature of the load is reluctant to the change of current.

Shukla and Tripathi investigated the speed of induction motor by varying firing angle of thyristor in 2013[1]. Most of the work done by them through simulation. Firing angle of induction motor was varied by varying the potentiometer value which was connected with microcontroller. In 2012, a review journal paper was published based on the speed control technique of induction motor by variable frequency drive system [2]. In this journal, the techniques of speed control were shown like that Volts/Hertz control, how to adopt VFD method. The load characteristics like constant torque load, constant horse-power load, various types of inverter, cycloconverter and PWM method were also shown in this journal. In 2013,a journal was published on the topics of speed control method of induction motor by cycloconverter with thyristors in which it was described about the cycloconverter, its use and it was shown from the paper that, cycloconverter produced one frequency ac voltage from different frequency ac voltage[3]. Moreover, cycloconverter can handle loads of various power factor and allowed to flow power in various direction. Efficient sine wave output was produced in low frequencies. Another journal paper was published in 2014 by Suneeth and Usha on speed control of single phase induction motor using AC chopper by asymmetrical PWM method in which PWM method was used to switch on IGBT's. The goal of that research was to maintain the speed constant in different load conditions by using asymmetrical PWM method. It was used to reduce harmonics too[4].

In our research work, the speed control of single phase induction motor using anti parallel back to back connected thyristor are done via different techniques from other research works. The gate pulses that are fed by the microcontroller are programmed in a sequential manner. Gate pulses are generated carefully so that the firing sequences will be maintained. We investigated the controlling of speed of single phase induction motor with respect to varying firing angle. Moreover, relationship among firing angle, generated voltage and speed is shown.

2. METHODOLOGY

Methods for controlling the speed of induction motor are voltage/frequency control method, voltage control method, adding rheostat in the stator side of the motor, adding and changing the number of poles. Among the methods, voltage/frequency control method and voltage control method are frequently used for controlling speed. In this research work stator voltage control method are adopted.First of all, the synchronous speed is defined as

$$N_s = \frac{120 \times f}{P} \quad (1)$$

Where, $N_s$is the synchronous speed in r.p.m, P is the number of pole.
Now, the speed of induction motor becomes,

$$N_m = N_s(1-s) \quad (2)$$

Where s is theslip andN_m is the rotor speed in r.p.m. The torque produced in induction motor is

$$T = \frac{1}{2\times\pi\times N_s} \times \frac{s\times E_2^2 \times R_2}{R_2^2 + (sX_2)^2} \quad (3)$$

Where, $E_2$is the induced voltage in the rotor side in volt, R_2 is the rotorresistance in ohm, X_2 is the rotor leakage reactance in ohm and

$$\frac{1}{2\times\pi\times N_s} = \text{constant}$$

So, from the equation of torque above, it is observed that torque is related proportional to the rotor voltage. The speed which also has the proportional relation with the torque, that means its also proportional relation with voltage. So, speed will change with the change of induced voltage in the rotor. Another important criteria of the single phase motor is that from the definition of double field revolving theory, the alternating flux can be looked upon as composed of two revolving fluxes, each of half the value and revolving synchronously in opposite directions[5]. If the slip of the rotor with respect to forward rotating flux is $s_f$ands_b is the slip with respect to backward rotating flux then,

$$s_b = 2 - s_f \quad (4)$$

In this method, the speed are regulated by varying the firing angle of the thyristor pair.

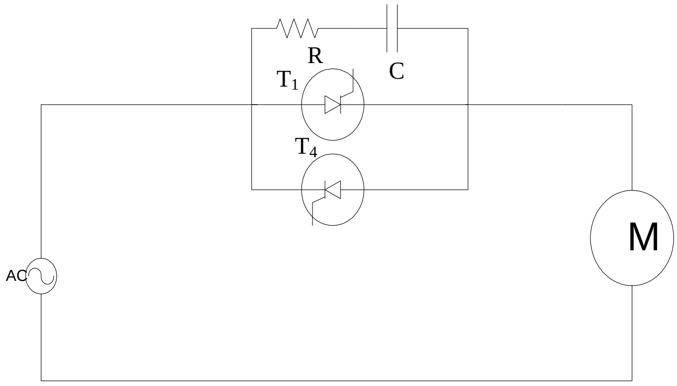

Fig.1: Schematic diagram for proposed method

The pulsatic waveforms for firing angle α=30° that are given in the gate of different thyristors are shown below:-

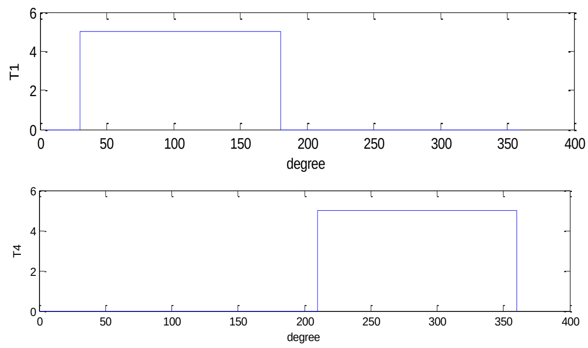

Fig.2: Gate pulse for T_1&T_4 in the range of α=30°

The pulsatic waveforms for firing angle α=60° that are given in the gate of different thyristors are shown below:-

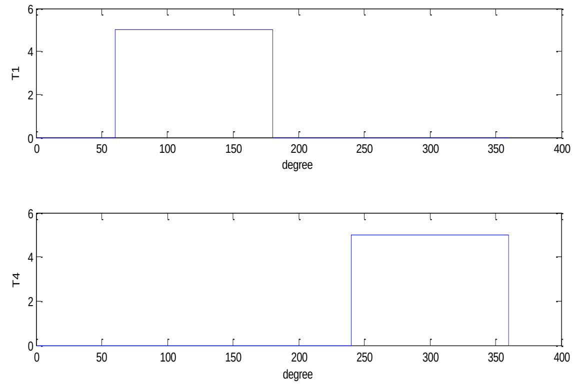

Fig.3: Gate pulse for T_1&T_4 in the range of α=60°

The pulsatic waveforms for firing angle α=90° that are given in the gate of different thyristors are shown below:-

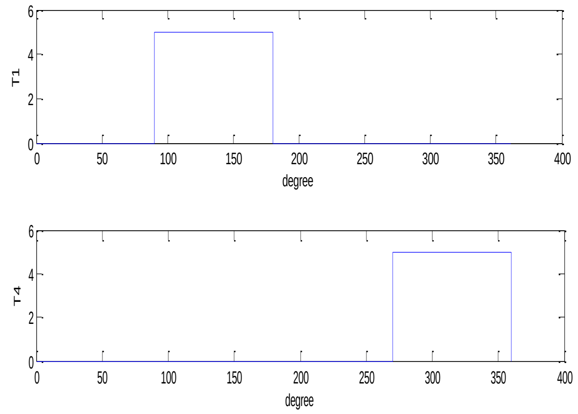

Fig. 4: Gate pulsefor T_1&T_4 in the range of α=90°

Gate pulses for remaining delay is generated in identical manner. As mentioned earlier, the sequence of gate pulses are shifting right direction with the increasing delay angle. Those gate pulses will chop the incoming line voltage and these chopped sinusoidal voltage will be provided to stator circuit of the subjected motor. Hence with an increasing delay angle a decreasing speed will be obtained.

3. Results and Analysis

For this research work a 220V, 200W, 4 pole single phase induction motor has been used to observe speed regulation using antiparallel back to back connected thyristors. The values of firing angle, speed and voltage has been taken. Different values of parameters are compared and power loss has been calculated individually for single phase induction motor. The comparison of firing angle, generated voltage andspeed are shown differently for single phase induction motor in table I:

TABLE I. Relation Among Various Firing Angle, Voltage And Speed

Firing angle, α (Degree)	Terminal Voltage, V_t(Volt)	Motor Speed, N_m (R.p.m)
30°	207.34	1411
60°	161.63	1102
90°	94.01	641
120°	45.17	400

It is observed from the relationship that with the increasing of firing angle generated voltage is decreased that causes the falling of the speed of single phase induction motor. Fig.4 shows that the voltage drop doesn't decrease linearly. The voltage has been dropped drastically with the increase of firing angle of the thyristor pair.

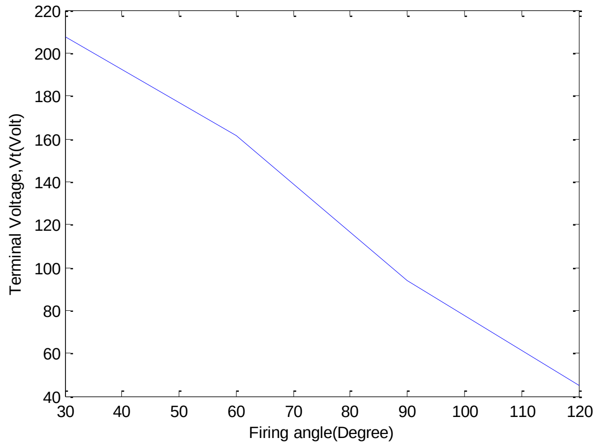

Fig. 5: Firing anglevs Terminal Voltage curve

In Fig.5voltage has been plotted with respect to firing angle and it's observed that for the range of 0°-30° of firing angle, voltage decreases almost linearly in a slower rate. Again for the variation of delay angle within 30°-120°, voltage changes rapidly than the prior. Fig.6 shows the relation between speed and firing angle.

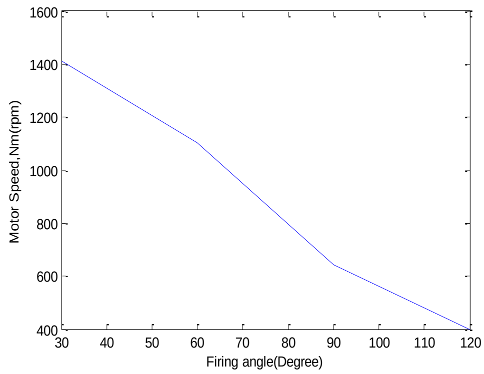

Fig. 6: Firing angle vs Motor Speed curve

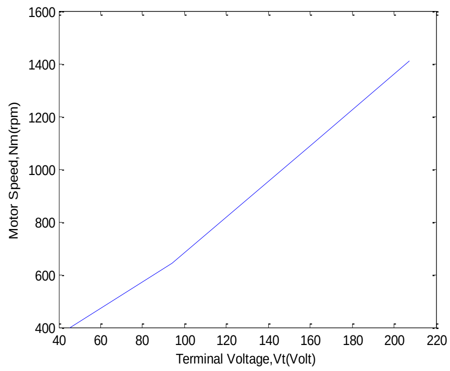

Fig.7: Terminal Voltage vs Motor Speed curve

TABLE II. CALCULATION OF POWER LOSS FOR DIFFERENT FIRING ANGLE

Evaluated Parameters	**For Firing angle α=30°**	**For Firing angle α=60°**	**For Firing angle α=90°**	**For Firing angle α=120°**
Stator current, I_{stator}(Ampere)	5.79	6.88	4.598	2.253
Forward Rotor current, I_{rf} (Ampere)	2.37	5.31	3.75	1.84
Backward Rotor current, I_{rf} (Ampere)	4.79	5.69	3.80	1.86
Input power, P_{in} (Watt)	391.02	471.95	145.90	32.16
Power Factor, cosθ	0.33	0.4243	0.34	0.32
Forward torque, T_f(N-m)	292.02	326.44	75.46	14.32
Backward torque, T_b (N-m)	36.4	57.43	31.11	8.4
Slip with respect to forward rotating flux, S_f	0.06	0.2653	0.573	0.73
Slip with respect to backward rotating flux, S_b	1.94	1.74	1.43	1.27
Output power, P_{out} (Watt)	240.63	197.63	18.95	4.91
Power loss (Watt)	150.39	274.32	126.95	27.25

From the graphical representation and table that are shown above it is seen that with increasing firing angle, the output voltage is decreasing. Speed which is dependent on the output voltage is also decreasing in the same manner shown in Fig. 7. In our research work 5steps are shown because after 120° firing angle the output voltage becomes zero for which no speed is found.

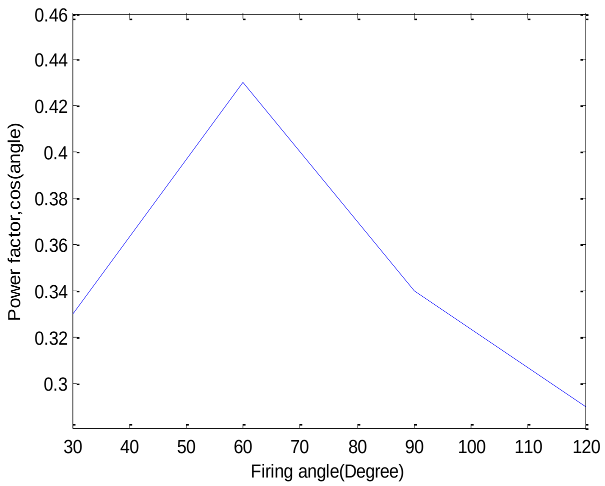

Fig. 8: Firing angle Vs Power Factor Curve

In the Fig. 8 the relationship between firing angle and power factor is demonstrated. Power factor increases to a certain level for increasing the firing angle and then begins to decrease as like as power loss.

Here from the equivalent diagram, it is observed that the rotor are split into two portions. One is the forward portion and the other is the backward.

The Forward impedance, $$Z_f = \frac{jx_m(\frac{r_2}{s} + jx_2)}{\frac{r_2}{s} + j(x_m + x_2)} \quad (5)$$

And the Backward impedance,

$$Z_b = \frac{jx_m(r_2/(2-s) + jx_2)}{\frac{r_2}{2-s} + j(x_m + x_2)} \quad (6)$$

$$I_1 = \frac{V}{Z_{total}} \ (7) \qquad V_f = I_1 Z_f \quad (8)$$

$$Z_{rf1} = \sqrt{(\frac{r_2}{s})^2 + x_2^2} \ (9)$$

$$Z_{rb1} = \sqrt{(r_2/(2-s))^2 + x_2^2}; \quad (10)$$

$$I_{rf1} = \frac{V_f}{Z_{rf1}}, \quad I_{rb1} = \frac{V_b}{Z_{rb1}} \tag{11}$$

From the calculation of single phase induction motor speed control, it is found that by increasing the firing angle of the thyristors speed, voltage and the most importantly its efficiency is decreasing.

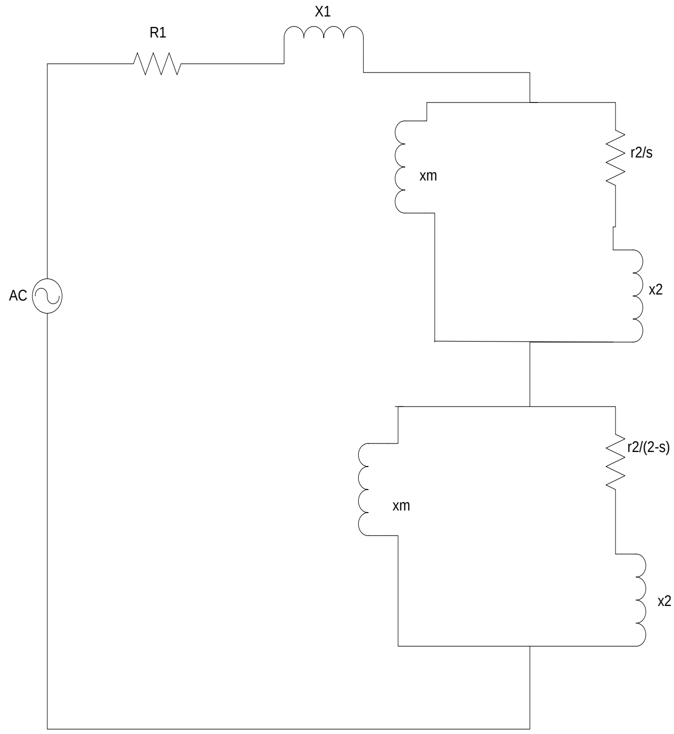

Fig. 9: Equivalent diagram of single phase induction motor

4. CONCLUSION

Controlling the speed of induction motor by using thyristor has one of the great advantages that it is a very precise process for controlling speed because thyristors are very fast switching and available power electronic device. It's seen that speed or voltage will be decreased if delay angle is made higher than the prior. The speed will be changed as soon as the firing angle is changed. It is a fantastic method for low power induction motor for controlling speed. It fits meticulously where steeper drop of speed is required.

5. ACKNOWLEDGMENT

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