Speed Control of Single Phase Induction Motor Using TRIAC & Reversal of Direction

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Abstract— This paper presents a technique to control the speed of single phase induction motor by using TRIAC and reversal of direction of motor. A single phase induction motor except that its stator is provided with a single phase winding. The rotor of any single phase induction motor is interchangeable with that of a poly phase induction motor. A single phase winding produce no rotating magnetic field and no starting torque. The speed of Induction motor can be varied in a narrow range by varying the voltage applied to the stator winding. This method is suitable for such application where the load varies approximately as square of speed, such as centrifugal pumps drives, fan load, refrigerator, blower etc.

Keyword-TRIAC, DIAC, Potentiometer, Single phase Induction Motor, Firing angle, DPDT switch.

I. INTRODUCTION

The characteristics of a single phase induction motor are identical to three phase induction motor except that single phase induction motor has no inherent starting torque and some special arrangement have to be made for making itself starting. Though single phase induction motor is not self-starting, we are using it because the three phase supply is not present at everywhere.

When pulse to gate are delayed then reduced voltage is applied to the induction motor stator terminals and thus as voltage and torque are proportional to each other torque decreases and simultaneously speed of the motor gets reduced[6]. The control circuitry consists of the following:

1. Triggering circuit.
2. TRIAC circuit.
3. Power supply circuit.
4. Direction reversal circuit.

The power supply circuit will provide AC supply 230 Volt, 50 Hz to the electronic devices which require the biasing voltage. The triggering circuit will generate the pulse and are given to TRIAC as gate pulses for triggering purpose and finally TRIAC circuit acts as Intermediate part between supply and induction motor. Therefore apply voltage from the supply to induction motor and thereby speeds are controlled. The direction reversal circuit uses DPDT switch for reverse the connection between the Capacitor terminals to the induction motor main terminal.

The terminal voltage across the stator winding of the motor can be varied for obtaining the desired speed control by controlling the firing angle of the semiconductor power devices (TRIAC in our project).

For any firing angle 'α' the average output voltage across a TRIAC is given by:

$$V= (2V' \cos\alpha/\pi) ;$$

V' is the maximum voltage provided.

II. POWER ELECTRONIC DEVICES

A. TRIAC

A TRIAC can conduct in both directions and is normally used in AC phase control. It can be considered as two SCRs connected in antiparallel with a common gate connection as shown in Figure 1[3]. Because a TRIAC is a bidirectional device, its terminals cannot be designated as anode and cathode. If terminal MT_2 is positive with respect to terminal MT_1, the TRIAC can be turn on by applying a positive gate signal between gate G and terminal MT_1. If terminal MT_2 is negative with respect to terminal MT_1, it is turned on by applying a negative gate signal between gate G and terminal MT_1. It is not necessary to have both polarities of gate signals, and the TRIAC can be turned on with either a positive or a negative gate signal[2]. In practice, the sensitivities vary from one quadrant to another, and the TRIACs are normally operated in quadrant I^+ (positive gate voltage and gate current) or quadrant III^- (negative gate voltage and gate current).

Characteristics of TRIAC

The TRIAC has on and off state characteristics similar to SCR but now the characteristic is applicable to both positive and negative voltages. This is expected because TRIAC consists of two SCRs connected ib parallel but opposite in directions. The gate triggering may occur in any of the following four modes (Fig. 2):[2]

Quadrant I operation: V_{MT21}positive; V_{G1} positive
Quadrant II operation: V_{MT21} positive; V_{G1} negative
Quadrant III operation: V_{MT21} negative; V_{G1} negative
Quadrant IV operation: V_{MT21} negative; V_{G1} positive

Where V_{MT21} and V_{G1} are the voltages of terminal MT_2 and gate with respect to terminal MT_1.

The gate is the control terminal of the device, by applying proper signal to the gate the firing angle of the device can be controlled. The gate triggering circuit usually generates trigger pulses for firing the device. The trigger pulse should be of sufficient magnitude and duration so that firing of the device is assured. Usually the duration of 35μs is sufficient for sustaining the firing of the device[5].

A typical TRIAC (BT136) has following features[8]:

1. Gate Turn-On voltage (V_{gt}): 1.5 V
2. Peak Off-State voltage (V_{drm}): 500 V
3. On State current (I_t): 4.0 A
4. Gate current (Igt): 25 mA
5. Typical voltage change over time (dV/dT):250V/μs

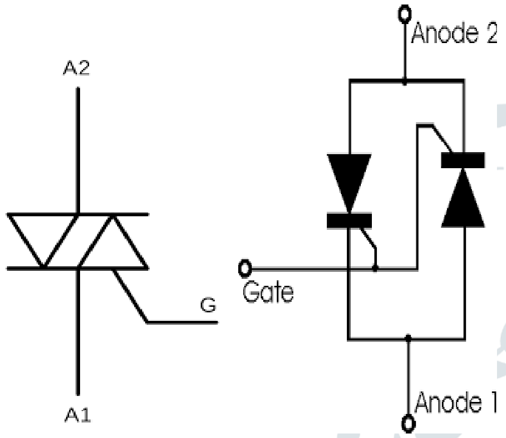


Fig 1: TRIAC equivalent circuit and Symbol

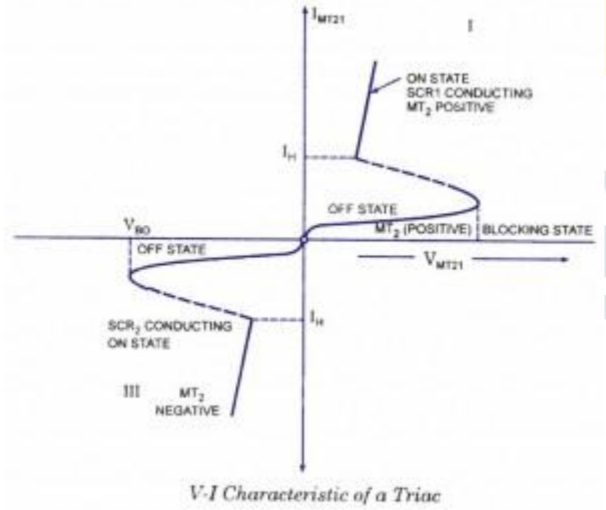


Fig 2: Characteristics of TRIAC

B. DIAC (DB2)

The DIAC is a diode that conduct electrical energy only after its break over voltage, V_{BO}, has been reached momentarily. The term is an acronym of diode for alternating current.

When breakdown occurs, the diode enters a region of negative dynamic resistance, leading to a decrement in the voltage drop in the diode, usually a sharp increase in current through the diode. The diode remains in conduction until the current through it drops below a value characteristic for the device, called the holding current I_H. Below this value, the diode switches back to high resistance, non-conducting state. This behavior is bidirectional meaning typically the same for both directions of current. Most DIACs have a three layer structure with breakover voltage of approximately 30V. Their behavior is similar to that of a neon lamp, but it can be more precisely controlled and takes place at a lower voltage[3]. DIACs have no gate electrode, unlike some other thyristors that they are commonly used to trigger, such as TRIACs, like quardrac, contain a built in series with the TRIAC's Gate terminal for this purpose.

DIACs are also called symmetrical trigger diodes due to the symmetry of their characteristic curve, because DIACs are bidirectional devices, their terminals are not labeled as anode and cathode but as A1 and A2 or main terminal M_{T1} and M_{T2}[2].

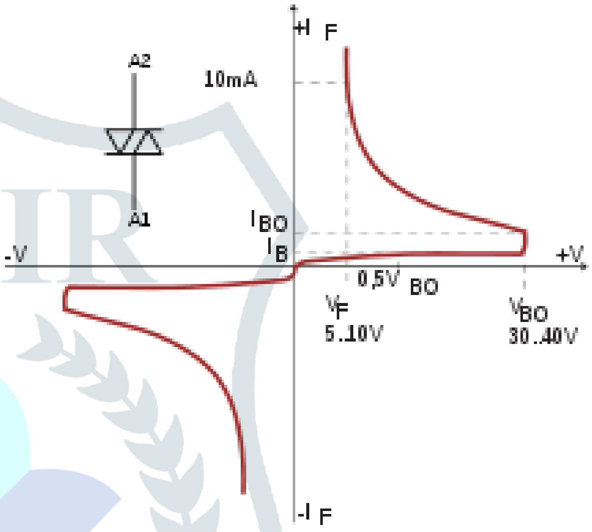


Fig 3: Characteristics of DIAC

III. INDUCTION MOTOR

An induction or asynchronous motor is a type of AC motor where power is supplied to the rotor by means of electromagnetic induction, rather than a commutator or slip ring as in other types of motor. Single phase versions are used in small appliances. There speed is determine by the frequency of supply current, so they are most widely used in constant speed applications, although variable speed versions, using variable frequency drives are becoming more common. The most common type is the squirrel cage motor, and this term is sometimes used for induction motors generally.

In both induction and synchronous motors, the stator is powered the alternating current (poly phase current in large machines) and design to create a rotating magnetic field which rotates in time with the AC oscillations[1]. In a induction motor the rotor rotates at a slower speed than the stator field. Therefore the magnetic field through the rotor is changing (rotating). The rotor has winding in the form of close loop of wire[7]. The rotating magnetic flux induces current in the winding of the rotor as in a transformer. These current in turn create magnetic fields in the rotor, that interact with (push against) the magnetic field created will be such as to oppose the change in current through the winding. The cause of induced current in the rotor is the rotating stator magnetic field, so to oppose this the rotor will start to rotate in the direction of the rotating stator magnetic field to make relative speed between rotor and rotating stator magnetic field zero[1].

For these currents to be induced, the speed of physical rotor must be lower than that of the stator's rotating magnetic field (n_s), or the magnetic field would not be moving relative to the rotor conductors and no current would be induced. As the speed of the rotor drops below synchronous speed, the rotation rate of magnetic field in the rotor increases, inducing more current in the windings and creating more torque. The ratio between the rotation rate of magnetic field as seen by the rotor (slip speed) and the rotation rate of stator's rotating field is called *"slip"*. Under load, the speed drops and the slip increases enough to create sufficient torque to turn the load. For this reason, induction motors are sometimes referred to as asynchronous motor. An induction motor can be used as induction generator, or it can be unrolled to form the linear induction motor which can directly generate linear motion. Generally, induction motors are categorized based on the number of stator windings. They are:

1. Single-phase induction motor
2. Three-phase induction motor

There are probably more single-phase AC induction motors in use today than the total of all other types put together. It is logical that the least expensive, lowest maintenance type motor should be used more often. The single-phase AC induction motor bests fit this description. As the name suggests, this type of motor has only one stator winding (main winding) and operates with a single-phase power supply. In all single-phase induction motors, the rotor is the squirrel cage type.

Three-phase AC induction motors are widely used in industrial and commercial users. These motors are self starting and do not require other starting devices. The power capabilities and efficiency is higher as compared to single-phase motors. Popular applications include lathes, pumps, compressors, farm equipments and other mechanical duty applications.

IV. DPDT SWITCH

It is known as "Double Pole Double Throw toggle switch". It works just like two separate SPDT switches attached to the same switch. DPDT switch has total six pins in which middle's two pin is used for output. Top (or bottom) two pin is used for input. By using this switch we can change the polarity of applied input voltage. It has two states ON-ON and can be used in multiple output situations[9]. Inside this switch the pin-1 connected to pin-6 and pin-2 connected to pin-5. Pin-3 and pin-4 are used for external component connection and we can connect only one load in six pin DPDT switch.

DPDT switch are commonly used for the purpose to move the device like motor, robot in forward, reverse, right and left direction.\

Fig 4: DPDT switch

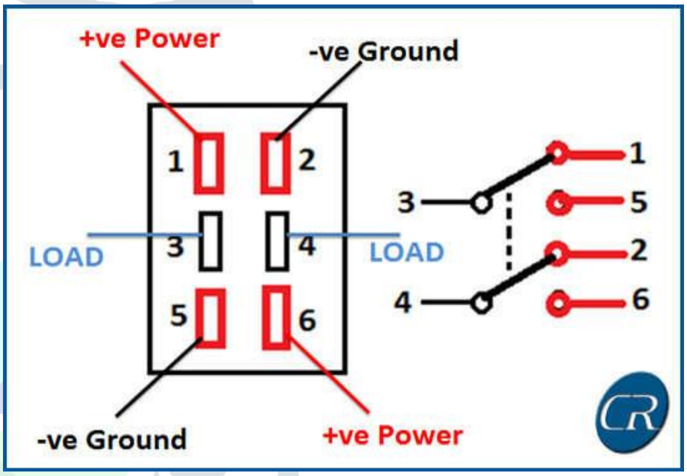
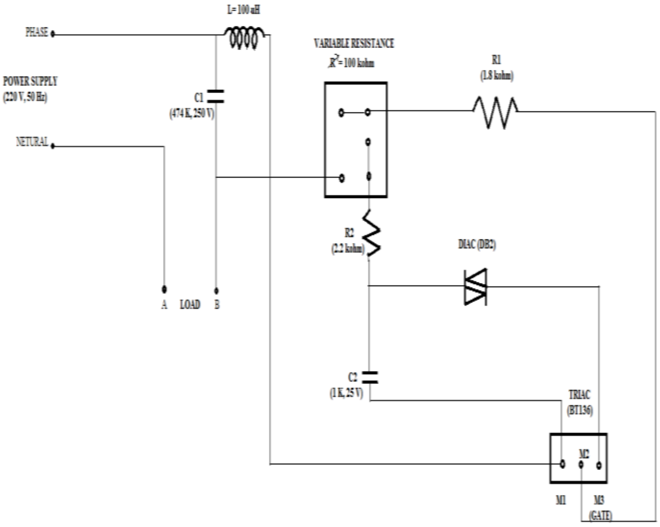


Fig 5: DPDT switch schematic connection symbol

V. CIRCUIT DIAGRAM



VI. HARDWAREMODEL

We have used induction motor as an exhaust fan, DPDT switch, TRIAC, DIAC etc in our project. The live model of connection of our project is shown below:

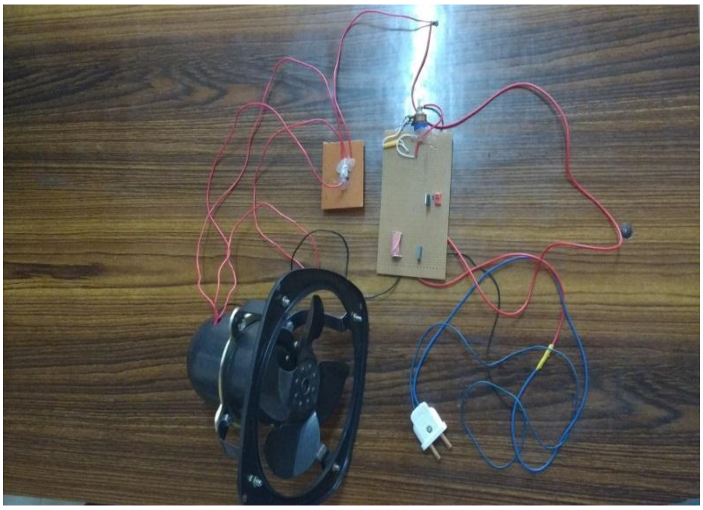


Fig 6: Hardware model of our project

VII. MATHAMATICAL ANALYSIS

Table 7.1: Analysis of variation in output voltage and firing angle correspond to fixed input supply:

S.No	Input voltage (V)	Output voltage (V)	Firing angle (α) in deg.
1.	220	216	34.37
2.	220	200.9	75.55
3.	220	180.7	109.26
4.	220	163.2	132.30
5.	220	145.7	152.66
6.	220	135.1	163.72
7.	220	116.2	175.65
8.	220	110.7	187.83
9.	220	88.6	208.13

Table 7.2: Analysis of single-phase induction motor speed corresponding to different firing angle:

S.No	Firing angle (α) in deg.	Speed (RPM)
1.	34.37	2636
2.	75.55	2622
3.	109.26	2556
4.	132.30	2428
5.	152.66	2258
6.	163.72	2086
7.	175.65	1832
8.	187.83	1252
9.	208.13	816

VIII. RESULT

The voltage vs time graphof TRIAC obtained from the analysis is shown below. Here on x-axis 'time' and on y-axis 'voltage'.

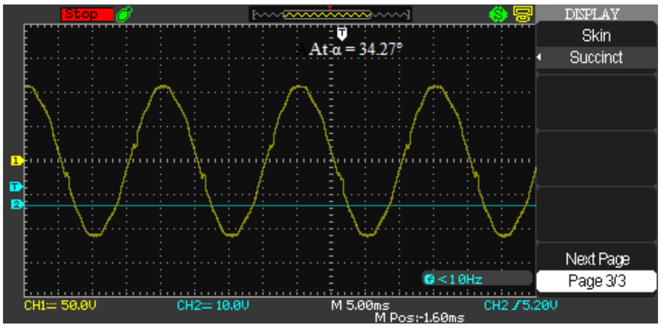


Fig 7: (Graph between Voltage and Time at α=34.27°)

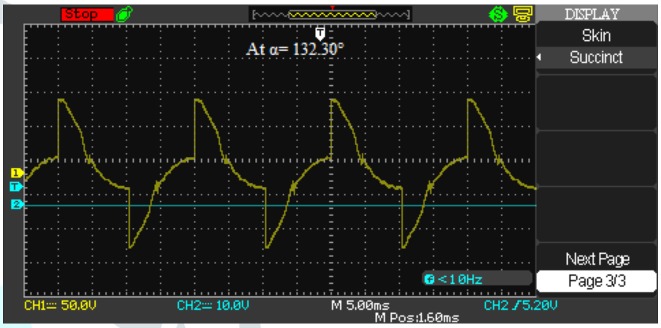


Fig 8: (Graph between Voltage and Time at α=132.30°)

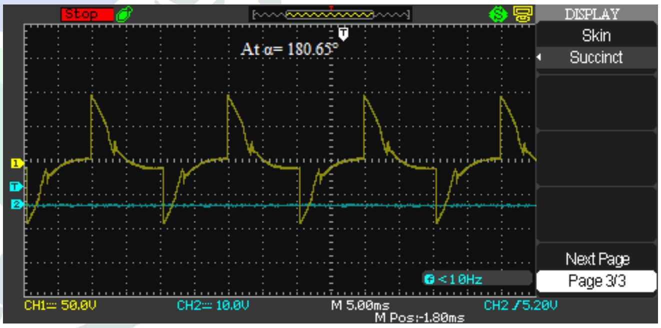


Fig 9: (Graph between Voltage and Time at α=180.65°)

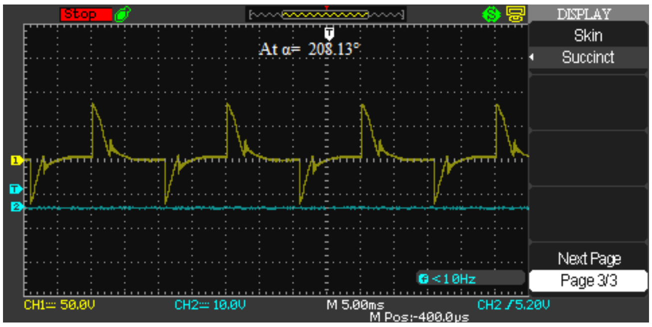


Fig 10: (Graph between Voltage and Time at α=208.13°)

From the above observation and analysis the following result is obtained. As we can see in the Fig 7 the speed of the motor is maximum at minimum firing angle (α). As we increase the firing angle (α) the speed of the single-phase induction motor decreases as seen in Fig. 8, 9 and 10. When the firing angle (α) reaches its peak value the speed of single-phase induction motor is controlled. Hence Fig. 11 shows, as firing angle is increasing, speed of the induction motor is decreasing.

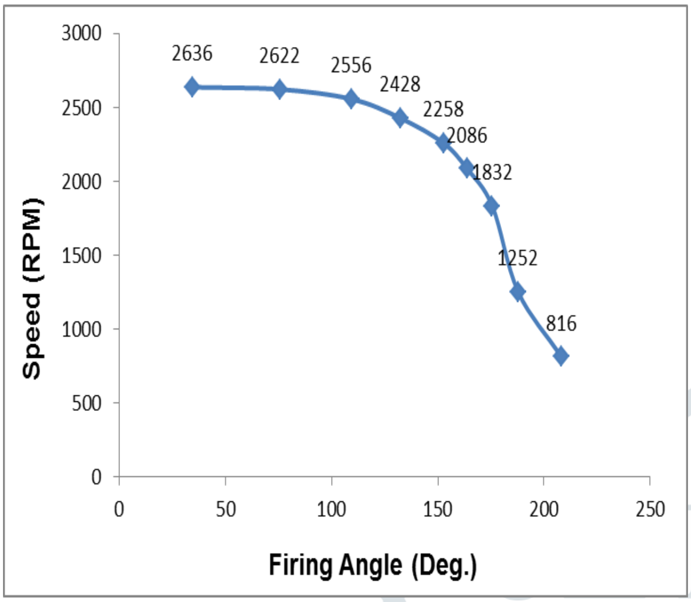


Fig. 11: Graph between Speed vs firing angle

IX. CONCLUSION

In this paper we proposed a new method to control the speed of single–phase induction motor in both directions by the use of a semiconductor device TRIAC and reversed its direction by the use of DPDT switch. This method is the effective and efficient method to control the speed of single-phase induction motor in today's world.

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