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RESEARCH ARTICLE

DESING & MODELING OF SCR BASED CONTROLLER FOR SPEED CONTROL OF SINGLE PHASE INDUCTION MOTOR

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ABSTRACT

This concept of restriction on the power supplied to a device is known as AC power control. AC power control allows us to efficiently use the available power for various applications. There are two types of AC power control: ON-OFF control or pulse skipping modulation control and phase angle control. In on-off control, the load is connected to the AC supply for short interval of time and the AC supply is switched off for some interval. A fast switching device like a thyristor is used to connect and disconnect the load to the AC power supply. In phase method, the load is connected to the AC supply for a specific period of both the half cycles. Firing angle control based AC power control is designed here which is a type of phase angle control. The circuit regulates the AC power supplied to any load like an electric bulb, motor, amplifier etc.

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INTRODUCTION

Induction motor has replaced DC drives in many applications due to its rugged construction, cost effectiveness. Its application varies from domestic such as washing machine, pumps, refrigerators, etc. To industrial applications such as industrial robots, electric vehicles, and elevators and so on. To obtain energy efficiency instead of running machine at a constant speed, speed control method is used. The conventional speed control methods suffer from various disadvantages like mechanical wear and tear, frequent maintenance requirement, less efficient and bulky. Therefore the use of power electronic devices and controllers play a vital role. It improving the above factors and also help them in soft starting. To achieve this simple and compact power electronic controller circuit called AC voltage controller is connected between the input ac supply and the load (single phase induction motor). Ac voltage controllers are semiconductor based circuits which convert fixed alternating voltage to variable alternating voltage without the change in frequency (IJIREEICE).

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Some of the main applications for ac voltage controllers are for domestic and industrial heating, Transformer tap changing, lightening control, speed control of single phase and three phase ac motor drives. Earlier, the devices used for these applications were auto transformer, magnetic amplifiers, saturable reactors etc. But these devices are now replaced by thyristors and Triac based ac voltage regulators because of their high efficiency, flexibility in control, compact size and less control (Oluwasogo, 2014) Since the ac voltage controllers are phase-controlled devices, thyristors and Triac are line commutated and as such no complex commutation circuitry is required in these controllers. The purpose of an AC voltage controller, or AC regulator, is to vary the RMS voltage across the load at a constant frequency. For regulating the power flow in ac voltage controllers, control strategies are of two types:

- Phase control
- On-and-off control

SINGLE PHASE INDUCTION MOTOR:

Induction motor is variable speed electromagnetic device which convert the A.C. input to mechanical output. It works on the principle of faraday's electromagnetic induction. Single phase power system is widely used as compares to three phase system for domestic purpose, commercial purpose and to some extent in industrial purpose. As the single phase system is more economical and the power requirement in most of the houses, shops, offices are small, which can be easily met by single phase system. The single phase motors are simple in construction, cheap in cost, reliable and easy to repair and maintain (IJIREEICE).

CONSTRUCTION OF SINGLE PHASE INDUCTION MOTOR

Like any other electrical motor induction motor also have two main parts namely rotor and stator.

STATOR OF SINGLE PHASE INDUCTION MOTOR

The stator of single phase induction motor has laminated stamping to reduce eddy current losses on its periphery. The slots are provided on its stamping to carry stator or main winding. In order to reduce the hysteresis losses, stamping are made up of silicon steel (Oluwasogo, 2014) When the stator winding is given a single phase AC supply, the magnetic field is produced and the motor rotates at a speed slightly less than the synchronous speed Ns which is given by

$$N_S = 120\ f\ /P$$

Where, f = supply voltage frequency, P = no. Of poles of the motor. The construction of the sator of asychronous motor is similar to that of three phase induction motor except there are two dissimilarity in the winding part of the single phase induction motor. Firstly the single phase induction motor are mostly provided with concentric coils. As the number of turns per coil can be easily adjusted with the help of concentric coils, the mmf distribution is almost sinusoidal. Except for shaded pole motor, the asychronous motor has two stator windings namely the main winding and the auxiliary winding. These two windings are placed in space quadrature with respect to each other.

ROTOR OF SINGLE PHASE INDUCTION MOTOR

The construction of the rotor of the single phase induction motor is similar to the squirrel cage three phase induction motor. The rotor is cylindrical in shape and has slots all over its periphery. The slots are not made parallel to each other but are bit skewed as the skewing prevents magnetic locking of stator and the rotor teeth and makes the working of induction motor more smooth and quieter i.e less noise. The squirrel cage rotor consist of aluminum, brass or copper bars. These aluminum or copper bars are called rotor conductors and are placed in the slots on the periphery of the rotor (IJIREEICE) Thr rotor conductors are permanently shorted by the copper or aluminum rings calles the end rings. In order to provide mechanical strength these rotor conductors are braced to the end ring and hence form a complete closed circuit resembing like a cage and hence got its name as squirrel cage induction motor (Oluwasogo, 2014) As the bars are permanently shorted by the end rings, the rotor electrical resistance is very small and it is not possible to exernal resistance as the bars are permanently shorted. The abscence of slip ring and brushes make the construction of single phase induction motor very simple and robust.

WORKING

When single phase AC supply is given to the stator winding of single phase induction motor, the alternating current starts flowing through the stator or main winding. This alternating current produces an alternating flux called main flux. This main flux also links with the rotor conductors and hence cut the rotor conductors. According to the faraday's law of electromagnetic induction, emf gets induced in the rotor. As the rotor circuit is closed one so, the current starts flowing in the rotor. This current is called the rotor current. This rotor current produces its own flux called rotor flux. Now there are two fluxes one is main flux and another is called rotor flux. These two fluxes produce the desired torque which is required by the motor to rotate.

CAPACITOR START CAPACITOR RUN INDUCTION MOTOR

The working principle and construction of Capacitor start inductor motors and capacitor start capacitor run induction motors are almost the same. We already know that single phase induction motor is not self starting because the magnetic field produced is not rotating type. In order to produce rotating magnetic field there must be some phase difference. In case of split phase induction motor we use resistance for creating phase difference but here we use capacitor for this purpose. We are familiar with this fact that the current flowing through the capacitor leads the voltage. So, in capacitor start inductor motor and capacitor start capacitor run induction motor we are using two winding, the main winding and the starting winding. With starting winding we connect a capacitor so the current flowing in the capacitor i.e I_{st} leads the applied voltage by some angle, φ_{st}. The running winding is inductive in nature so, the current flowing in running winding lags behind applied voltage by an angle, φ_m. Now there occur large phase angle differences between these two currents which produce an resultant current, I and this will produce a rotating magnetic field. Since the torque produced by these motors depends upon the phase angle difference, which is almost 90°. So, these motors produce very high starting torque. In case of capacitor start induction motor, the centrifugal switch is provided so as to disconnect the starting winding when the motor attains a speed up to 75 to 80% of the synchronous speed but in case of capacitor start capacitors run induction motor there is no centrifugal switch so, the capacitor remains in the circuit and helps to improve the power factor and the running conditions of single phase induction motor.

METHODOLOGY

CIRCUIT DIAGRAM:

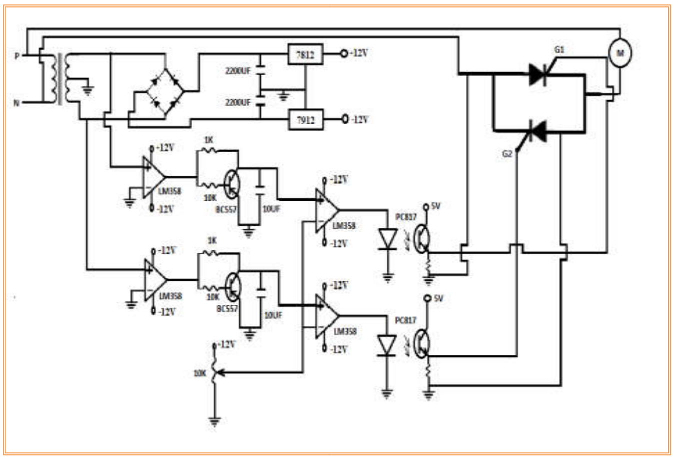

Fig. No. 1 Circuit diagram

BLOCK DIAGRAM

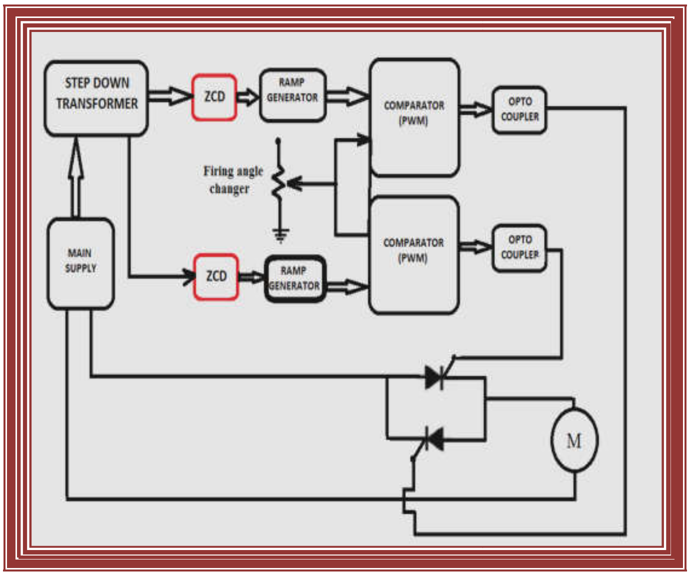

Fig. No. 2 block diagram

The device is aimed at substituting commonly used TRIAC phase angle control drives. This circuit is capable of supplying single-phase AC. Induction motor (or general AC inductive / resistive load) with varying AC voltage. The same as in the TRIAC control, the voltage applied to the load can be varied from zero to maximum value. The circuit is aimed at low cost, low/medium-power applications; it does not use a conventional converter topology to produce output voltage waveform. It directly modulates the mains AC voltage. (Sharad Chandra Rajpoot *et al*., 2014) Compared to costly converter, it requires lower number of active and passive power components.

COMPONENT CONTENT

SUPPLY UNIT

TRANSFORMER

A transformer is a static device which transfers the electrical energy between two or more circuits through electromagnetic induction. A varying current in one coil of the transformer produces a varying magnetic field, which in turn induces a voltage in a second coil. Power can be transferred between the two coils through the magnetic field, without a metallic connection between the two circuits (Sharad Chandra Rajpoot, 2014).

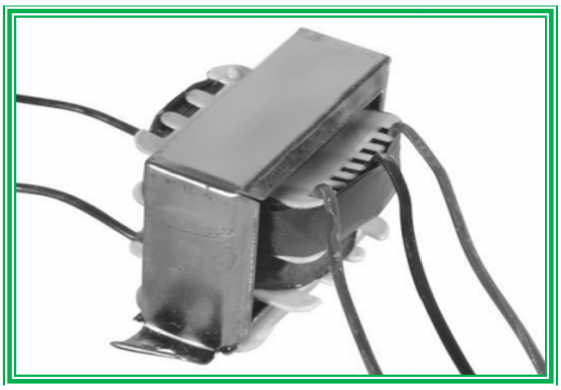

Fig. No. 3 transformer

Transformer specifications

Step down Transformer	Input Voltage	Output Voltage	Output Current
Centre tap	230V	12-0-12V	1MA
Centre tap	230V	12-0-12V	1MA
Normal	230V	12V	1MA
Normal	230V	12V	1MA

Table no. 1 transformer specifications

FULL WAVE BRIDGE RECTIFIER

This type of single phase rectifier uses four individual rectifying diodes connected in a closed loop “bridge” configuration to produce the desired output. The main advantage of this bridge circuit is that it does not require a special centre tapped transformer, thereby reducing its size and cost. The single secondary winding is connected to one side of the diode bridge network and the load to the other side as shown in fig. no. 4 The four diodes labelled D1, D2, D3, D4 are arranged in series pairs with only two diodes conducting current during each half cycle. During the positive half cycle of the supply, diodes D1 and D2 conduct in series while diodes D3 and D4 are reverse biased and the current flows through the load. During the negative half cycle of the supply, diodes D3 and D4 conduct in series while diodes D1 and D2 are reversed biased and the current flows through the load (Sharad Chandra Rajpoot, 2014)

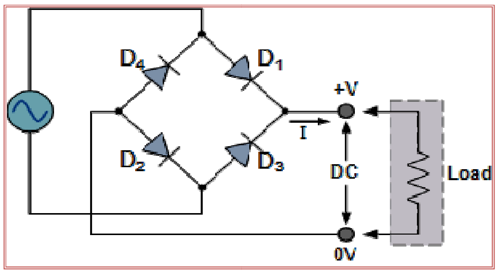

Fig. No. 4 Bridge rectifier

THE SMOOTHING CAPACITOR

The full wave bridge rectifier give us a greater mean DC value with less superimposed ripple while the output wave form is twice that of the frequency of the input supply frequency. We can therefore increase its average DC output level even higher by connecting a suitable smoothing capacitor across the output of the bridge circuit as shown fig. no. 5

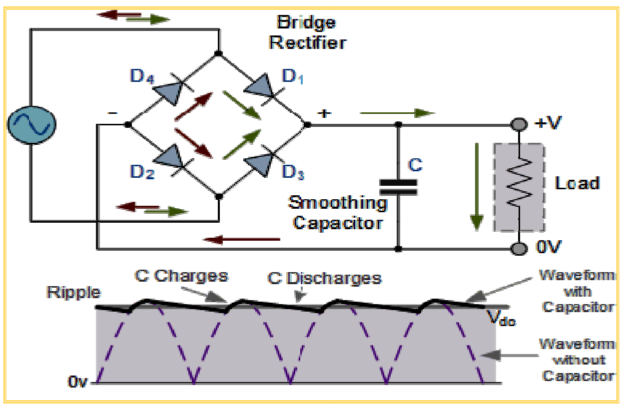

Fig No. 5 Full wave bridge rectifier with smoothing capacitor

SPECIFICATION BRIDGE RECTIFIER

- Forward voltage (V_F) =1.1V.
- Maximum full load reverse current=30μA.
- Reverse current at rated V_R=5μA.
- Total capacitance=15pF.

VOLAGE REGULATOR:

A voltage regulator is designed to automatically maintain a constant voltage level. A voltage regulator may be a simple feed forward design or may include negative feedback control loops.

It may use an electromechanically mechanism or electronic components. Depending on the design, it may use to regulate one or more AC or DC voltages. Here we use two voltage regulators 7812 for positive dc voltage (fig. no.6) & 7912 for negative dc voltage.

Fig. No.6 voltage regulator

CONTROL UNIT

THYRISTOR

A thyristor is normally four layer three-terminal device. Four layers are formed by alternating n-type semiconductor and p-type semiconductor materials. Consequently there are three p-n junction formed in the device. It is a bistable device. The three terminals of this device are called anode (A), cathode (K), and gate (G) respectively as shown in fig. No.7. The gate (G) terminal is control terminal of the device. That means, the current flowing through the device is controlled by electrical signal applied to the gate terminal. The anode and cathode are the power terminals of the device handle the large applied voltage and conduct the major current through the thyristor (Jamal, 2014)

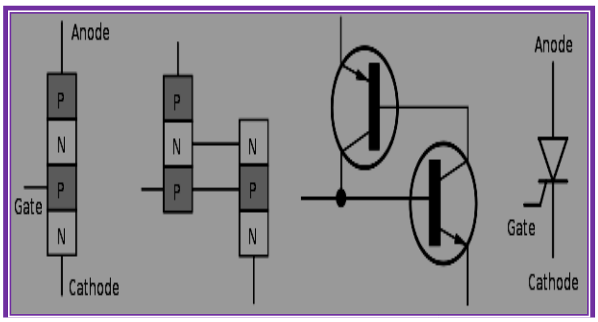

Fig. No. 7 symbol & circuit diagram

TRANSISTOR specifications

- collector-emitter voltage = 4V
- collector-base voltage = 50v
- base current peak = 200mA
- emitter current peak = 200mA

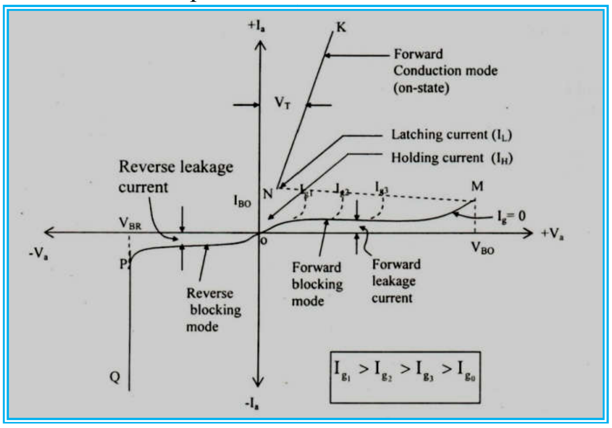

Fig. No. 8 thyristor chharactristics

FORWARD BLOCKING MODE

Now considering the anode is positive with respect to cathode, with gate kept in open condition. The thyristor is now said to be forward biased as shown

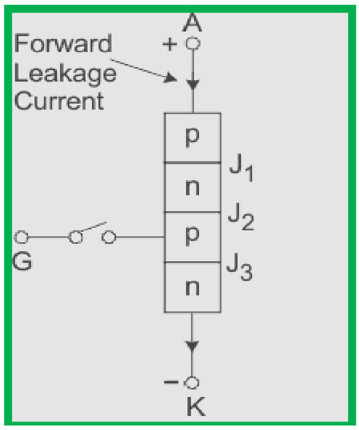

Fig. No. 9 Forward blocking mode of thyristor

As we see the junctions J1 & J3 are now forward biased but junction J2 goes into reverse biased condition. In this particular mode, a small current, called foreward leakage current is allowed to flow initially as shown in the diagram for characeristic of thyristor shown in fig. no. 9.

Forward conduction mode

When the anode to cathode forward voltage is increased, with gate circuit open, the reverse junction J2 will have an avalanche breakdown at forward breakover voltage Vbo leading to thyristor turn on. Once the thyristor is turned on we can see from the diagram for characteristics of thyristor, that the point M at once shifts towards N and then anyywhere between N and K. Here NK represents the forward conduction mode of the thyristor shown in fig. no.8. In this mode of operation, the thyristor conducts maximum current with minimum voltage drop, this is known as the forward conduction or the turn on mode of thyristor.

LM-358 OPERATIONAL AMPLIFIER

An operational amplifier or OP-AMP is a DC-coupled voltage amplifier with a vey high voltage gain. Op-amp is basically a multistage amplifier in which a number of amplifier stages are connected to each other in a very complicated manner. Its internal circuit consist of many transistors, FETs and resistors. All this occupies a very little space. So, it is picked in a small package and is available in the integrated circuit (IC) form. The term op-amp is used to denote an amplifier which can be configured to perform various operations like amplification, subtraction, differentation, addition, integration etc.

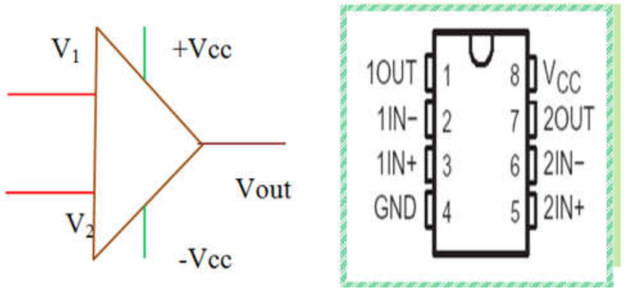

Fig. no.10 operational amplifier Pin configuration circuit diagram (LM-358)

OPERATIONAL AMPLIFIER (LM358)

- supply voltage(v^+) = 32V maximum
- differential input voltage = 32V maximum
- input voltage : Minimum = -0.3v

Maximum = 32v

An op-amp has two input terminals and one output terminal. The op-amp also has two input voltage supply terminal as shown above. It has a differential input and a single output. The terminal marked as negative (-) is called as an inverting terminal and the terminal marked as positive (+) is called as a non inverting terminal of the operational amplifier. If we connect an input signal at the inverting terminal of the op-amp than the amplified output signal is 180 degree out of phase with respect to the applied input signal, wheres if an input is conneced to the non-inverting terminal than the output signal obtained will be in phase i.e it will have no phase shift with respect to the input signal.

Also as seen from the circuit symbol above it has two input power supply terminals +Vcc and –Vcc. For the operation of an op-amp a dual polarity DC supply is essential. In the dual polarity supply the =Vcc is connected to the poitive supply of one power source or battery and the –Vcc terminal is connected to the negative supply of anothe source. However few op-amps can also operate on a single polarity supply. There is no common ground terminal in th op-amp hence the ground has to be established externally. The op-amp offers all the advantages of IC's such as high reliability, small size, cheap, less power consumption.

OPTOCOUPLER

An Opto-coupler (also known as optical isolator) is a semiconductor device that uses a short optical transmission path to transfer an electrical signal between circuits or elements of a circuit, while keeping them electrically isolated from each other. These components are used in a wide variety of communications, control and monitoring system that use light to prevent electrical high voltage from affecting a lower power system receiving a signal. In its simplest form, an opto-coupler consist of a light-emitting diode (LED), infrared light emitting diode (IRED) or laser diode for signal transmission and a photosensor (phototransistor) for signal reception. Using an optocoupler, when an electrical current is applied to the LED, infrared light is produced and passes through the material inside the optoisolator. The beam travels across a transparent gap and is picked up by the receive, which converts the modulated light or IR back into an electrical signal. In the abscence of light, the input and output circuits are electrically isolated to each other. Electronic equipment, as well as signal and power transmission line, are subjected to voltage surges from radio frequency transmission, lightening strikes and spikes in the power supply. To avoid disruption, opto-isolaters offer a safe interface between high-voltage components and low-voltage devices.

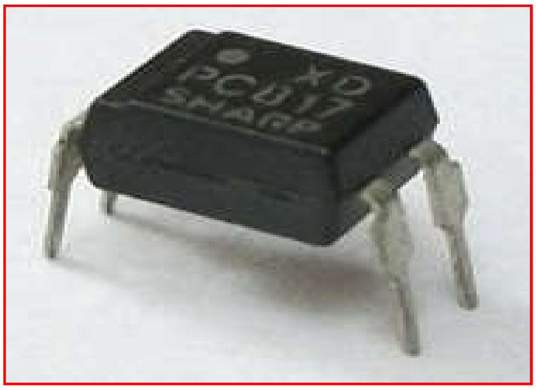

Fig.No.11 Opto-coupler

WORKING OF HARDWARE MODEL

WORKING

The single phase ac power supply of 230V, 50Hz is step down by means of a centre tap transformer to get the two polarities which are 180 degree out of phase from each other. This two step down voltage of 12V is applied to a full wave bridge rectifier which converts the AC voltage into pulsating DC voltage. This pulsating voltage is passed through the capacitor to remove filter it. The two voltage regulator (7812 & 7912) is used to get two voltage polarities of +12V & -12V. These two voltages are given to the supply terminal of op-amp. One another centre tap transformer is used to get two polarities of voltage which are 180 degree out of phase. The one polarity is given to the non-inverting terminal of one operational amplifier and another polarity is given to the non-inverting terminal of second amplifier. Since the feedback of both the op-amp is infinity, the voltage produced by it is in the form of rectangular pulses. These pulses are given to the PNP transistor and capacitor.

The collector emitter terminal of the PNP transistor is grounded. The transistor act as a switch and the PNP transistor works only when the collector voltage is less than the emitter voltage. Hence during the positive half cycle of the rectangular pulse, the PNP transistor act as a open switch and the charging of capacitor take place & during the negative half cycle of rectangular pulse the transistor act as a short circuit and the current is grounded through emitter, and discharging of capacitor take place and the capacitor generates the saw tooth signal. The two generated saw tooth signal is fed to the non-inverting terminals of two op-amps; the inverting terminals of these two op-amps are connected to the regulator. The saw tooth signal is compared with the dc voltage of 12V and the degree out of phase with each other.

This two PWM signal is given to the two opto-isolator which is used to isolate the main working circuit from the AC voltage. The opto-isolaters work on a dc voltage of 5V. Therefore we use two more step down transformer for these two opto-isolaters. The output of the opto-isolaters is given to the gate terminal of the SCRs. The two SCRs are connected anti-parallel. The firing angle of the thyristor can be varied by means of the regulator and hence the speed of the motor is controlled.

ADVANTAGES

- Single phase motor is that it requires a two wire supply.
- Single-phase motors are less expensive to manufacture than other motors.
- Capacitor-start motors are good general purpose motors and they are ideal for most occasions.
- The single phase motors are simple in construction, cheap in cost, reliable and easy to repair and maintain.
- The current rating of the thyristors is very high and therefore they will not damage easily.

LIMITATIONS

- Single phase motors are that their power is limited.
- They do not have good starting torque and they have a complex starting switch in some cases.
- Speed control of induction motors is difficult.
- At low loads, the power factor drops to very low values.

RESULT ANALYSIS

SIMULATION MODEL

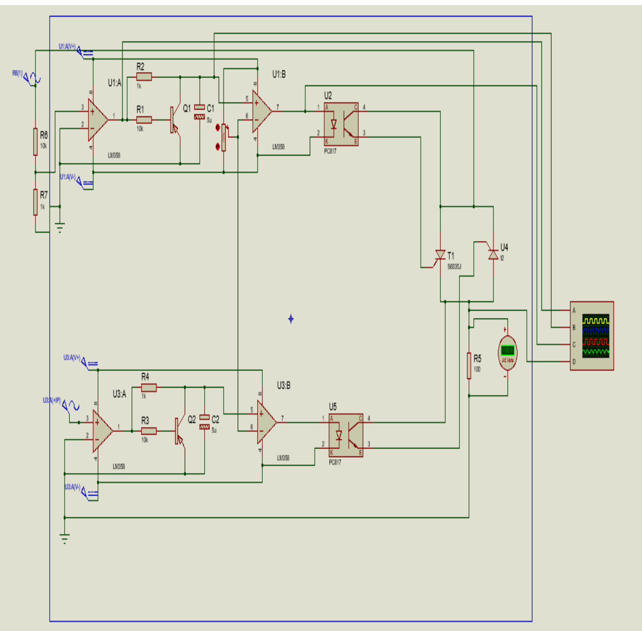

Fig. No. 12 Simulation model

WAVEFORMS

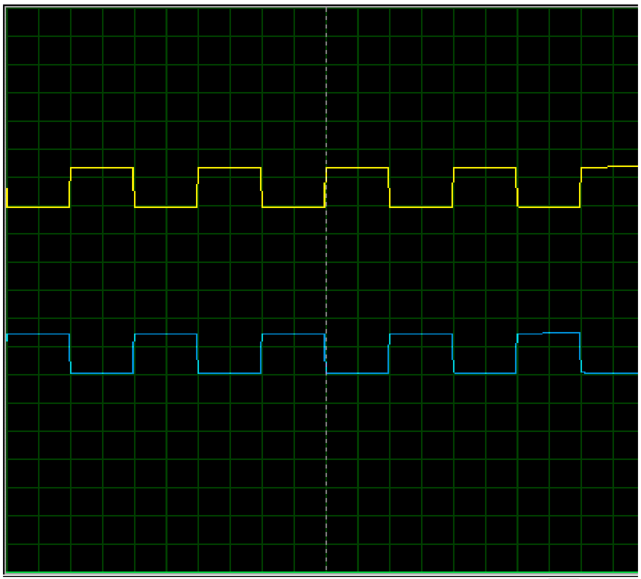

Fig. No. 13. Rectangular pulses

GENERATION OF SAWTOOTH PULSES

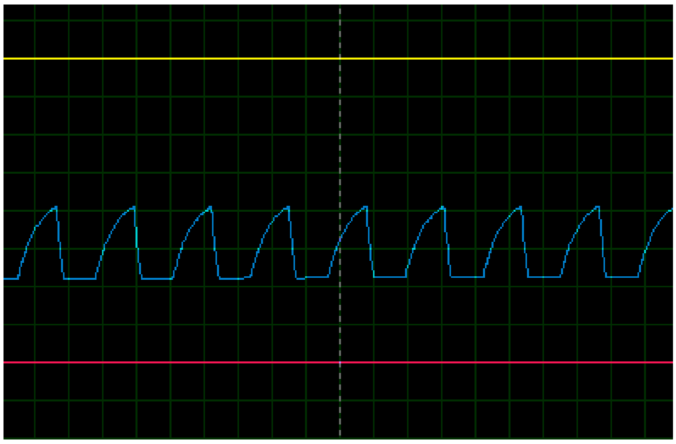

Fig. No. 14 Saw-tooth pulses

GENERATION OF PWM SIGNAL

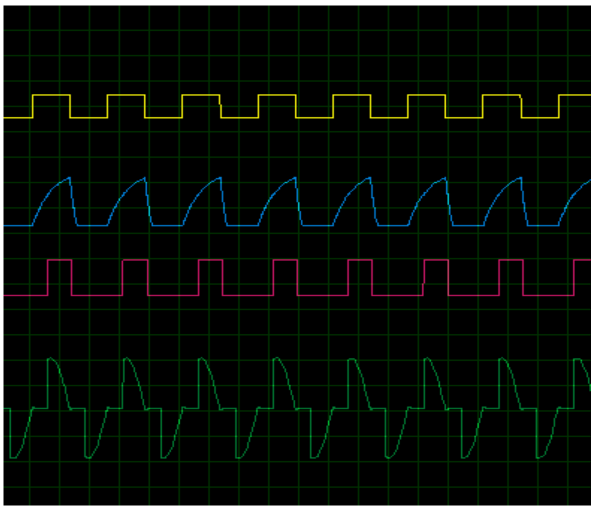

Fig. No.15 PWM signal

Conclusion

high-efficiency drive capable of supplying s single-phase A.C. induction motor with a PWM modulated sinusoidal voltage. The circuit operation is controlled by the pulse generator. The device is aimed at substituting commonly used TRIAC phase angle control drives. This circuit is capable of supplying single-phase A.C. induction motor (or general A.C. inductive / resistive load) with varying A.C. voltage. The same as in the TRIAC control, the voltage applied to the load can be varied from zero to maximum value. On the other hand, it uses a pulse width modulation technique (PWM), and when compared to the phase-angle control used for TRIACS, it produces much lower high order harmonics. Because the circuit is aimed at low-cost, low/medium power applications, t does not use a conventional converter technology to produce output voltage waveform. It directly modulates the mains A.C. voltage. Compared to costly converter, it require lower number of active and passive components. In summary, a device attempted here takes advantage of both low price of the phase-angle control and low harmonics content and high efficiency that we can get with standard converter technology.

Model Structure

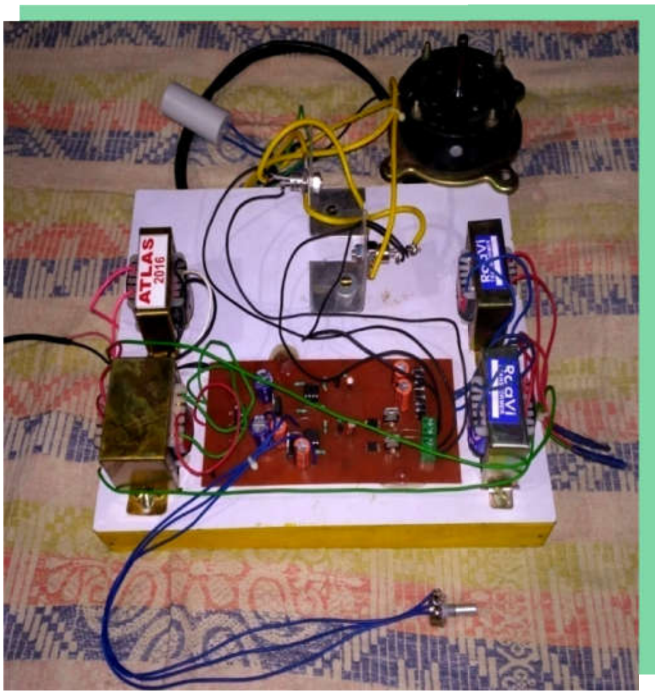

Fig. No. 16. Model structure

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