INPUT POWER FACTOR IMPROVEMENT IN THREE PHASE AC VOLTAGE CONTROLLER

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ABSTRACT- Pulse width Modulation technique is implemented for Single Phase AC Voltage Controller or Ac voltage regulator.AC Voltage controller is made switched on and off several times in cycle by using PWM control method. Simulation Model is presented in the Paper and there is Comparison placed in the Paper between the Phase angle Control method and PWM control method. This Paper deals with the harmonic reduction in output voltage. FFT analysis for both Phase angle control and PWM Control is presented. In the PWM technique, the switch of ACVC is turned ON and OFF several times in each half cycle. The width of pulses can be varied for controlling the output voltage. The harmonics is reduced by using the PWM technique. If the harmonics in the input current is high then it can distort the supply voltage. The higher order harmonics in the input current can be filtered with the help of the filters but the lower harmonics cannot be filtered out. So the PWM technique becomes so important to implement for switching the ACVC.

KEYWORDS: Harmonic, Lower order harmonics, THD, PWM control, Phase Angle Control

1. INTRODUCTION

AC Chopper or AC Voltage regulators or AC Voltage Controller has been widely used to obtain the variable ac from the fixed ac source. The Phase angle control method (PAC) of Ac voltage regulator is used in application like industrial heating, lighting control and starting and speed control of induction motors. PAC method is simple and can handle large power economically but delayed firing angle causes discontinuity in load current, significant harmonics in load current and also lagging power factor occur in ac side even if load is resistive.

These problem can be solved by introduction of Symmetric angle control(SAC),Asymmetrical angle control(AAC),Time ratio control of Frequency(TRC) and by using freewheeling path or other[1].

In this paper, the Pulse width modulation technique is used to improve the input power factor of single-phase regulator. The input power factor is based on the reduction of total harmonic distortion (THD) in the output voltage and input current. The THD is measure in simulation. The switching is done with the help of PWM pulses and switch is made on and off number of time per half cycle.

2. DESCRIPTION OF PWM AC VOLTAGE CONTROLLER

The Pulse Width Modulation technique is use to operate the AC voltage regulator. The Pulse Width Modulation (PWM) is obtained from comparing the Carrier signal, which is triangular signal with the reference signal, which can be the sinusoidal signal, dc signal or step signal. Here the SPWM technique is used. SPWM is the Symmetrical Pulse Width Modulation. In this method the reference signal is compare with the triangular carrier wave, the gating signal is generated for the turning on and off the switch. The multiple pulse are generate in the one-half cycle so it is called as MPWM –Multi Pulse Width Modulation technique. The main advantage of using the PWM control is the output voltage can be control without any additional component and by using the PWM control, the lower order harmonics can be eliminated or minimized and the higher order harmonics can be easily filtered out[2].

The THD of the ACVC can be reduced by using the PWM control then phase angle control method. The THD is the Total Harmonic distortion which measures the closeness in a shape between the output voltage and its fundamental component. Harmonic causes more heating, adds the voltage or current in neutral wire which causes the temperature rise and heating of the wire. So the harmonics should be as low as possible which can be achieved by the PWM technique. By reducing the harmonics in the input current and output voltage the input power factor is improve. As many researchers states that by increasing the THD that is total current harmonic distortion causes the reduction in input power factor[3].

3. COMPARISON OF PHASE ANGLE CONTROL AND PWM CONTROL

3.1 Simulation Block of Phase angle control of ACVC

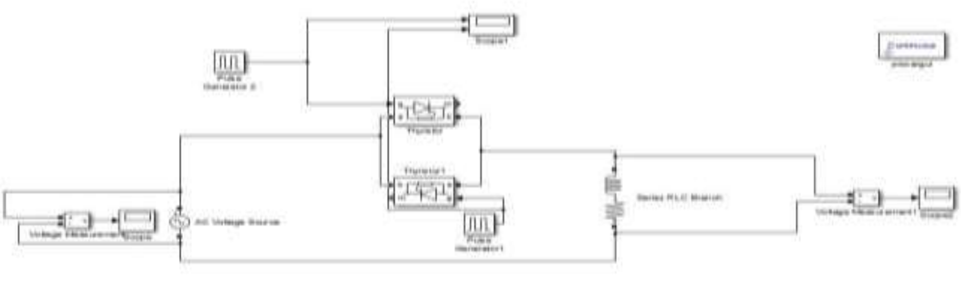

Figure 1 Phase Angle Control Method

The simulation block of Phase Angle controlled ACVC is prepare and shown in Figure 1. It contain two SCR and Thyristor respectively. The single-phase supply of 230V, 50 Hz is applied to the ACVC. Both thyristor are connected in parallel with each other as shown in Figure 1. Pulse generators trigger the SCR. 'Pulse generator 2' triggers the SCR (thyristor) and Pulse generator 1 triggers 'Thyristor 1'. In Pulse generator, the magnitude of pulses is set to one and frequency of pulses are 50 Hz. The both SCR are triggered at 90 degree of each half cycle. The 'Thyristor' is triggered in terminal of supply then 'Thyristor' and load. In negative cycle, it is reverse of it.

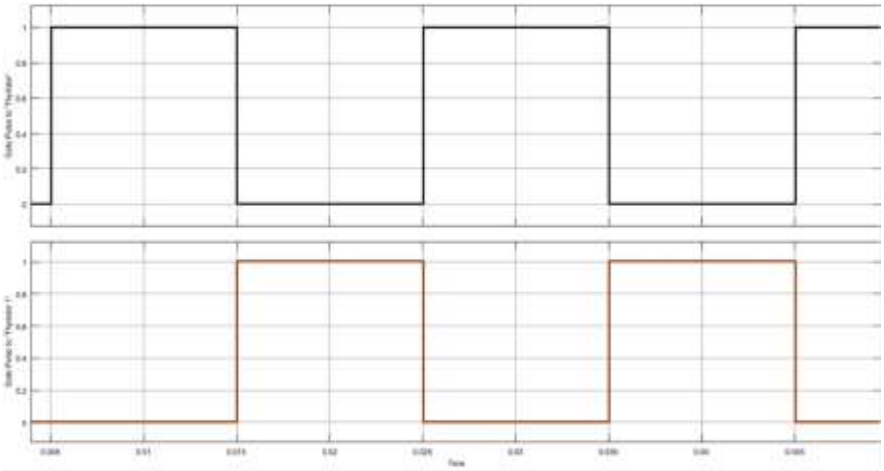

Figure 2 Gate pulse to trigger ACVC

The gate pulses shown above are applied to both the SCRs .The 'Thyristor' is applied by the 'Pulse generator 2' with magnitude 1 of pulses of 50 Hz frequency. The 'Pulse generator 1' with same magnitude applied to the 'Thyristor 1' but have the phase angle of 90 degree.
The output voltage is as shown in above figure of Phase Angle Control with RL load. The voltage is only available after giving the gate signals that is after the 90 degree. The current in positive cycle flows from the 'Thyristor' and in negative cycle flows from the 'Thyristor 1'. When the polarity of the voltage is change, then the current flows from the same direction as inductor opposes the change in flow of current. Therefore, the inductor freewheels it energy with opposite polarity and so the voltage is develop in opposite polarity of supply voltage [2].

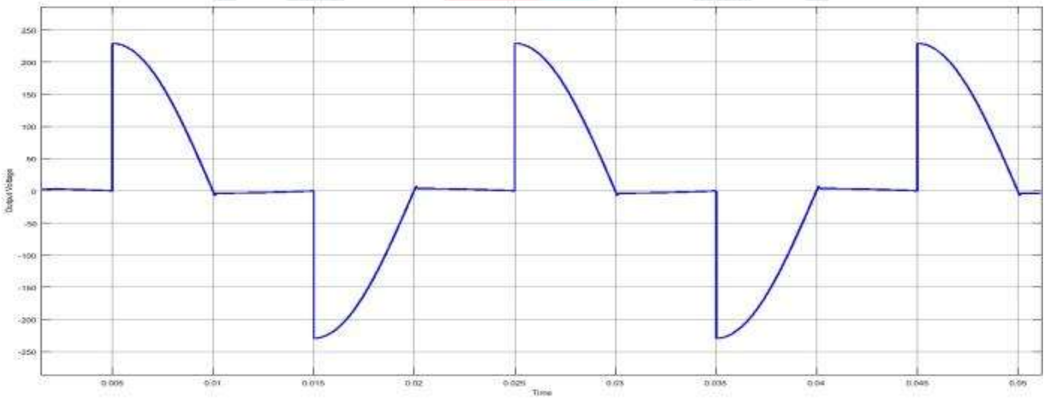

Figure 3 Output Voltage of Phase angle control ACVC

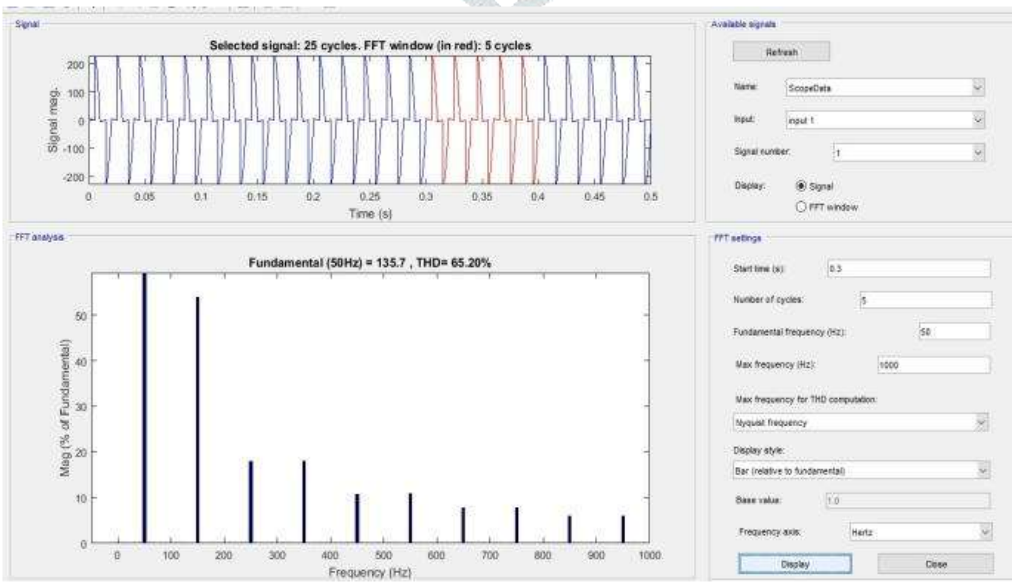

Figure 4 Results of Phase angle control method

The results of Total harmonics distortion is shown in the above Figure 4. The THD of AVCV at 50 Hz frequency is 65.20%, which is more than the Phase Angle Control method. The more THD in ACVC makes the device unstable. As it increases the distortion in the input current and output voltage, which causes heating and the current flows in neutral wire.

3.2 Simulation Block of 1-Ø PWM in ACVC

Simulation is done in the MATLAB 2015 software. As shown in block diagram Figure 5.The Simulation model is prepared after referring the block diagram. The block diagram consists of single-phase supply, which is gave by AC voltage source in simulation model. The ACVC consist of two switches which are MOSFET. One MOSFET with four diode operate per half cycle. Diodes are connect in common cathode configuration.

A 230 V, 50 Hz AC supply is given to ACVC. ‘Diode 0,1,2,3’ are connect with ‘MOSFET 0’ and ‘Diode 4,5,6,7’ are connect with ‘MOSFET 1’.Which are provide for freewheeling purpose. The PWM technique is develop in Arduino Uno by programming logic. Here the PWM technique is develop by using repeating sequence, Constant block and relational operator. The triangular waveform of 5 kHz with one amplitude is generated by repeating sequence .The relational operator compares triangular wave and constant wave of 0.7 amplitude.

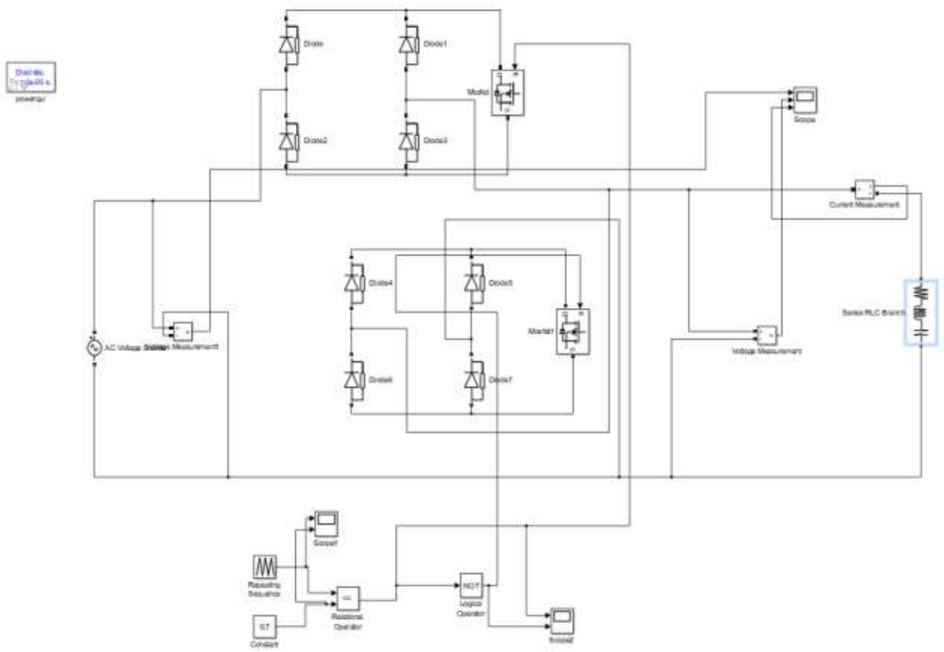

Figure 5 Block diagram of Simulation

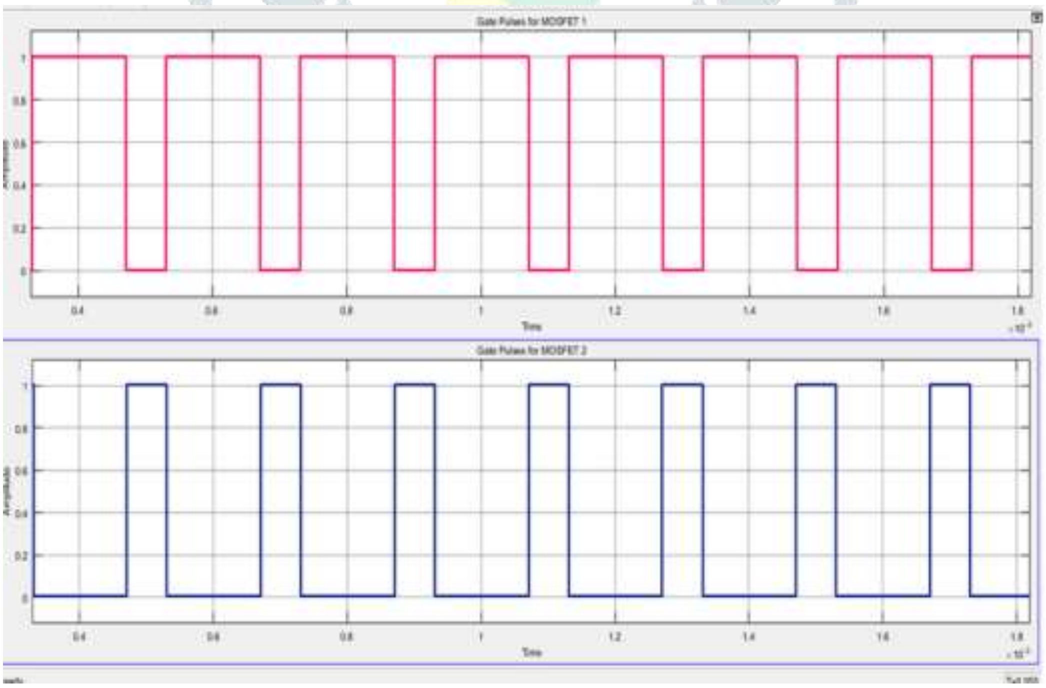

Figure 6 PWM pulses of the switch

The output of relational operator is gave to ‘MOSFET 0’ and further it is invert by using a logic operator ‘NOT’ Block which is given to ‘MOSFET 1’.

The output voltage across the load that is RLC series branch is display in scope. The FFT analysis is done in powergui block. The Total Harmonic Distortion is find from powergui block by doing the FFT analysis on the output waveform. The Scope with three input port shows waveform of input voltage, output voltage and output current. The two different pulses are apply to two MOSFETs. The output voltage can be control by controlling the width of the pulses and by changing the number of pulses per half cycle. When the Gate pulse of 'MOSFET 1' is high or logic 1 then gate pulse of 'MOSFET 2' will low or logic 0 and vice versa.

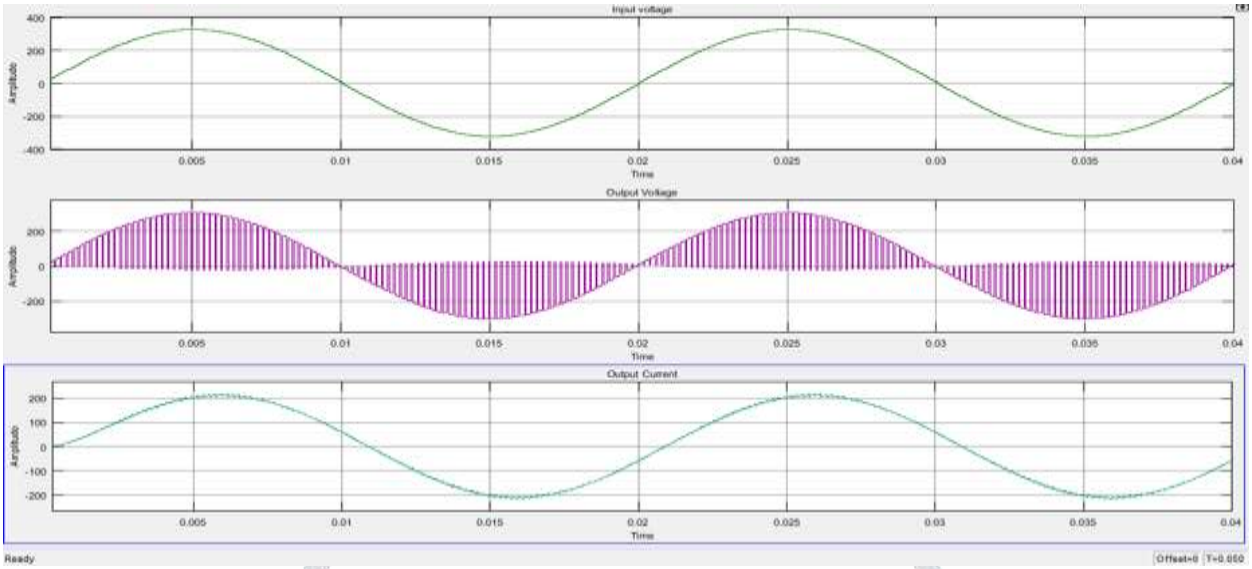

Figure 7 Output voltage of ACVC

3.3 Simulation Result of 1-∅ PWM Control of ACVC

The input voltage, output voltage and output current is shown in figure. It is display in scope and is shown in figure. The input voltage waveform is 230 volt, 50 Hz. The output voltage contains PWM.

The simulation is arrange as shown in simulation model. The simulation result can by obtain from the scope connected to the block. The scope connected with the 'Repeating sequence' Block, 'Constant' Block, 'Relational Operator' consists of two input ports. So the two different switching sequence is obtained from the 'Scope' as shown in Figure 6.

The input voltage, output voltage and output current waveform are shown in Figure 7. The figure shows that the voltage and current are harmonics free and has same phase angle.

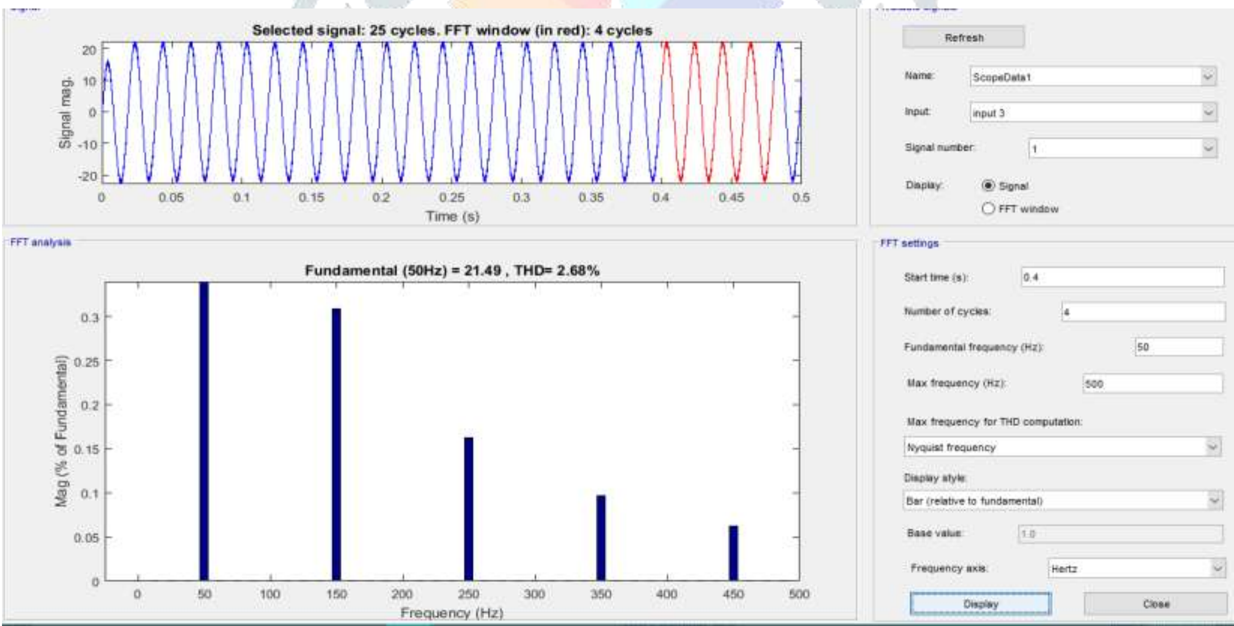

Figure 8 Result of PWM technique

The voltage and current are in phase so input power factor of the ACVC increases.

The Figure 8 shows the result of PWM control ACVC from which we can found that the THD present in output is only 2.68 % which is very less than the THD obtained from the Phase Angle Control method.

3.4 Simulation Block of 3-∅ PWM in ACVC

In the ACVC, we have used the common cathode connection, which has four diodes and one MOSFET operating in positive cycle and same in negative cycle. Number of MOSFET used here is less so cost reduces. As Arduino, cost reduces for controlling the switches and generating the PWM pulses. In 3-∅ the block is given below. The three 1-∅ are connected in such a way to get the output.Three 1-∅ ACVC are connected to get 3-∅ output. The output of each 1-∅ ACVC is given to 3-phase transformer. The 3-∅ transformer is connected to 3-∅ R-L-C series circuit branch. The output voltage and current waveform shown in figure.It is displayed in different colours like Red, Blue, and Yellow.

The 3-∅ transformer with 12 terminal is used to convert 1-∅ to 3-∅ ACVC and to connect load to 3-∅ ACVC. The PWM generator will generate same as that of 1-∅ ACVC. 'Three phase V-I Measurement' block measures the voltage and current. The capacitor is connected between phase and neutral to filter out harmonic from the output. 'Scope 4' shows output voltage and current.

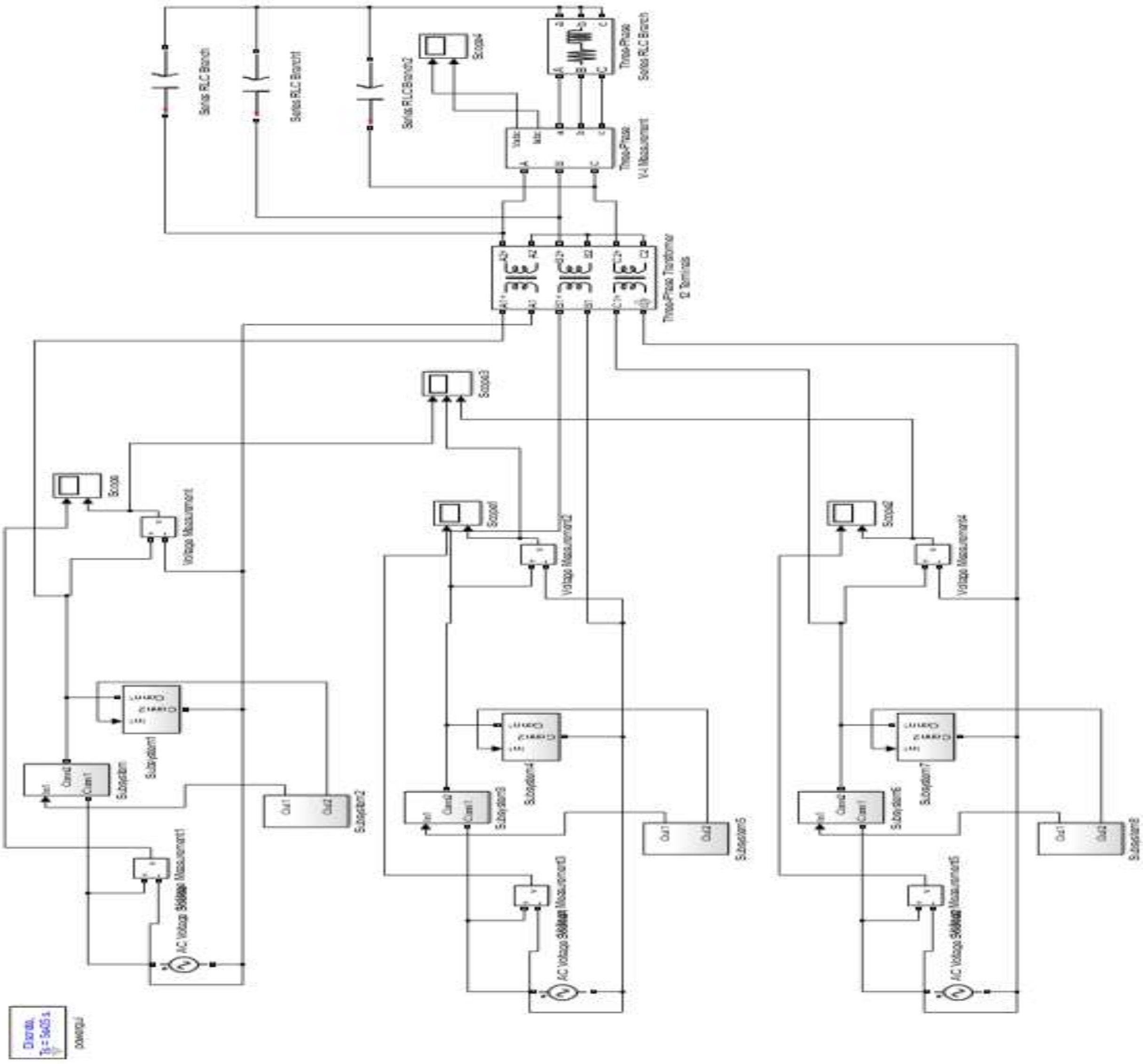

Figure 9 Simulation Model of 3 phase ACVC

3.5 Simulation Result of 3-∅ PWM Control of ACVC

The Simulation Result is obtain from the scope connected across the load. The 'Scope 4' shows the output voltage and output current of all the three phases. 'Three phase V-I measurement' block in the simulation measures the voltages and current of all the phases. 'Scope 4' is connected with the 'Three phase V-I measurement' block. So, the Output voltages and currents are displayed in this scope. The Figure 10 shows the Waveform of Output voltage and current. The three phases are indicated by different colour like Red, Yellow and Blue. The load is Inductive in nature then also the voltage and current seems to be in phase with each other.

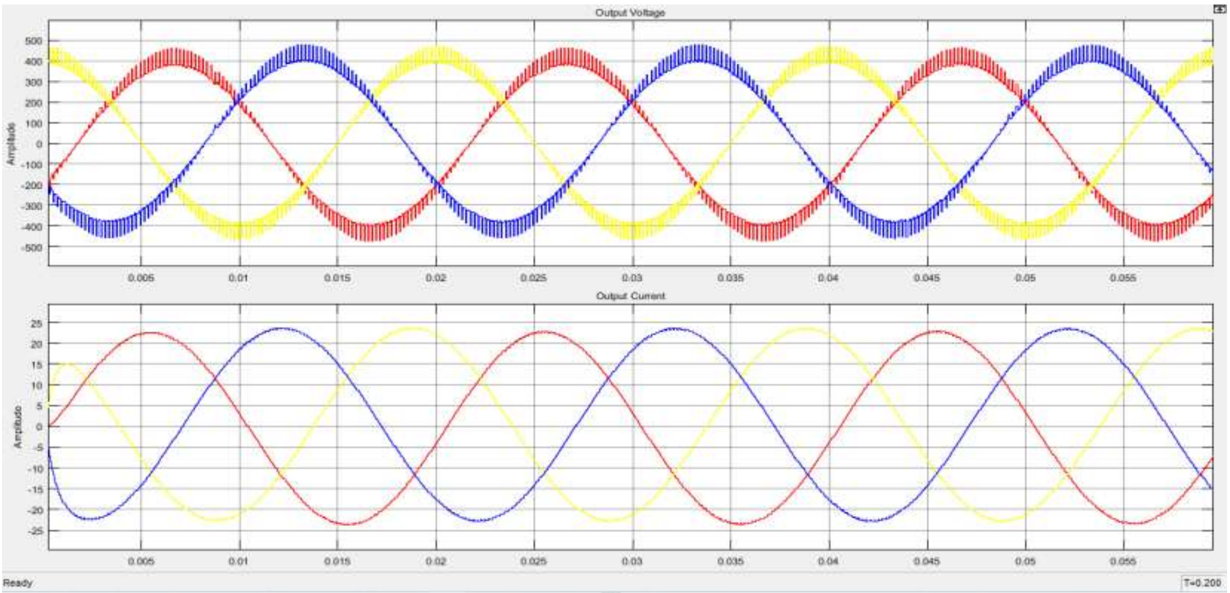

Figure 10 Waveform of Output Voltage and Output Current

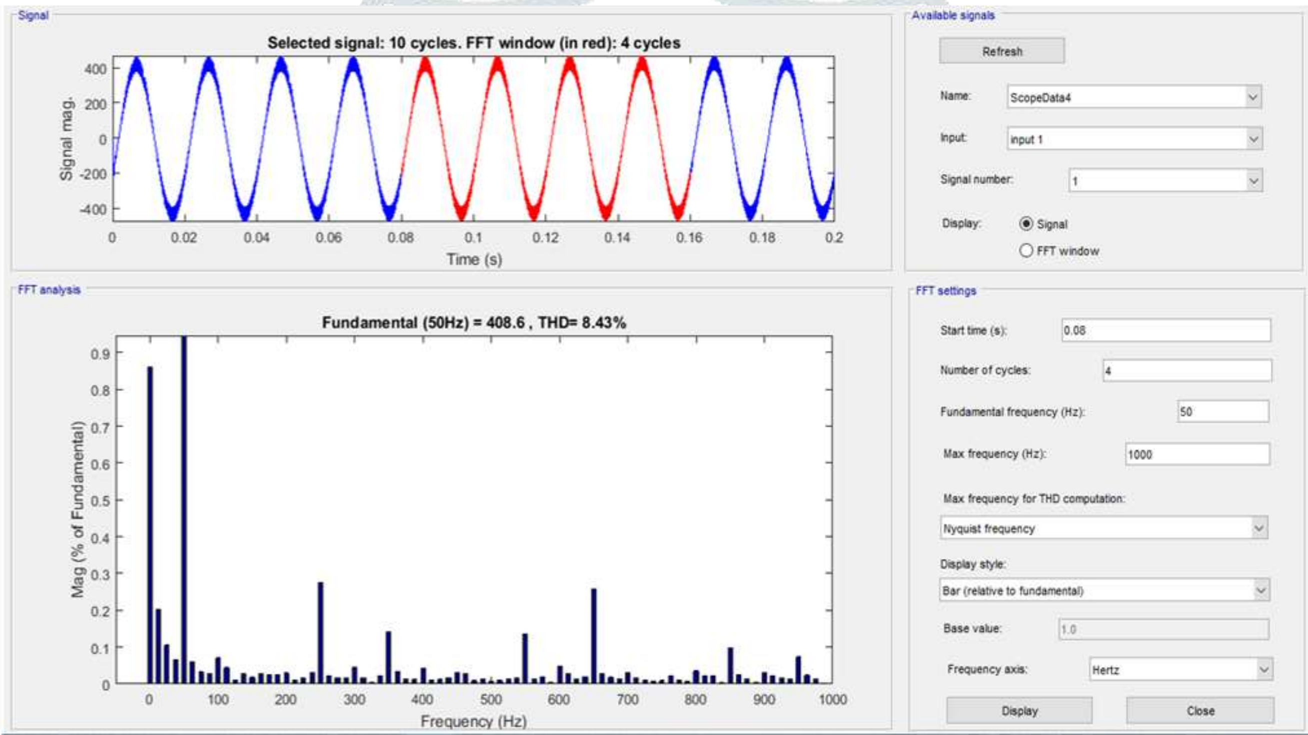

Figure 11 FFT analysis of Output Voltage of 3 phase ACVC

The FFT analysis for output voltage as shown in figure. The THD present in output voltage is 8.43% in 3 phase ACVC that is very less compare to phase angle control method. As it was 65.20% in phase angle control.

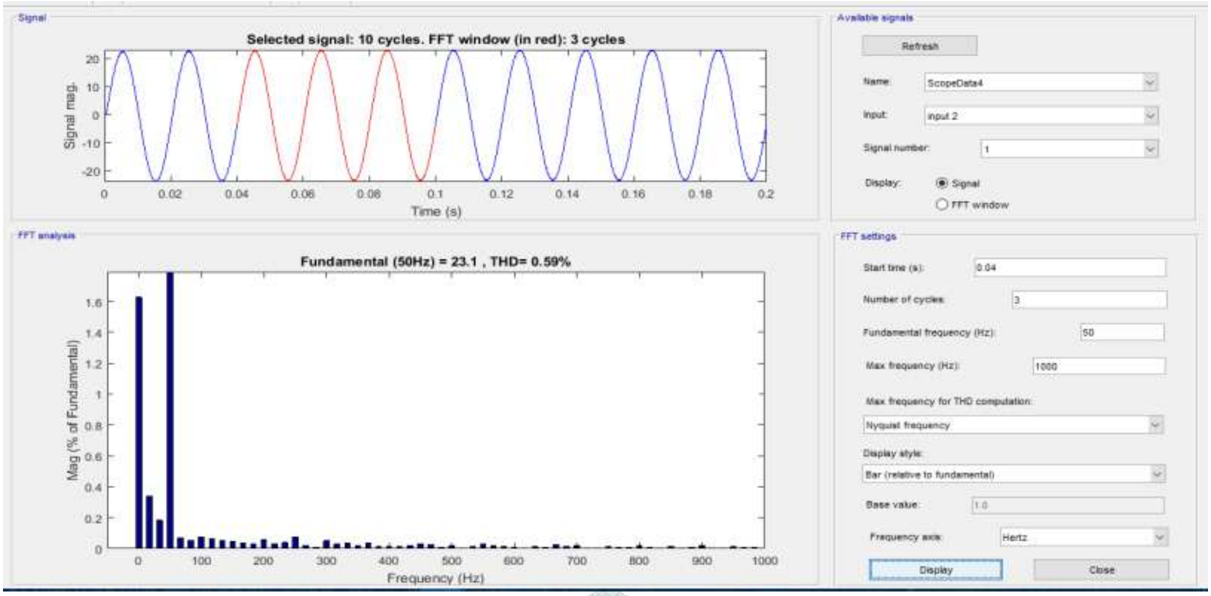

Figure 12 FFT analysis of Output Current of 3 phase ACVC

The THD present in output current is 0.59%, which is in range given by IEEE standards.

4. Hardware Implementation

4.1 Block Diagram to implement the PWM technique in ACVC

The block diagram of the PF improvement using ACVC is show below.

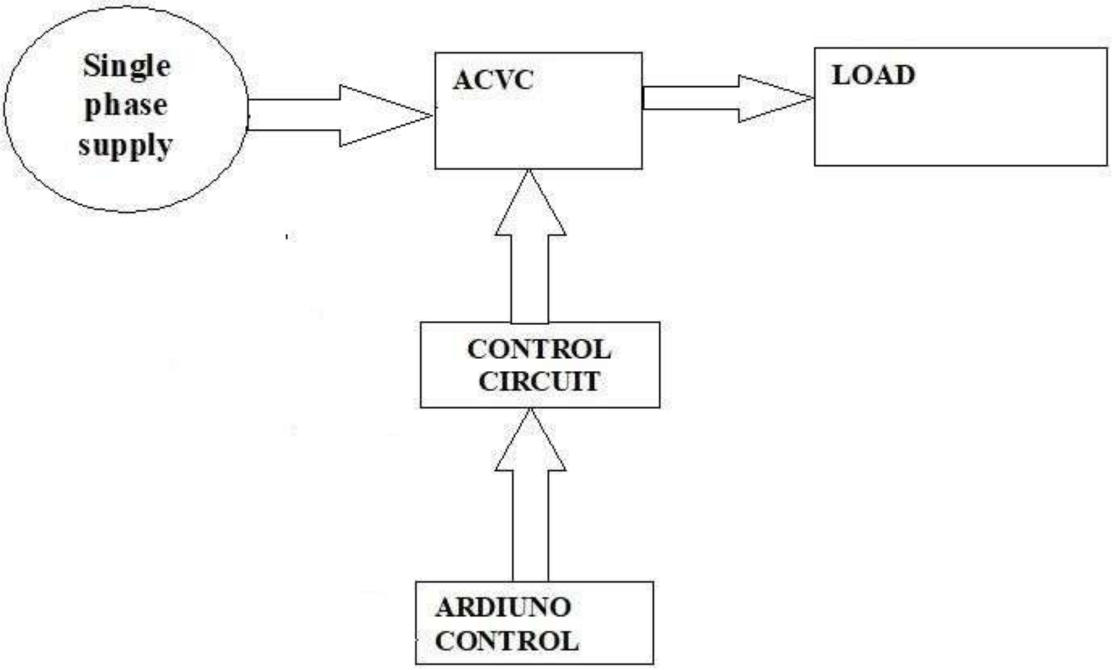

Figure 13 Block Diagram to implement the PWM technique in ACVC

The block diagram consist of following main parts.

1. Supply
2. ACVC
3. Load
4. Arduino control

The 230-volt 1-ϕ supply is given to AC Voltage Controller. The ACVC is made up of diode and MOSFET. The common cathode connection is used. The switches can be MOSFET, IGBT, and SCR. In PWM technique, the switch has to be made ON and OFF several times in a cycle. The Switch should be such that it can be made ON and OFF easily.

However, as SCR is latching device we cannot use SCR, as it cannot be off without commutating circuit. MOSFET has high switching frequency then IGBT and has low power loss. We have used MOSFET in place of SCR and IGBT.

The load here used is RLC series branch. The programming logic will generate PWM, which will used to trigger the switches in ACVC. The main aim of this project is improve the input power factor and reduce the harmonics in output voltage and input current by giving the PWM pulses to switches.

4.2 Hardware Implementation

4.2.1. AC Voltage controller circuit

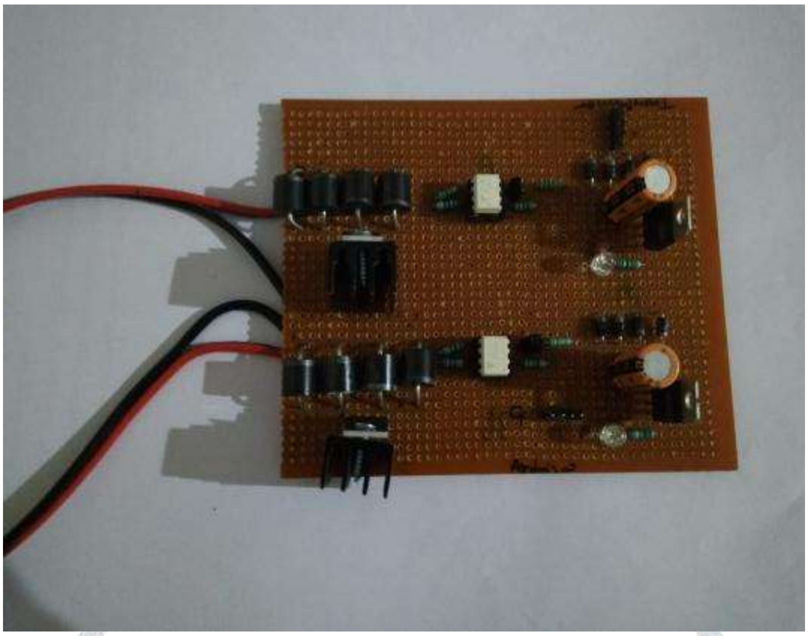

Figure 14 AC Voltage Controller circuit

The AC voltage controller circuit is as shown in the Figure 14.The ACVC is the basic arrangement of Switches and diodes. The four diodes and one MOSFET is connected in Common cathode configuration for the positive cycle and negative cycle. So, there are two sets. Each set consist of one MOSFET and four Diodes. There is one set for positive cycle and one set for negative cycle. For freewheeling of stored energy in case of inductive load.

The diodes are connected back to back. The MOSFET is connected between the four diodes where two anode terminals and two cathode terminal are faced. The input and output are taken from the terminal at which one cathode and one anode of the two set are met .The MOSFET, which are connected in each set are capable of withstanding the High switching frequency. The frequency of Switching on and off the MOSFET are 2KHz.So time of one full cycle is 500 micro second.

The Switching frequency is kept as high as possible. So, that AC voltage controller can generate the voltage as close as the input supply. The MOSFET is switch on and off by giving the gate signals. When supply is given to AC voltage controller, the MOSFET 1 will be switched on and complete the cycle by passing through load and when there is inductive load the MOSFET 2 will be used to dissipate the energy which is stored in the inductor.

The AC voltage controller is supplied with the 230 V AC supply. The 230 V AC supply is step down to 18V AC supply by Step down transformer. That 18 V is supplied to AC voltage Controller while testing purpose.

4.2.2 Control circuit

It consist of Arduino Uno and Variable resistor. Arduino Uno consist of 14 input-output digital pin and six analog input –output pins. The PWM pulses are generated with help of Arduino Uno .So, digital pin 6 and 7 are define as output pins. When pin 6 is high, the pin 7 will be low and after some delay it will be vice-versa.

The program is loaded with help of USB connector. The Variable resistor has three terminal, two of them are for fixed connection and one is slider. Slider is connect with circular knob so, it is change as per our requirement. The variable resistor can vary resistance from 0 to 10k-ohm resistance. Variable resistor is connect here only to vary the width of pulses.

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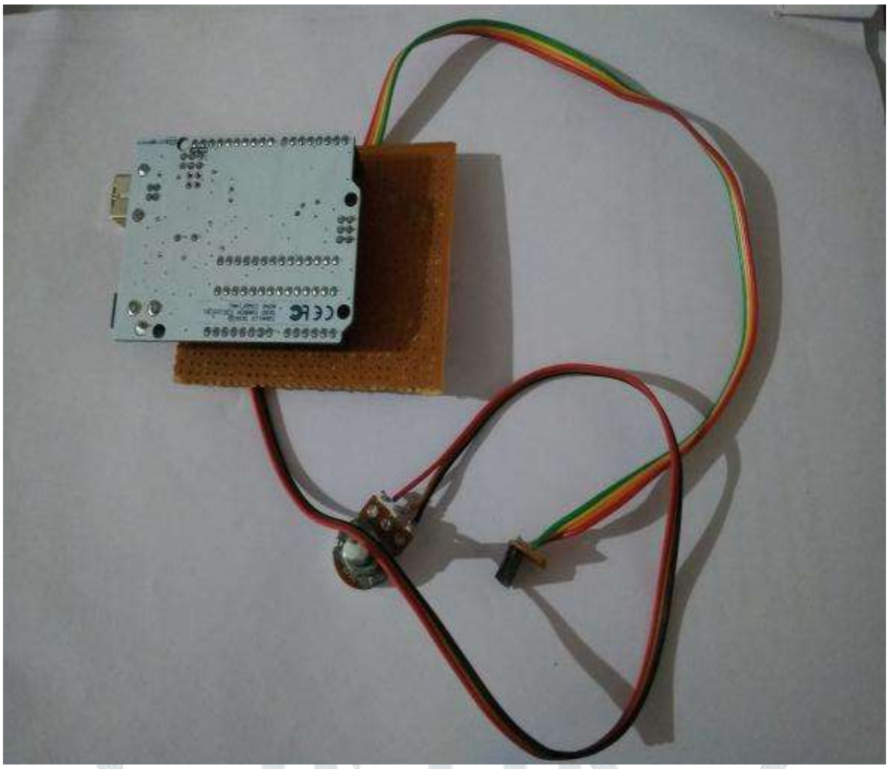

Figure 15 Control Circuit

The variable resistor can set some resistance value and then variable probe is connect with analog input-output pin 0.
The variable resistor or pre-set consist of 2 fixed connection which are connected with ground and 5V respectively and 1 variable probe is connected with analog pin number 0.The program in Arduino has time of 0.5 mille second that is 500 micro second ,which gives pulse range of 2 kHz.
From control circuit the PWM pulses output, which is to be given to ACVC in positive and negative cycle, is taken out from digital pin number 6 and pin number 7.The output is connected to female bug strip. The four output is taken from the Arduino or control circuit, which are connected to female bug strip connected in power circuit. The first and second output is PWM pulses for positive and negative cycle of ACVC. Third output is ground while fourth output is connected to 5V supply.

4.2.3 Opto coupler circuit

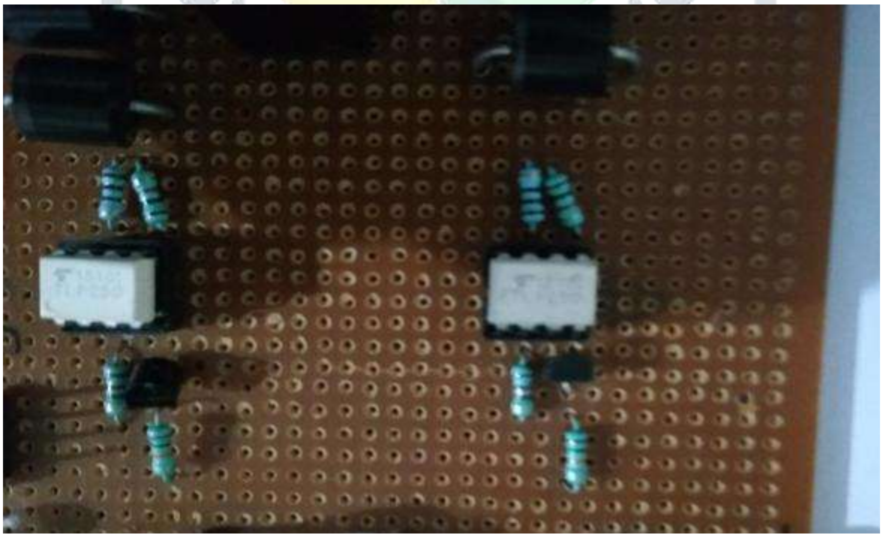

Figure 16 Opto coupler circuit

The Opto Coupler circuit consist of Opto coupler IC TLP 250.It has eight pins. The Pins are 1- N.C,2-Anode, 3-Cathode, 4-N.C, 5- GND, 6- VO (Output), 7- VO, 8 –VCC. The IC is supplied with the Voltage of 10-35V to the Pin number 8 which is VCC .The Pin number 2 and 3 is input of the IC which changes as per the Pulses. Pulses can be Positive as well as negative.
When pin number 2 is Positive with respect to the Pin number 3 then LED in the IC will be ON and Transistor 1 of the IC will get ON. So as a result, we will get Output VO across the Pin number 7 and Pin number 8.When Pin 2 is negative with respect to the Pin number 3 then LED will remain in OFF condition. Therefore, Transistor 2 within the IC will be ON condition. Therefore, output will be get between the pin number 6 and 5.The Opto coupler provides Ground isolation to the circuit. It protects the receiver side or the other side of the supply from the high Voltage interruption and amplifies the Voltage. The amplified Voltage is gave to MOSFET between Gate and Drain. It physically isolates the input side and output side from each other, and connect it with the help of only light source.

4.2.4 Regulated supply circuit

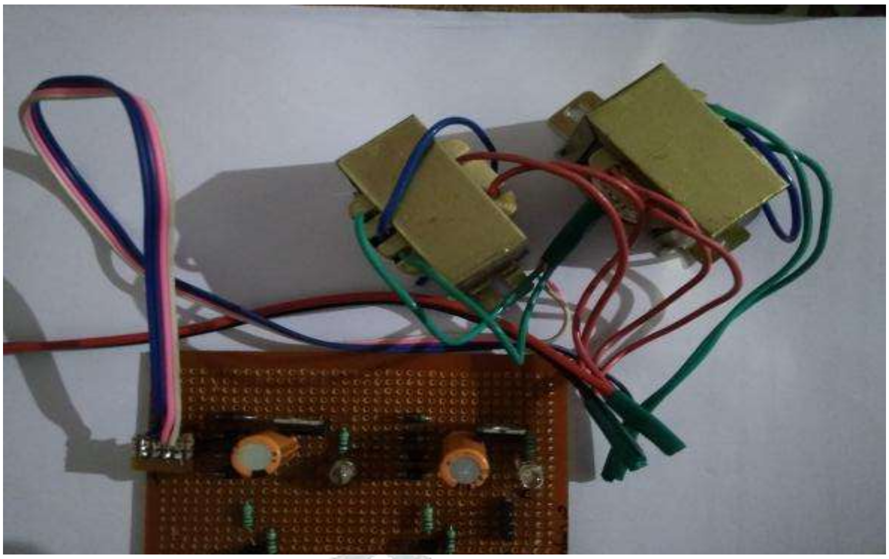

Figure 17 Regulated Power Supply

The regulated supply is design to give the 15 V supply to the Opto Coupler. The Opto coupler needs 10-35 V. So the regulated supply is made to give the regulated 15 V to the Opto coupler IC. The 15 V Supply is gave to the Pin number 8 of the Opto coupler IC.
The regulated supply is obtain from using step down transformer, bridge rectifier diode, capacitor and regulated IC 7815.The 230 V AC supply is step down to 18 V AC supply with the help of 9-0-9 V, 500 mille ampere transformer.
There are two sets of Mosfets. Therefore, to give voltage to MOSFET, two Opto coupler and regulated supply are designed. The two transformer are supply by 230 V ac supply to their primary side and 18 V ac supply is obtained at the secondary side of transformer. The two output of transformer is the applied diodes, which are connected in bridge configuration. The diode used are 1N4001, which have maximum RMS voltage of 35 V and maximum DC blocking capacity of 50 V.
The capacitor of 1000 microfarad, 25 V are connected with the diodes bridge arrangement. The capacitor positive terminal are connected with the bridge arrangement where two cathodes are met and negative is connected where two anode are met. The capacitor are connected in the circuit to filter out the ripples.
The Regulated IC 7815 is connected across the capacitor. The Regulated IC has three terminals which are IN, Common, OUT respectively. The capacitor is positive terminal is connected with IN terminal of IC and negative is connected to the common terminal of IC. Another capacitor of 0.1 micro farad is used to filter out ac ripples from regulated supply. The capacitor is connected across the OUT terminal of IC and Common terminal of IC.
The regulated 15 V is obtain across the capacitor and then apply to the Opto Coupler IC TLP 250.

4.3 Flow Chart

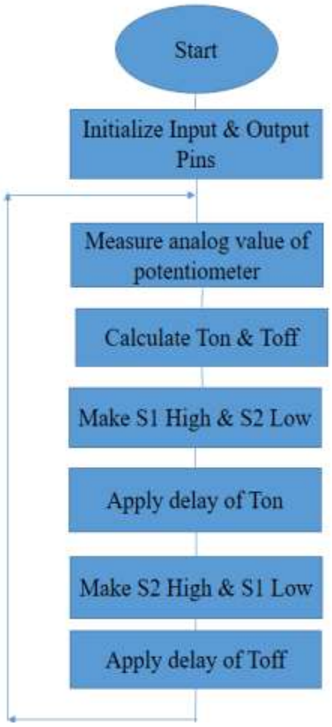

Figure 18 Flow chart for Logic of Programming

Flow chart of the program to be loaded in Arduino is shown in above figure. When starting the program we first initialize the input and output pin. The output pins are the pins, which are used to generate the output PWM pulses. The PWM pulses is than applied to the MOSFETs. The output pins for R phase is pin number 5 and pin number 6, for Y phase the output pins are pin number 7 and pin number 2 and for B phase the output pins are pin number 3 and 4.The input pin is analog 0 pin. The input is given at Analog 0 (A0) by varying the potentiometer.

The Potentiometer has three terminals, two of them are fixed which are connected to Vcc and Ground of Arduino and one is Variable is connected to Analog 0 (A0) of Arduino. The Potentiometer is varied to vary the width of the output of AC Voltage Controller. The pulses having frequency of 2 kHz is to be generated. Therefore, time for 1 cycle is 520 microseconds. To generate pulses for Positive cycle of AC Voltage Controller delay of A0/2 is applied. For negative cycle, the pulses is given delay of 520-Time delay for Positive cycle. When AC Voltage Controller is given supply, switches connected to AC Voltage Controller is made ON by Arduino. The Pins for R phase are pin number 5 and pin number 6, for Y phase the output pins are pin number 7 and pin number 2 and for B phase the output pins are pin number 3 and 4. When Pin number 5 is ON of R phase, at same time Pin number 7 for Y phase and pin number 3 for B phase is made ON. The time T is given as Ton= (A0)/2.At same time other output pins are made OFF. When Pin number 6, 2 and 4 are made ON other pins are kept off. The time Toff for MOSFETs are Toff=520-Ton.The loop is repeated and PWM pulses of 2 kHz is generated continuously.

4.4 Working

The AC voltage controller consist of four diodes connected to MOSFET IRF840 for each half cycle. The two diodes cathodes are connected together and connected to the Drain terminal of MOSFET. In the same way the anode terminal of two didoes are connected to the Source terminal of MOSFET. For negative half cycle and for freewheeling of the energy in the case of inductive load same arrangement is made. The input supply and output of AC Voltage controller where one cathode and one anode of any two diodes are met. The Gate terminal of MOSFET is connected to the Output pin of Opto coupler IC TLP 250. The Output of TLP 250 is taken from the pin number 6 and 7.

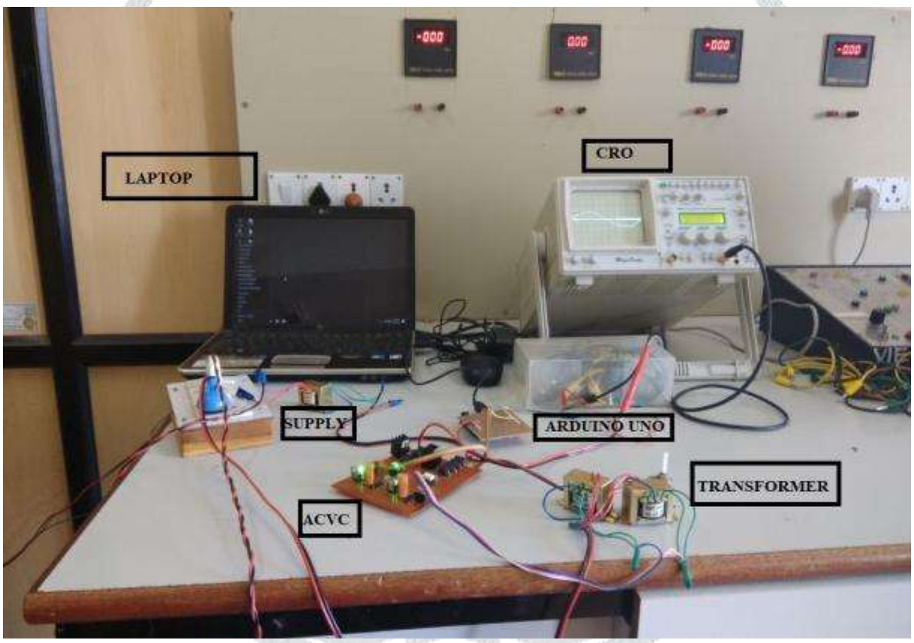

Figure 19 Whole setup of the circuit

The Arduino Uno is used for generating the Pulses. The Pulses generated is of 2 KHz. The digital output pins are 5 and 6 for R phase, pin are 7 and 2 for Y phase, pin number 3 and 4 for B phase. Each digital output pins are connected to the Opto coupler IC TLP 250. These Output pins are connected to the pin number 3 of Opto coupler IC. The Opto coupler is given Vcc of 5V in the pin number 2 by Arduino Uno board. Another supply is given to Opto coupler IC on pin number 8 of 15V by regulated supply circuit.

In between of Opto coupler and Arduino Uno board that is between pin number 5 of Arduino Uno and pin number 3 of Opto coupler one transistor is connected of NPN logic. The transistor BC547 is connected to amplify the signal if there is any reduction in voltage. BC547 consist of three terminals Collector, Base and Emitter respectively. The Base is connected to the pin number 5 of the Arduino Uno board, Emitter is connected to the Ground and Collector terminal is connected to the connected to the pin number 3 of Opto coupler.

Potentiometer is connected to the Vcc, Ground and analog 0 terminal of Arduino. The Potentiometer fixed contacts are connected to Vcc and Ground and Variable lead is connected to the analog output pin 0.The Potentiometer is varied and output waveform is also varied according to the change of resistance.

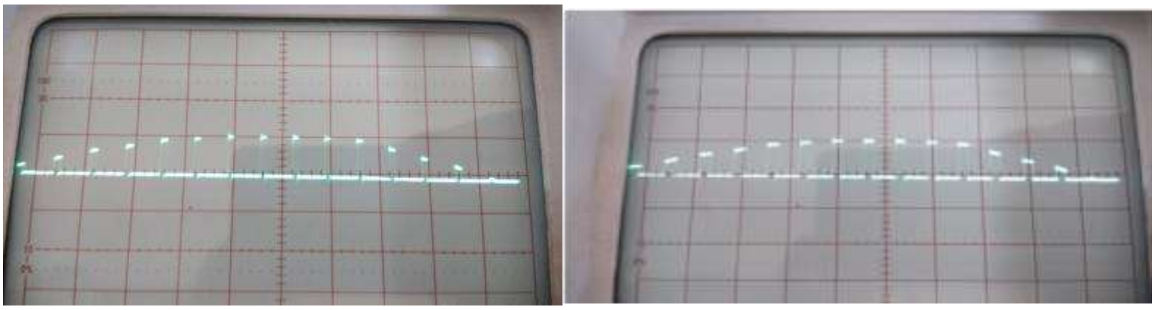

Figure 20 Output voltage of different width

The setup of the testing is shown in the Figure 19. We have used voltage probe of CRO, multimeter for the testing and done testing in laboratory.

CONCLUSION

From this project, we can conclude that the PF improvement in ACVC can be achieved by using the PWM technique. The harmonic, which are injected in the load current, are reduced by using the PWM technique. By increasing the PF, the efficiency of the ACVC increases and the harmonics in reduced. The noise caused by harmonic is reduce and more stable output is obtain. This improvement in Power factor and reduction in THD can be achieved only by using different controlling method.

FUTURE WORK

We have worked on hardware and put the output of single phase PWM AC Voltage Controller. In future, we will have results of three-phase hardware circuit.So,results put in this paper is for single phase only.

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