EELR15 – Power Electronics Laboratory

Three Phase Fully Controlled Bridge Controller

Triggered using Arduino Uno

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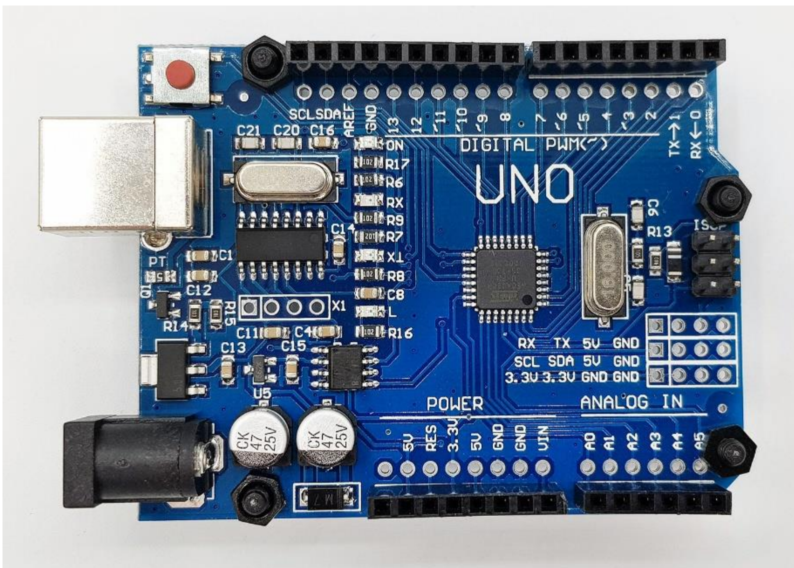


Aim/Objective:-

To study the three-phase full-controlled bridge converter with firing angles for fixed load.

Components/Equipment Used:-

Sr.No.	*Equipment/component*	*Ratings*	*Quantity*
1	SCRs (TYN612)	600V, 12A	6
2	Arduino Uno	---	1
3	3 Phase Autotransformer	(0-230)V, 50Hz	1
4	Resistors	470Ω, 1kΩ, 10kΩ	6,6,1
5	Multimeter, DSO	---	1,1
6	Connecting Wires/Probes	---	As required
7	Breadboard	---	1

Theory of Three-Phase Controller:-

Introduction:

A three-phase full-controlled converter is a power electronics device that converts AC power to DC power using semiconductor devices such as thyristors. This type of converter is widely used in various industrial applications for controlling the speed of DC motors, power transmission systems, and other power control applications. Let's explore the working, applications, and significance of a three-phase full-controlled converter.

<u>Working of Three-Phase Full-Controlled Converter:</u>

1. *Rectification:*

a) The converter takes in three-phase AC power as input.
b) The AC voltage is rectified to DC voltage using six thyristors arranged in a three-phase bridge configuration.

2. *Controlled Operation:*

a) The firing angle of the thyristors is controlled to regulate the average DC voltage output.
b) By controlling the firing angle, the effective value of the DC output voltage can be adjusted, allowing for the control of power delivered to the load.

3. *Output Smoothing:*

Depending on the application, additional filters or smoothing circuits may be used to reduce ripples in the DC output.

Applications of Three-Phase Full-Controlled Converter:

1. *DC Motor Speed Control:*

Three-phase full-controlled converters are extensively used in industries for controlling the speed of DC motors. By adjusting the firing angle, the average DC voltage applied to the motor can be varied, thereby controlling the motor speed.

2. Power Transmission Systems:

In high-voltage direct current (HVDC) transmission systems, three-phase full-controlled converters are employed to convert AC power from the grid to DC power for efficient long-distance transmission.

3. Battery Charging:

Three-phase full-controlled converters are used in battery charging systems, where precise control of charging voltage and current is required.

4. Welding Power Supplies:

These converters find application in welding power supplies for controlling the welding current.

5. Uninterruptible Power Supplies (UPS):

In some UPS systems, three-phase full-controlled converters are utilized to convert AC power to DC power for charging the backup batteries.

Significance:

1. *Efficient Power Control:*

Three-phase full-controlled converters provide efficient control over the power delivered to the load, making them suitable for applications where precise power regulation is required.

2. *Versatility:*

These converters are versatile and can be used in various applications, including motor drives, power transmission, and power supplies.

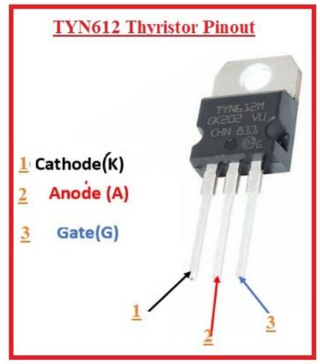
3. *Reduced Harmonics:*

The controlled operation of the converter allows for the reduction of harmonics in the output, contributing to improved power quality.

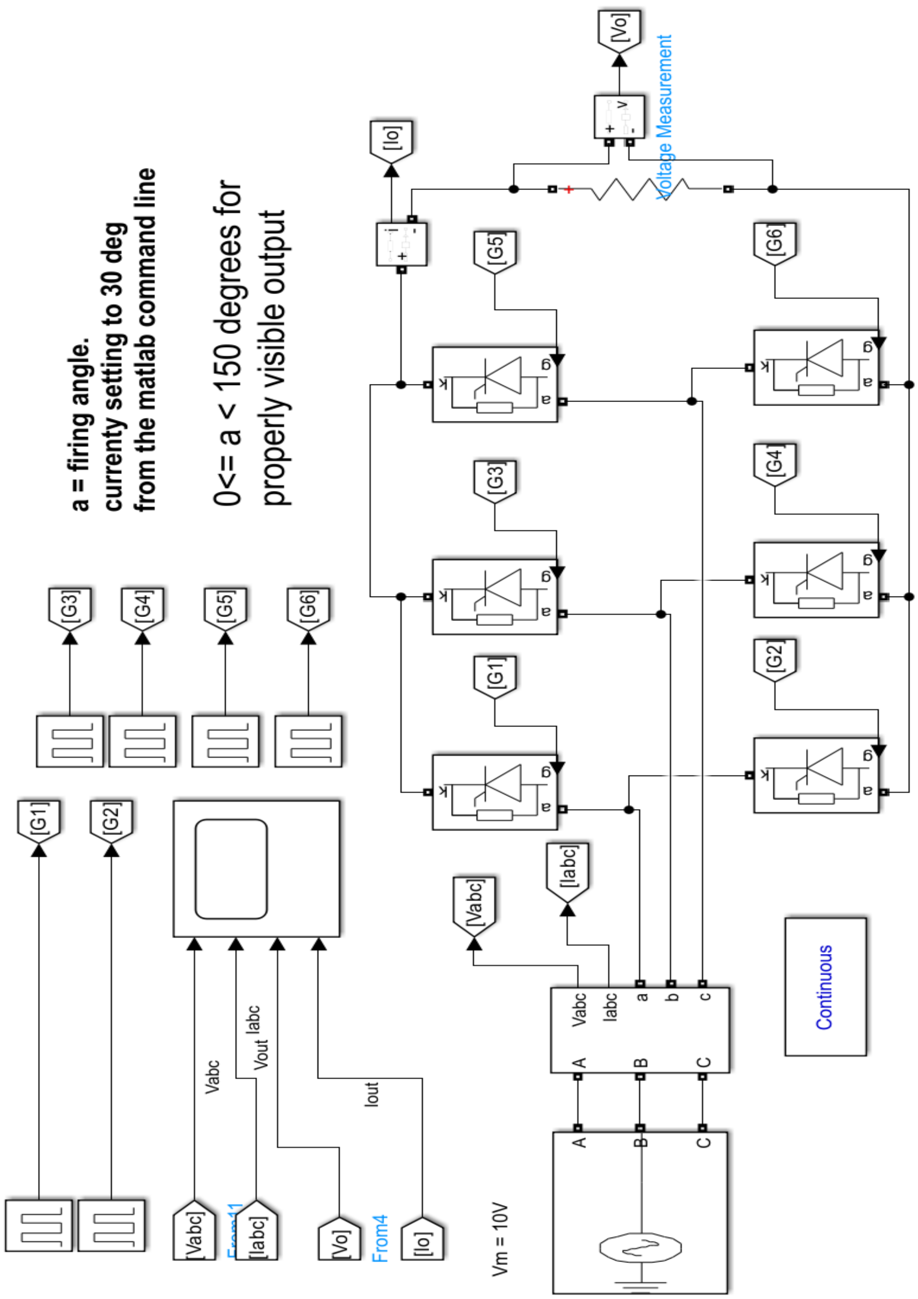
4. *High Power Applications:*

In industrial settings, these converters are capable of handling high power levels, making them suitable for heavy-duty applications.

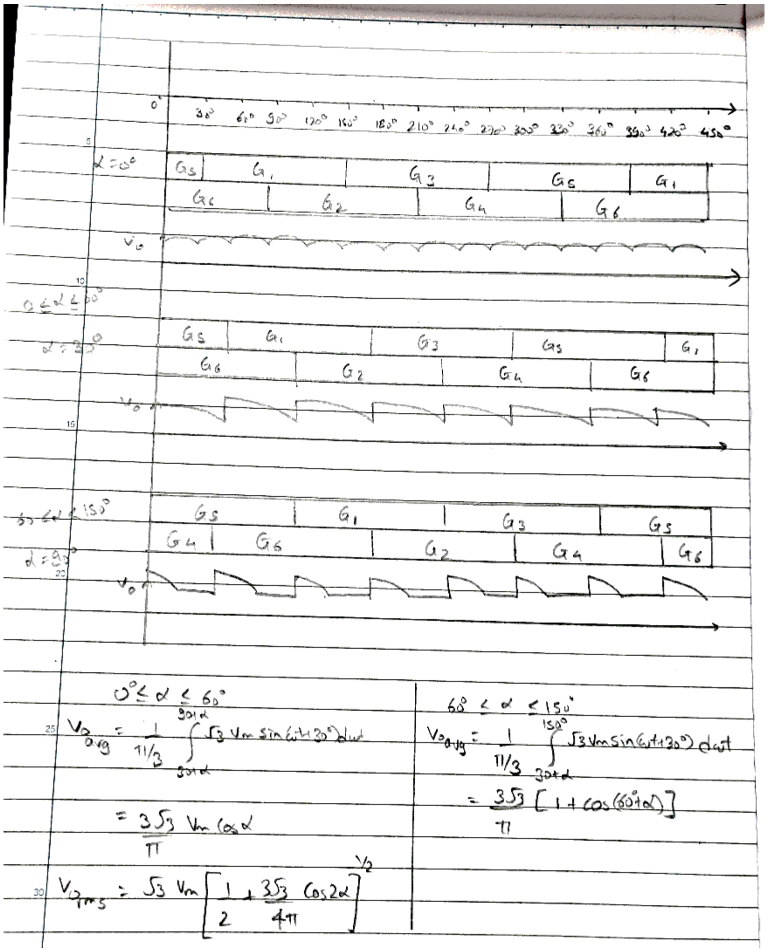
In summary, the three-phase full-controlled converter is a crucial component in power electronics, enabling efficient and controlled conversion of AC power to DC power for a wide range of applications across different industries.



Circuit Diagram:-



Working:-



Referring to circuit diagram, there are two operating conditions for obtaining the output based on the firing angle (α) in degrees:-

1. $0^0 \leq \alpha \leq 60^0$
2. $60^0 \leq \alpha \leq 150^0$

Case 1. For $\alpha = 0^0$

Angle	Conducting SCRS
$0^0 \leq \alpha \leq 30^0$	G5,G6
$30^0 \leq \alpha \leq 60^0$	G1,G6
$60^0 \leq \alpha \leq 90^0$	G1,G6
$90^0 \leq \alpha \leq 120^0$	G1,G2
$120^0 \leq \alpha \leq 150^0$	G1,G2
$150^0 \leq \alpha \leq 180^0$	G3,G2
$180^0 \leq \alpha \leq 210^0$	G3,G2
$210^0 \leq \alpha \leq 240^0$	G3,G4
$240^0 \leq \alpha \leq 270^0$	G3,G4
$270^0 \leq \alpha \leq 300^0$	G5,G4
$300^0 \leq \alpha \leq 330^0$	G5,G4
$330^0 \leq \alpha \leq 360^0$	G5,G6

Case 1. For $\alpha = 30^0$

Angle	Conducting SCRS
$0^0 \leq \alpha \leq 30^0$	G5,G6
$30^0 \leq \alpha \leq 60^0$	G5,G6
$60^0 \leq \alpha \leq 90^0$	G1,G6
$90^0 \leq \alpha \leq 120^0$	G1,G6
$120^0 \leq \alpha \leq 150^0$	G1,G2
$150^0 \leq \alpha \leq 180^0$	G1,G2
$180^0 \leq \alpha \leq 210^0$	G3,G2
$210^0 \leq \alpha \leq 240^0$	G3,G2
$240^0 \leq \alpha \leq 270^0$	G3,G4
$270^0 \leq \alpha \leq 300^0$	G3,G4
$300^0 \leq \alpha \leq 330^0$	G5,G4
$330^0 \leq \alpha \leq 360^0$	G5,G4

Case 2. For $\alpha = 90^0$

Angle	Conducting SCRS
$0^0 \leq \alpha \leq 30^0$	G5,G4
$30^0 \leq \alpha \leq 60^0$	G5,G4
$60^0 \leq \alpha \leq 90^0$	G5,G6
$90^0 \leq \alpha \leq 120^0$	G5,G6
$120^0 \leq \alpha \leq 150^0$	G1,G6
$150^0 \leq \alpha \leq 180^0$	G1,G6
$180^0 \leq \alpha \leq 210^0$	G1,G2
$210^0 \leq \alpha \leq 240^0$	G1,G2
$240^0 \leq \alpha \leq 270^0$	G3,G2
$270^0 \leq \alpha \leq 300^0$	G3,G2
$300^0 \leq \alpha \leq 330^0$	G3,G4
$330^0 \leq \alpha \leq 360^0$	G3,G4

Arduino Code:-

```
// Define the SCR gate pins
const int G1 = 2;  // Replace with the actual pin numbers
const int G2 = 3;
const int G3 = 4;
const int G4 = 5;
const int G5 = 6;
const int G6 = 7;
// Define the time parameters
const float timePeriod = 0.02;  // Time period in seconds
const float pulseWidth = 0.02 * 0.05;  // Pulse width (5% of time period)
float a = 30.0;  // Phase angle in degrees (initial value set to 30 degrees)

void setup() {
  // Configure SCR gate pins as output
  pinMode(G1, OUTPUT);
  pinMode(G2, OUTPUT);
  pinMode(G3, OUTPUT);
  pinMode(G4, OUTPUT);
  pinMode(G5, OUTPUT);
  pinMode(G6, OUTPUT);
}
```

```
void loop() {
  // Calculate the phase delays in microseconds
  long delayG1 = long(a * timePeriod * 1000000 / 360.0);
  long pulseOn = long(pulseWidth * 1000000);
  long delay60degEFF = long(60 * timePeriod * 1000000 / 360.0 - pulseWidth * 1000000);
  delayMicroseconds(delayG1);
  // Trigger the SCRs with phase delays
  digitalWrite(G1, HIGH);
  delayMicroseconds(pulseOn);
  digitalWrite(G1, LOW);

  delayMicroseconds(delay60degEFF);

  digitalWrite(G6, HIGH);
  delayMicroseconds(pulseOn);
  digitalWrite(G6, LOW);

  delayMicroseconds(delay60degEFF);

  digitalWrite(G3, HIGH);
  delayMicroseconds(pulseOn);
  digitalWrite(G3, LOW);
```

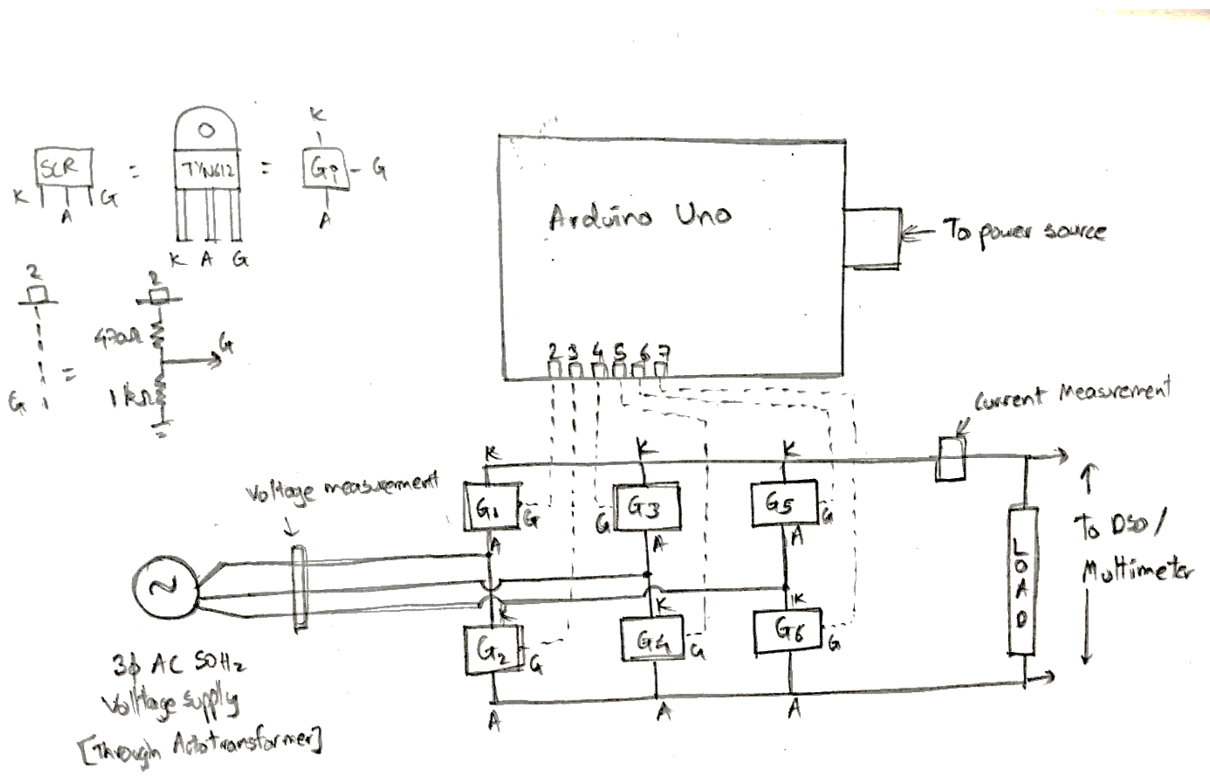
```
  delayMicroseconds(delay60degEFF);

  digitalWrite(G2, HIGH);
  delayMicroseconds(pulseOn);
  digitalWrite(G2, LOW);
  delayMicroseconds(delay60degEFF);
  digitalWrite(G5, HIGH);
  delayMicroseconds(pulseOn);
  digitalWrite(G5, LOW);

  delayMicroseconds(delay60degEFF);

  digitalWrite(G4, HIGH);
  delayMicroseconds(pulseOn);
  digitalWrite(G4, LOW);

  delayMicroseconds(delay60degEFF - delayG1);

  // Add a delay before the next cycle (adjust as needed)
  // delay(1000);  // Delay between cycles in milliseconds
}
```

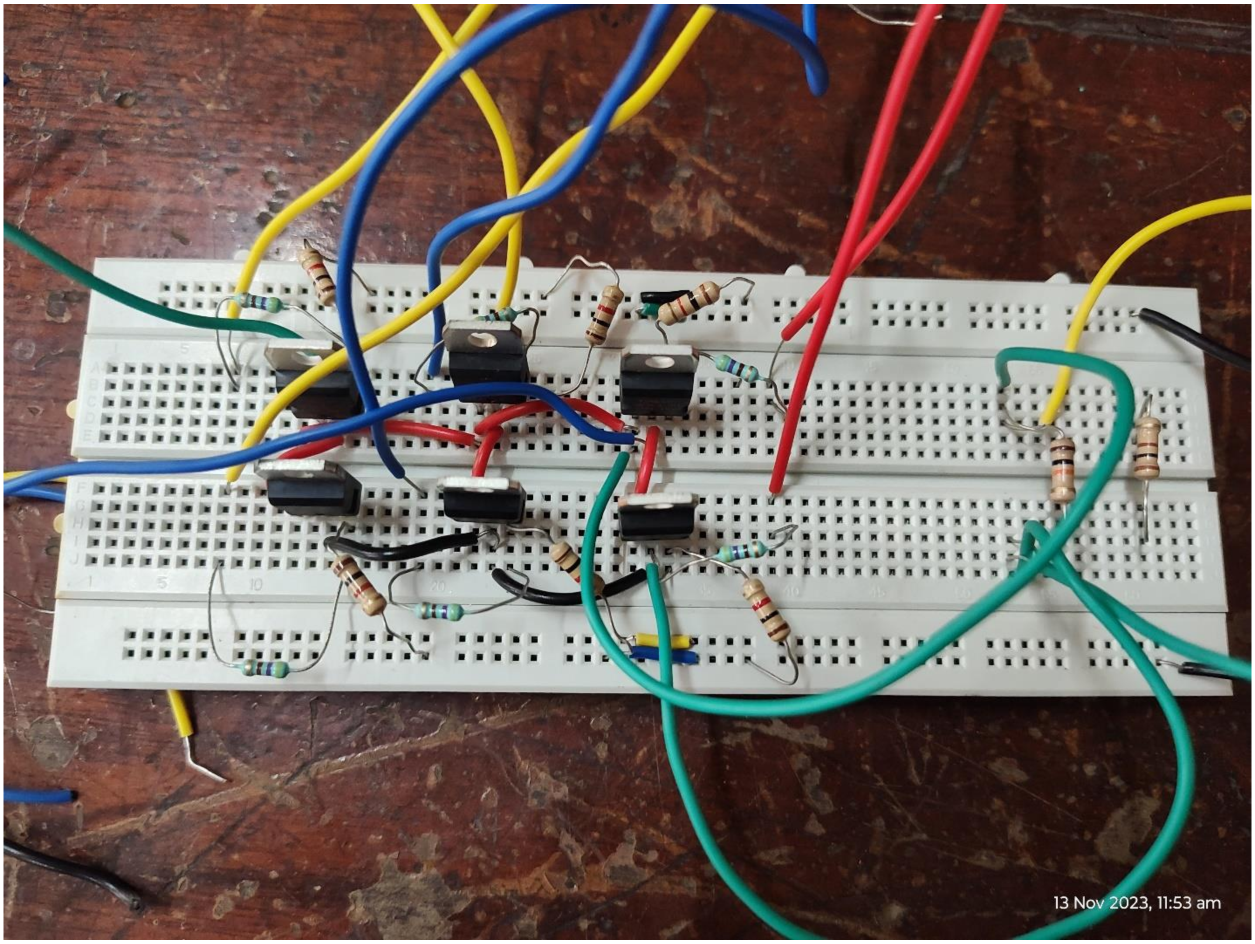
Experimentation & Discussion:-

1] *Procedure*

- Make all connections as per the circuit diagram and ensure that Arduino is not powered, Load is attached, and Autotransformer is in minimum position.
- First connect the 230V 3-phase AC supply from the Auto Transformer to the circuit.
- Connect firing pulses from Arduino to the six different SCRs as indicated in the circuit.
- Connect appropriate resistance on the gate of each SCR to generate a current pulse as Arduino is a voltage control device.
- Connect load (R-Load) across the circuit as shown in the circuit diagram.
- Connect DSO probes and observe the waveforms of voltage and current at different points in the circuit to understand the circuit.
- Measure output voltage and current by connecting the AC voltmeter and ammeter. Tabulate all readings. Also, save the waveforms.

2] *Circuit Connections:*





3] Calculations:

Given Data:- V_m = 10V, f = 50Hz, α = 30^0, 90^0

There are two operating conditions for obtaining the output based on the firing angle (α) in degrees:-

1. $0^0 \le \alpha \le 60^0$

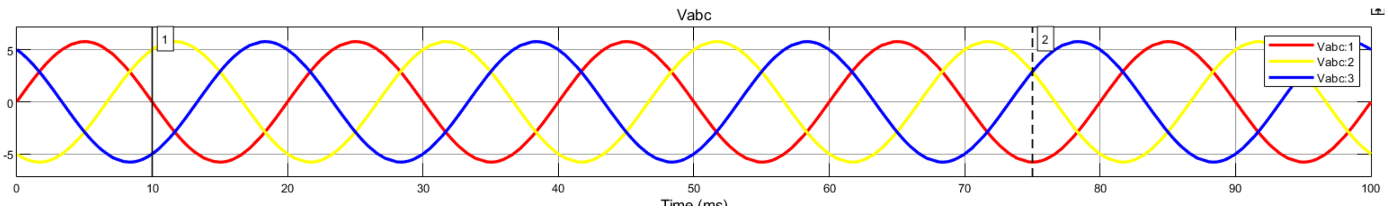
   Voavg = 1/(π/3) $\int_{30+\alpha}^{90+\alpha} \sqrt{3}\, Vm\, Sin(wt+30)d(wt)$ = 3√3 V_m Cosα / π
   = 3√3 * 10 * Cos(30^0) / π = 14.32V.

2. $60^0 \le \alpha \le 150^0$

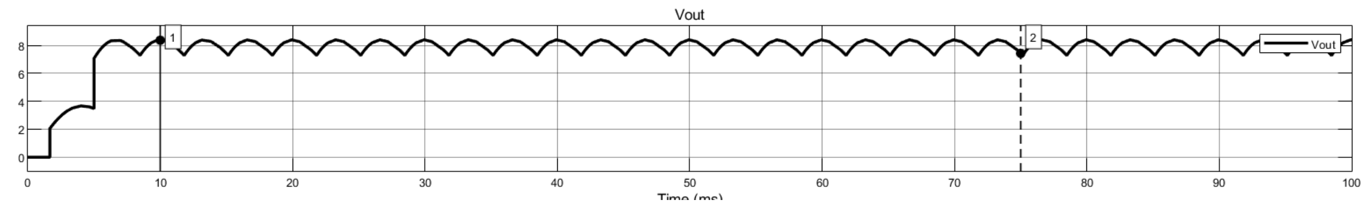
   Voavg = 1/(π/3) $\int_{30+\alpha}^{150} \sqrt{3}\, Vm\, Sin(wt+30)d(wt)$ = 3√3 V_m [1 + Cos(60^0 + α)] / π
   = 3√3 * 10 * [1 + Cos(60^0 + 90^0)] / π = 2.22V.

4]   *Simulation Waveforms:*

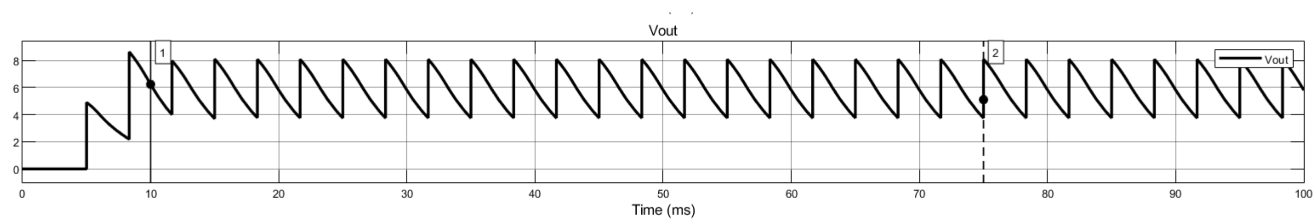
Input Voltage Waveform



Output Voltage Waveform for $\alpha = 30^0$



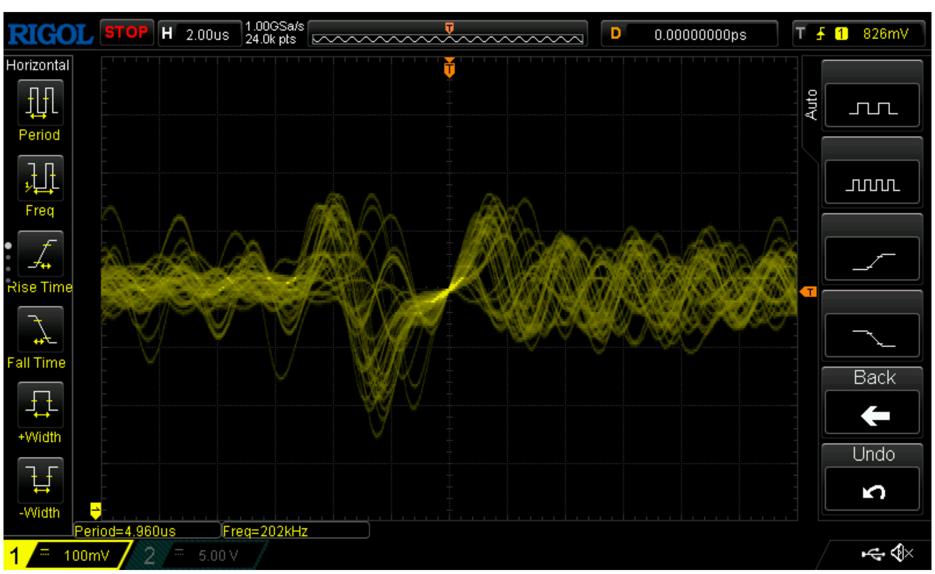
Output Voltage Waveform for $\alpha = 90^0$



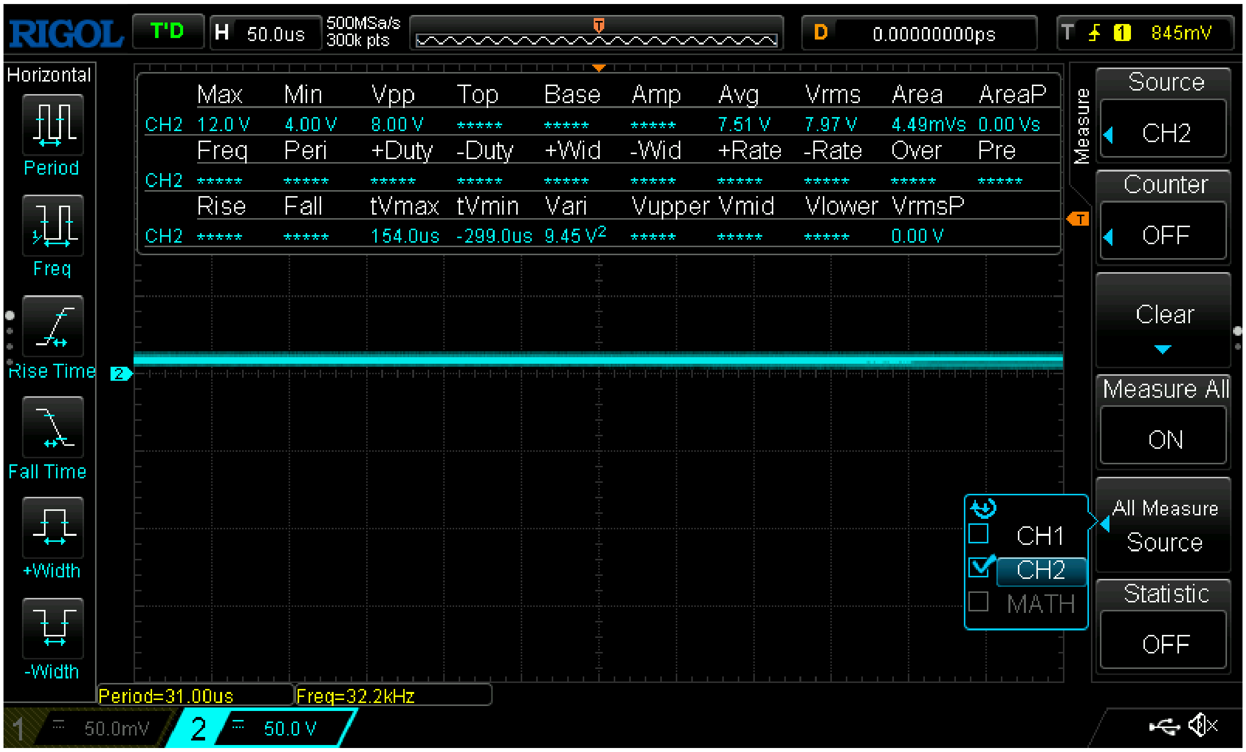
As the Load is resistive in nature, the current waveform will be the same as the Voltage waveform

5]   *Output Waveforms:*

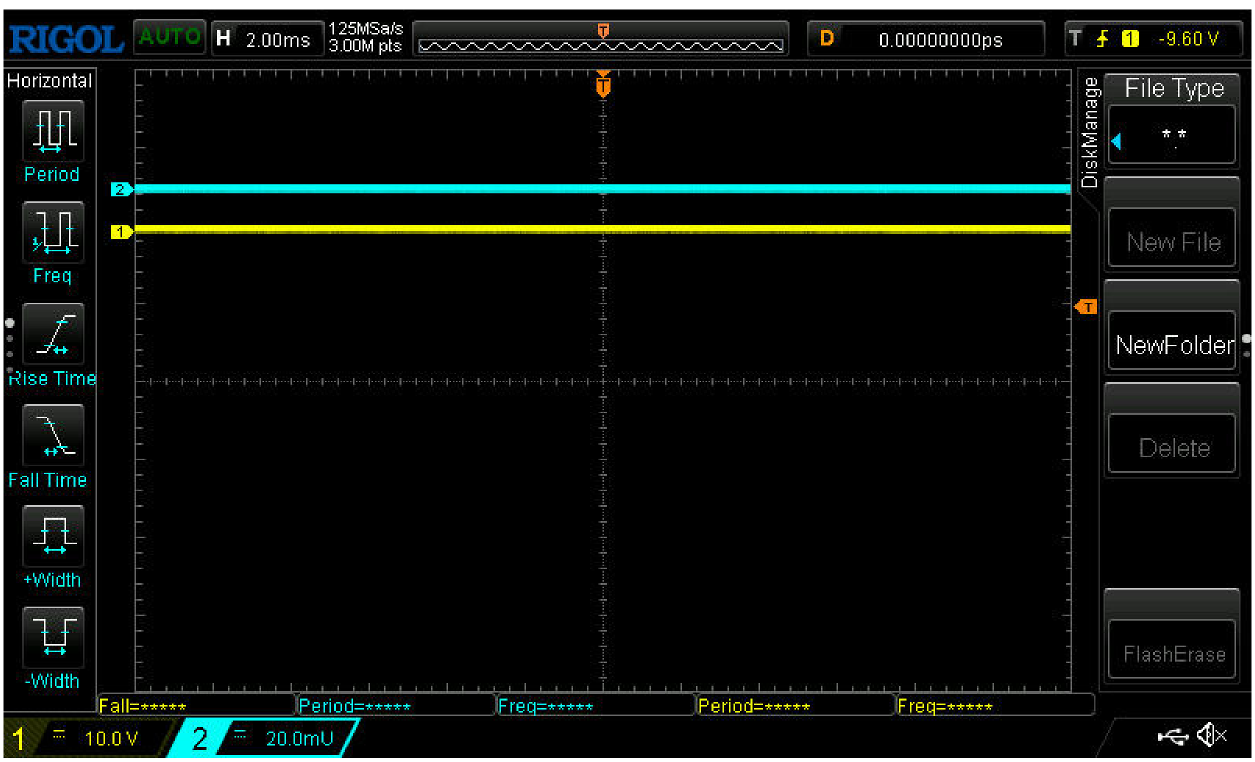
Current Waveform: -



Output Voltage Waveform for Firing angle (α) = 30º -



Output Voltage Waveform for Firing angle (α) = 90º -



Results:-

I. *Calculated Average Output Voltages:*

- For the firing angle range $0^0 \leq \alpha \leq 60^0$, the calculated average output voltage (V_{oavg}) is 14.32V.
- For the firing angle range $60^0 \leq \alpha \leq 150^0$, the calculated average output voltage (V_{oavg}) is 2.22V.

II. *Theoretical Expectations:*

- The calculated average output voltages align with theoretical expectations based on the given firing angle ranges.
- These values provide insights into the expected behavior of the three-phase full-controlled converter for the specified operating conditions.

III. *Voltage Control with Firing Angle:*

- The calculations confirm the influence of the firing angle ($0^0 \leq \alpha \leq 150^0$) on the average output voltage.
- As α increases within the specified ranges, the average output voltage decreases, showcasing the controllability of the converter.

IV. *Practical Implications:*

- The calculated values serve as a reference for practical experimentation and measurement of the three-phase full-controlled converter's output.
- The theoretical expectations provide a basis for understanding how variations in the firing angle impact the output voltage.

Conclusion:-

V. *Suitability for Motor Speed Control:*

- The experimental setup demonstrated the suitability of the three-phase full-controlled converter for applications demanding control over the speed of DC motors.
- By adjusting the firing angle of the SCRs, the rectifier effectively controlled the voltage supplied to the motor, thus regulating its speed.

VI. *Firing Angle Control For Voltage Adjustment:*

- Firing angle control proved effective in adjusting the output voltage.
- Calculations and simulations aligned with practical observations, confirming the controllability of the converter.

VII. *Limitations in Measurement Equipment:*

- Challenges were encountered in accurately measuring the waveform outputs at specific firing angles using the available measurement equipment (DSO and multimeter).
- The clarity of waveforms, especially at extreme firing angles, was affected by the limitations of the instruments.

Inference:-

I. *Verification of Theoretical Concepts:*
- The experiment verified the theoretical concepts of firing angle control in a three-phase full-controlled converter.
- The calculated and simulated values provided a basis for understanding the expected behavior of the system.

II. *Practical Challenges:*
- Practical challenges, such as limitations in measurement equipment, were encountered in obtaining clear and precise waveforms, especially at extreme firing angles.
- These challenges highlight the importance of considering practical constraints in experimental setups.

III. *Application in Motor Control:*
- The successful demonstration of motor speed control reaffirms the practical application of three-phase full-controlled converters in industrial settings.
- Controlling the firing angle allows for precise regulation of power delivered to the load.

In conclusion, while the experiment validated the theoretical principles of the three-phase full-controlled converter, practical challenges underscore the importance of considering real-world limitations in experimental setups. The successful application of firing angle control in motor speed regulation highlights the practical significance of such converters in industrial power control applications.

Links:-

1. MATLAB Simulink file (https://drive.google.com/file/d/14G_R_ONvEzWw9J7PwRECdjHugvhYvrR0/view?usp=sharing)
2. Arduino Uno Code file (https://drive.google.com/file/d/1r4bE0HgKApP35gizbl6g3Oaj2mWoGVdg/view?usp=sharing)

Thank You!