AC Voltage Controllers

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POWER ELECTRONICS (ESI 012A)
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1. OBJECTIVES

- Understanding the characteristics of AC voltage controllers by phase.
- To control the speed of a motor using an AC voltage controller by phase.

2. MATERIALS

- 24V, 2A center tap transformer.
- TIC236D TRIAC or similar.
- 127V AC motor
- 100Ω (2W) resistor.
- A control circuit to trigger TRIACs, based in discreet devices, integrated circuits or micro-controllers.

3. PROCEDURE

1. Given the circuit from Fig. 1, calculate the RMS voltage and current in the load when the TRIAC is triggered at: 1, 2, 3, 4, 5, 6 and 7 ms (with symmetric values for the second trigger).
2. Build the circuit from Fig. 1 with the correct coupling and measure the same values of the previous point.

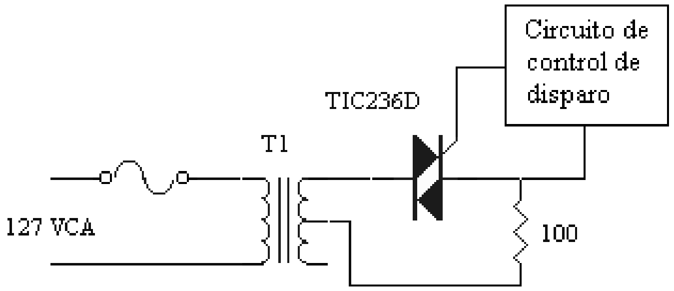

Fig. 1: AC voltage controller by phase.

3. Build the circuit from Fig. 2 using an opto-coupler (opto-isolator) and watch what happens with different trigger angles. Check the voltage waveform at the load.
4. Analyze and calculate what happened on the previous points.

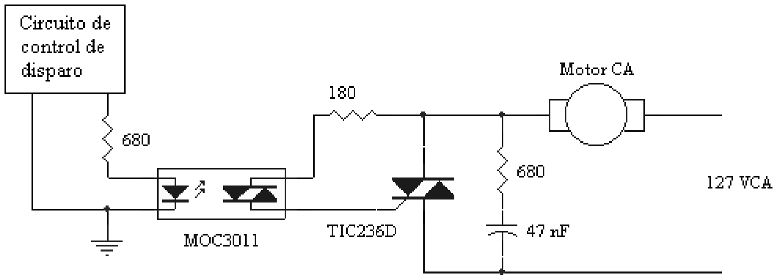

Fig. 2: AC voltage controller on a motor.

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4. CALCULATIONS

For the circuit in Fig. 1, and calculate the RMS voltage by using equation (1).

$$V_{RMS}=\sqrt{\frac{1}{T}\int_{0}^{T}[V_{signal}(\omega t)]^{2}d\omega t} \qquad (1)$$

The voltage at the load depends from the trigger period (α), and therefore no voltage at the load will exist until the thyristor has been triggered. Then by analyzing the signal we have that:

$$V_{RMS}=\sqrt{\frac{1}{T}\int_{\alpha}^{T/2}V_{p}^{2}\sin^{2}(\omega t)d\omega t}+\sqrt{\frac{1}{T}\int_{\alpha+T/2}^{T}V_{p}^{2}\sin^{2}(\omega t)d\omega t}$$

Thus calculating for the first part with different trigger values then with a transformer of $V_{RMS}=12[V]$ then we can build the next table.

α (ms)	V_{RMS} (V)
1	**11.93**
2	**11.50**
3	**10.48**
4	**8.86**
5	**6.65**
6	**4.23**
7	**1.93**

Below some graphics of a mathematical TRIAC emulation.

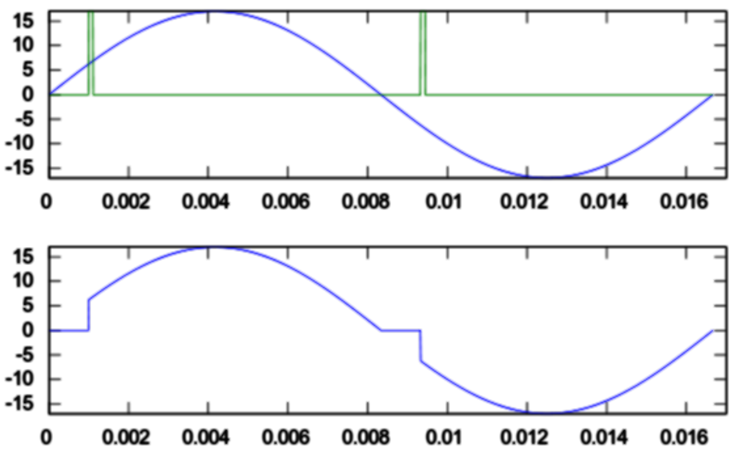

Fig. 3: Triggered at 1 ms.

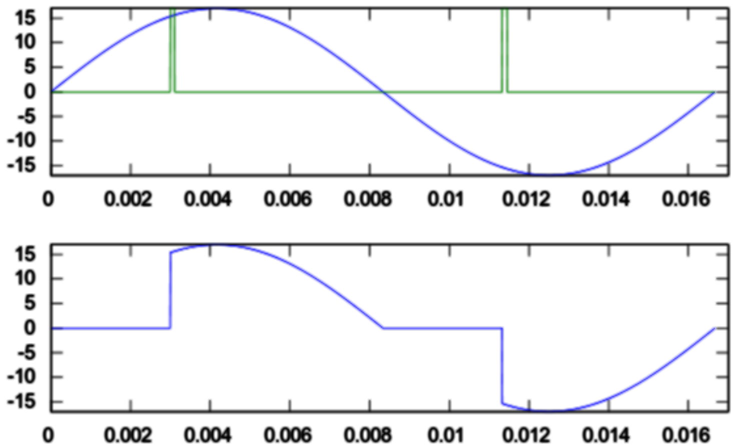

Fig. 4: Triggered at 3 ms.

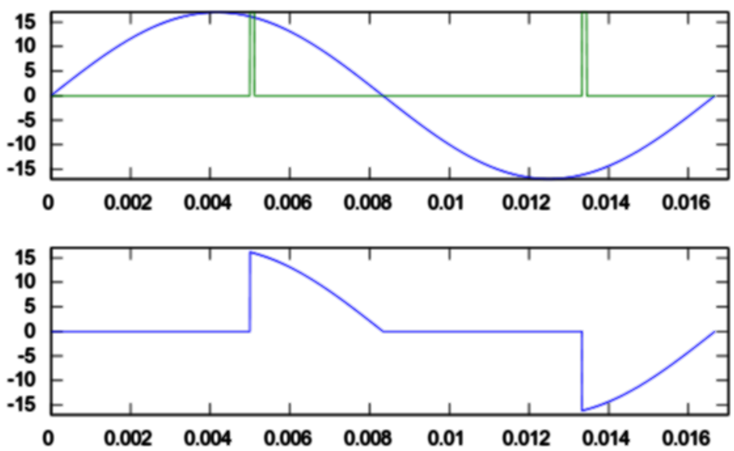

Fig. 5: Triggered at 5 ms.

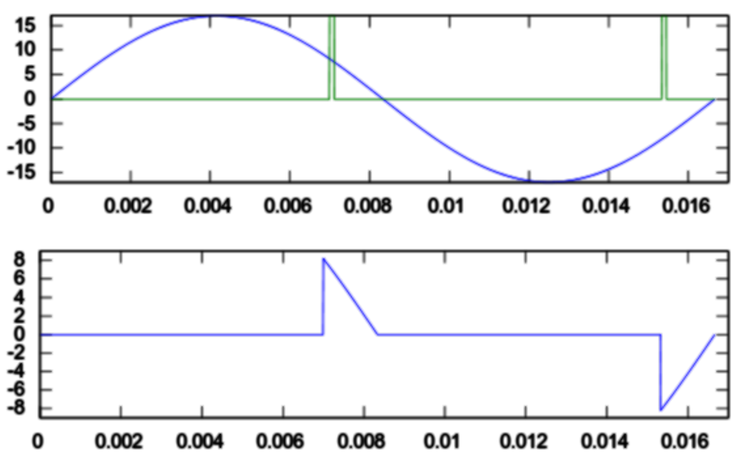

Fig. 6: Triggered at 7 ms.

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Now, for the AC motor load connected to the mains (127 V) the calculations give.

α (ms)	V_{RMS} (V)
1	**126.30**
2	**121.78**
3	**110.99**
4	**93.43**
5	**70.43**
6	**44.78**
7	**20.43**

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5. SIMULATIONS

Simulations were done by using SPICE with a resistive load of 100 Ω from Fig. 1.

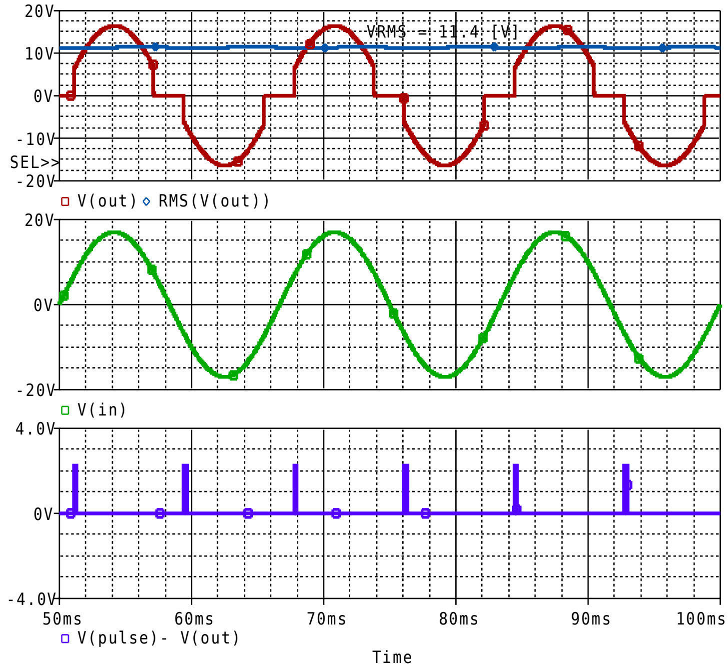

Fig. 7: Triggered at 1 ms.

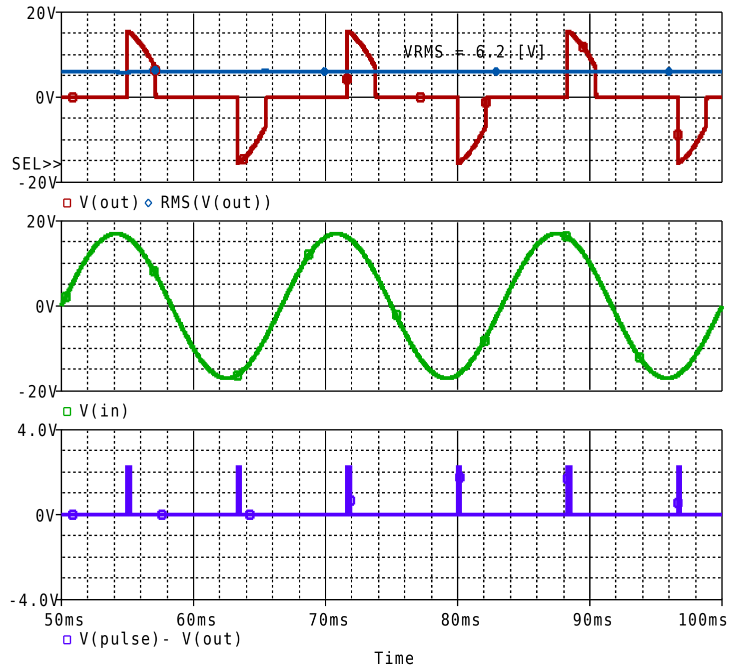

Fig. 9: Triggered at 5 ms.

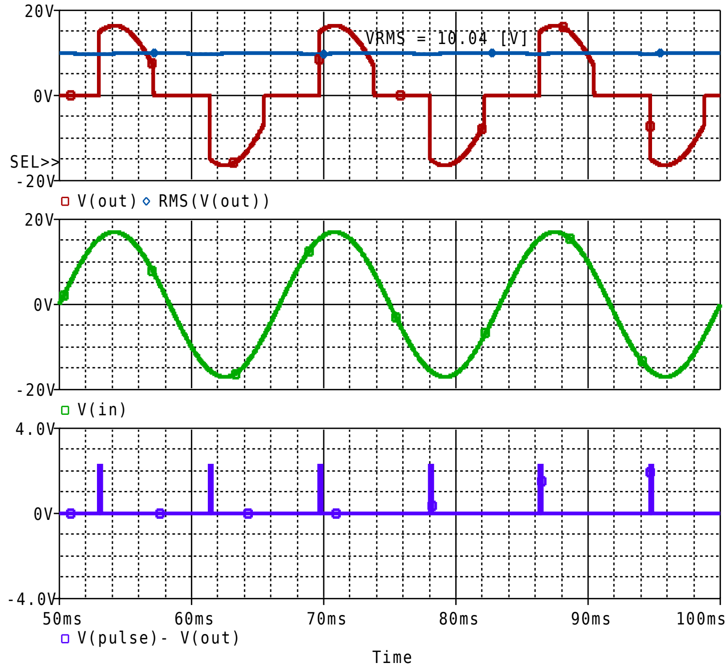

Fig. 8: Triggered at 3 ms.

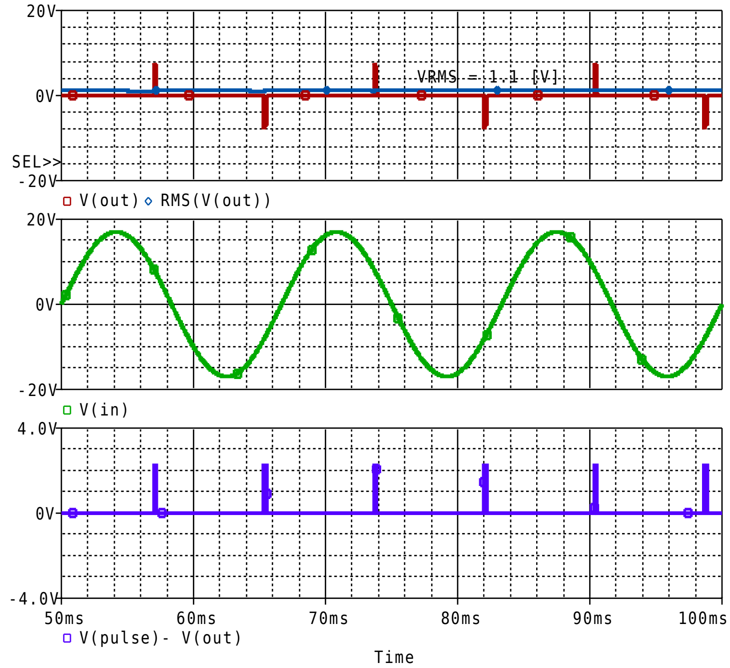

Fig. 10: Triggered at 7 ms.

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6. REAL-LIFE MEASUREMENTS

We used a SC146D TRIAC, and measuring the RMS voltage at the load from the first circuit (Fig. 1) we got.

α (ms)	V_{RMS} (V)
1	11.80
2	11.00
3	10.20
4	7.95
5	6.92
6	3.92
7	0.40

And for the AC motor circuit (Fig. 2), the measurements

α (ms)	V_{RMS} (V)
1	124.0
2	120.0
3	111.0
4	94.5
5	73.1
6	27.9
7	24.6

Fig. 11 & FIg. 12 display some plots from the first circuit with a pure resistive load.

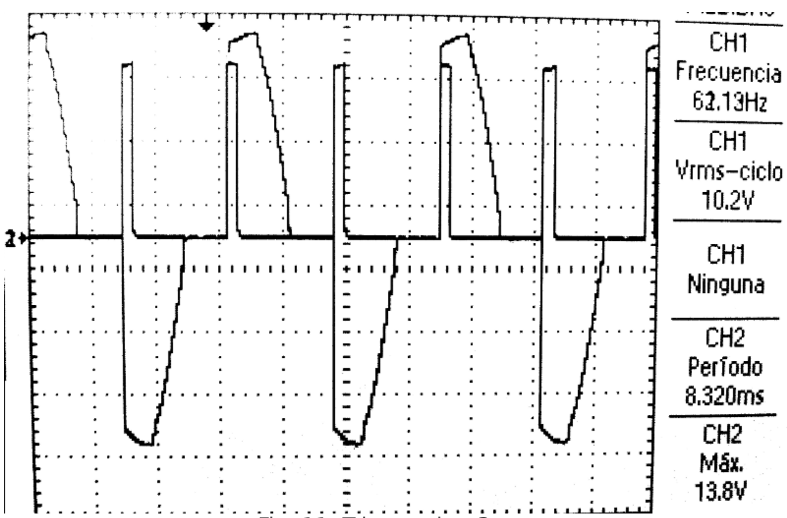

Fig. 11: Triggered at 3 ms.

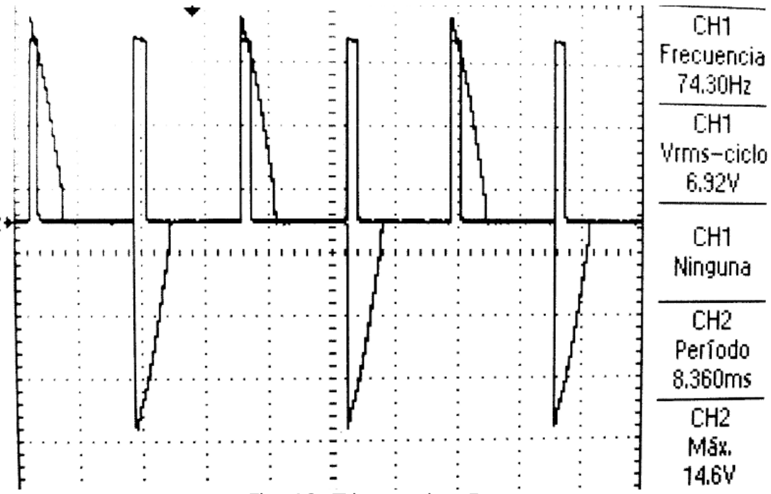

Fig. 12: Triggered at 5ms.

While the next plots (Fig. 13 & Fig. 14) correspond to the AC motor.

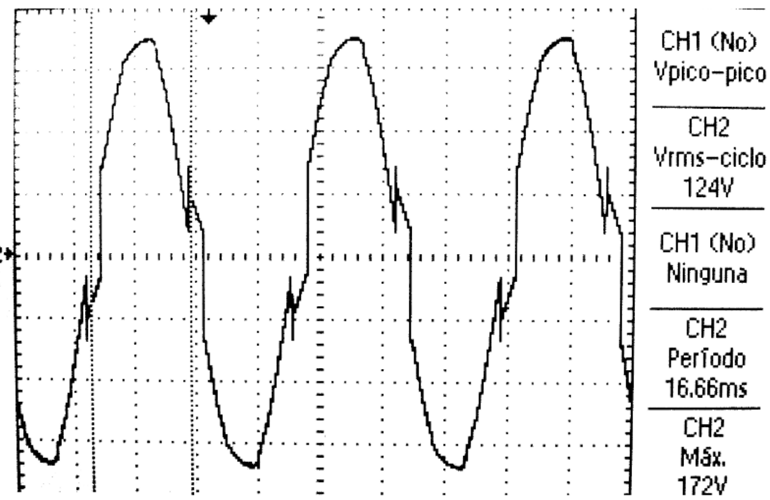

Fig. 13: Triggered at 1 ms.

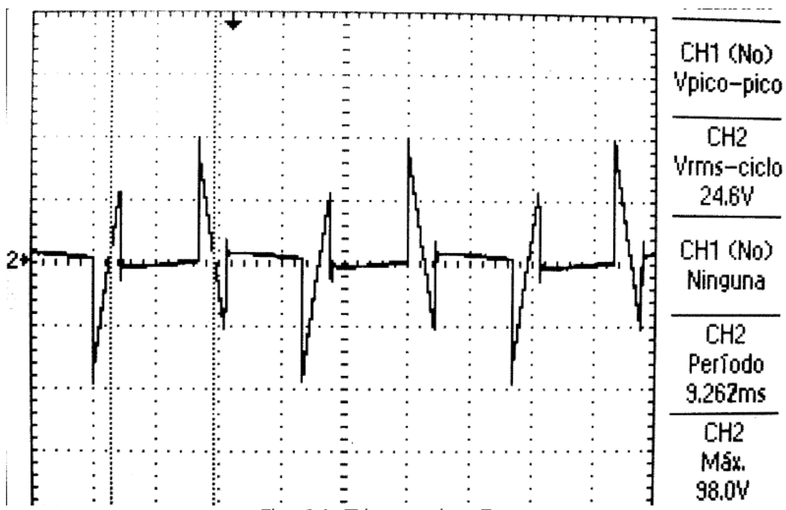

Fig. 14: Triggered at 7 ms.

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7. COMPARATIVE

Summarizing the results from the first circuit (Fig. 1) from previous sections, we can build up the following table.

	Calculations	***SPICE***	***Real Life***
α (ms)	V_{RMS} (V)	V_{RMS} (V)	V_{RMS} (V)
1	**11.93**	**11.40**	**11.80**
2	**11.50**	**10.93**	**11.00**
3	**10.48**	**10.04**	**10.20**
4	**8.86**	**8.30**	**7.95**
5	**6.65**	**6.20**	**6.92**
6	**4.23**	**3.66**	**3.92**
7	**1.93**	**1.10**	**0.40**

Then for the AC motor (Fig. 2), we got:

	Calculations	***Real Life***
α (ms)	V_{RMS} (V)	V_{RMS} (V)
1	**126.30**	**124.0**
2	**121.78**	**120.0**
3	**110.99**	**111.0**
4	**93.43**	**94.5**
5	**70.43**	**73.1**
6	**44.78**	**27.9**
7	**20.43**	**24.6**

8. CONCLUSIONS

We built a basic AC voltage controller by using a TRIAC, we had to synchronize the trigger pulses to the electric mains.

The controller allowed us to change the speed of our AC motor, we experienced some problems with the heat production as we kept the frequency constant and since:

$$\phi = \frac{V}{f}$$

therefore our motor temperature raised.

We also noticed that the snubber network allowed us to reduce the surges caused by the inertia of our rotating motor, by changing the values of such capacitors we can then also change the frequency of the dampened response caused by the RLC network.

We also learned that to measure directly onto the motor with an equipment that is also connected to the electrical mains. First we had to make sure which terminal was the **live, ground**, and **neutral** by using a volt-meter, grabbing one terminal and then connecting to each terminal in he connector**.** Then we proceed to connect the common ground with the neutral wire.