

05-VAWT Generator Testing

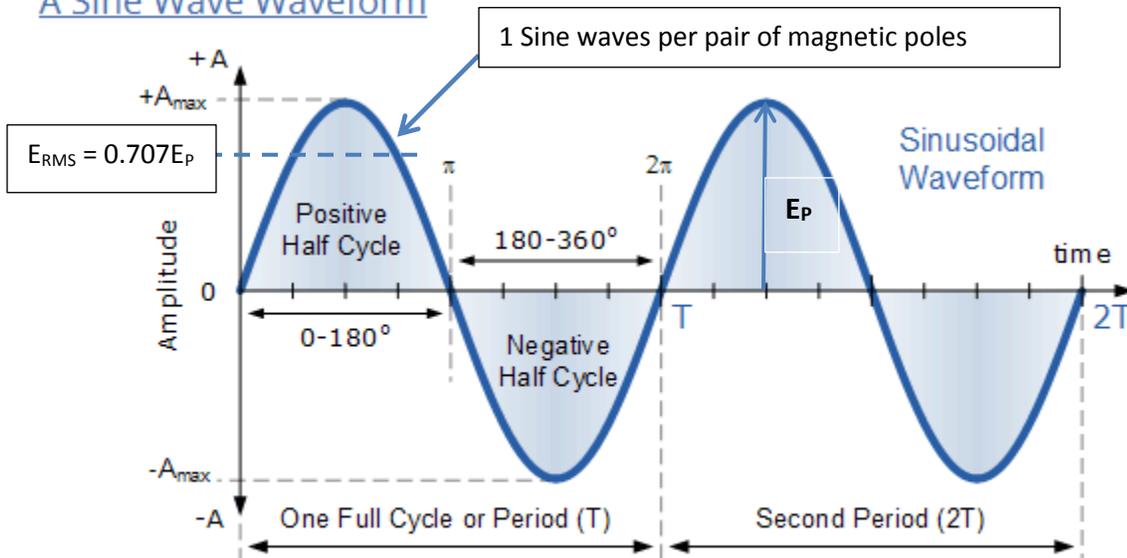
Introduction

The purpose of this module is to measure and calculate the generated voltage as a function of the rotational velocity (revolutions per second). This will be accomplished by connect the generator shaft to a drill press chuck, varying the drill speed and using a Digital Voltmeter (DVM) measure the generator voltage and the voltage frequency. A tachometer will be used to measure shaft rotation rate in revolutions per minute (RPM) and related to the voltage frequency. At the end of this module you will know how many volts are generated per shaft revolution.

Sinewave Voltage Waveform

The generator we will be testing uses four magnets and four coils. Faraday's Law tells us that for a four pole generator, each shaft revolution produces two sinewaves, or 2Hz and a revolution per second (60RPM). Refer to <http://www.electronics-tutorials.ws/waveforms/waveforms.html> for a more complete discussion of sinusoidal waves. A brief summary of related facts follows:

A Sine Wave Waveform



Units of periodic time, (T) include: Seconds (s), milliseconds (ms) and microseconds (μs).

For a 4 –Pole Generator

Frequency in Hz = (Shaft Revolutions per second) x 2

$$F \text{ (Hz)} = 2 \times \text{rps}$$

Revolutions per minute (RPM) can be calculated from the generator frequency.

Revolutions per minute (RPM) = Revolutions per second x 60

$$\text{RPM} = 60 \times \text{rps}$$

Revolutions per minute (RPM)- Frequency relationship

$$\text{RPM} = F \text{ (Hz)} \times 30$$

Root-Mean-Square Voltage (RMS)

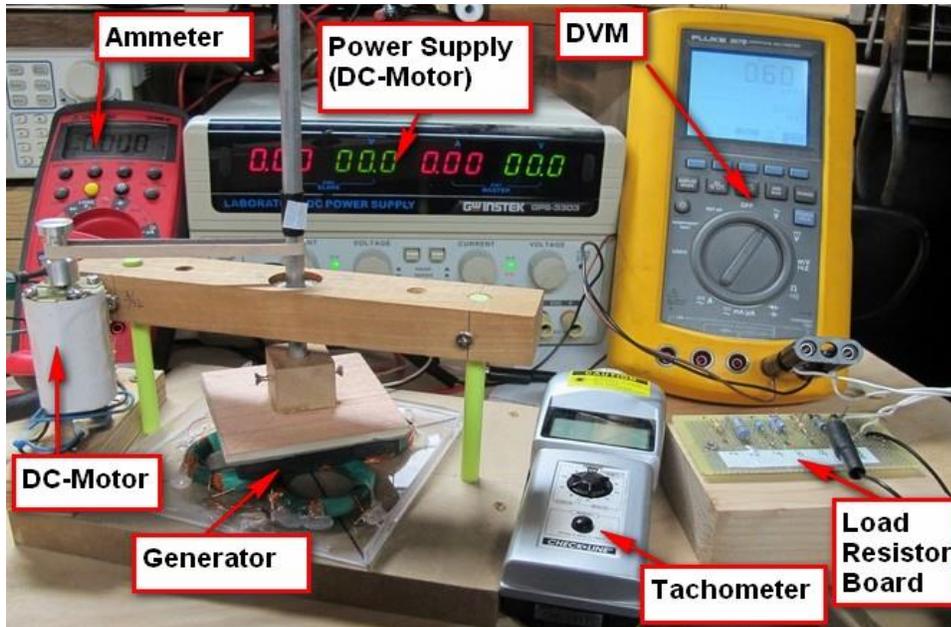
From the figure you can see that a sinewave is a alternating voltage (AC) that has both positive and negative values. An average of these values is zero. However, a sinusoidal electric current will heat a resistive load just like a battery or DC current will. The value of that voltage is 0.707 of the peak voltage (0.707 E_p). This means for a given electrical load (RL) the AC-RMS voltage will produce the same heat

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(power) a battery of the same value (10 v-rms = 10 v-dc). In this module all AV voltages will be measured as RMS voltages. We will not have to know the E_p value.

Generator Test Procedure

1. Connect the dc motor to the power supply.



Generator Test Setup

2. Secure the generator with the generator shaft approximately 3.5" from the motor shaft.
3. Couple the motor and generator shafts with a rubber band.
4. Connect the DVM to the generator coils. (the ones not connected to anything).
5. Measure the resistance using the ohmmeter. You should the total coil resistance plus the test lead resistance (approximately 13.5 ohms). If you do not get this troubleshoot the problem (loose wire?)
6. Change the DVM to AC Volts (this is an RMS voltage measurement)
7. Turn the power supply voltage knob the extreme counter clockwise position.
8. Turn on the power supply.
9. Adjust the power supply to start turn the shaft. You should start to see sinewave waveform appear on the DVM screen.
10. Continue to increase the voltage until you get close to the target RPM and frequency.
11. Record the actual voltage, RPM and frequency.
12. Repeat the procedure for the target values in the table below.

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- Record all data in your journal.
- This is the generator no-load data.

Measured Total Coil Resistance (R_G) =

		Measured No-Load	
RPM Target	RPM Actual	Freq. Hz	E_G
150			
210			
270			
330			
390			
450			
510			
600			

Load Testing Procedure

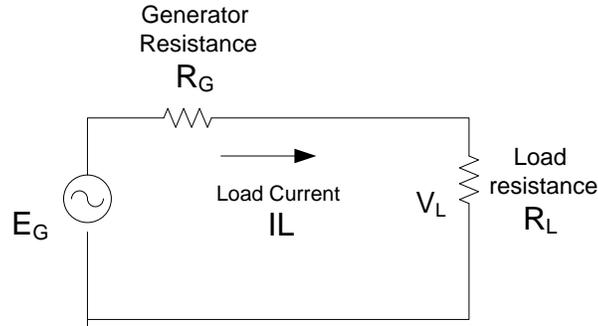
This involves connection various resistors across the output of the generator (DVM) terminals and measuring the resulting voltage (V_L). See the Generator equivalent circuit.



Load Resistors

- Adjust the generator speed to 510 RPM (as close as you can get).
- Using a jumper connector connect a load resistor starting with the highest value.
- Measure the resulting voltage with the DVM.
- Repeat the measurements for all load resistor values. The frequency should remain the same for all measurements.
- Record all data in your engineering journal.
- Referring to the Wind Turbine Equivalent Circuit Analysis, use EXCEL to calculate V_L .

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Equivalent Generator Circuit with Load Resistor

RPM Target	Target Freq. Hz	Measured Load Voltage				V _L	Calculated V _L $E_G = V_L$ for non-load $V_L = [E_G / (R_G + R_L)] R_L$ Use EXCEL for the calculations
		RPM Actual	Freq. Hz	RL ohms			
510	17.0			no-load			
510	17.0			4700			
510	17.0			27			
510	17.0			15			
510	17.0			10			
510	17.0			5			

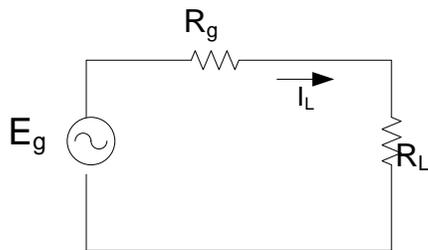
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Wind Generator Equivalent Circuit Analysis

The following is the equivalent circuit for a wind turbine.

E_g is the open circuit voltage with R_L open.

R_g = the internal generator resistance



Using Ohms law the current I_L is:

$$I_L = E_g / (R_g + R_L)$$

The voltage across the load resistor R_L is:

$$V_L = I_L R_L$$

Substituting for I_L :

$$V_L = [E_g / (R_g + R_L)] R_L$$

Divide by R_L :

$$V_L = E_g / (1 + R_g / R_L)$$

For $R_L = 10$ ohms, $R_g = 15$ ohms, $E_g = 3$ volts

$$V_L = (3) (10 / (15 + 10)) = (3) (10/25) = 1.2 \text{ volts}$$

Note: lowering R_g increases V_L