Experiments with 3-Phase Wind Turbines

For the Parallax Board of Education and Homework Board
Using the Whirlybird 3-Phase Wind Turbine

Experiment #3 – Adjusting The Load

Purpose

This experiment is designed to show how the wind turbine can power a resistive load of varying value. You will see how the wind turbine slows down by adding more and more load (less and less resistance).

You will come to understand that:

1. The wind turbine generates power based on the load applied to it…and

2. The wind turbine generates power based on the wind speed.

Background Information

If this is your first experiment or if you just need a refresher on some of the details please refer to the following background information guidelines:

- **Parts Assembly and Wiring Guidelines**
- **Coding Guidelines**
- **A/D Converter Chip Operation**
- **Resistor Color Codes**
- **Computing Current with Voltage Drop**
- **REEL Power Software Installation and Operation**

Wind Turbine Information

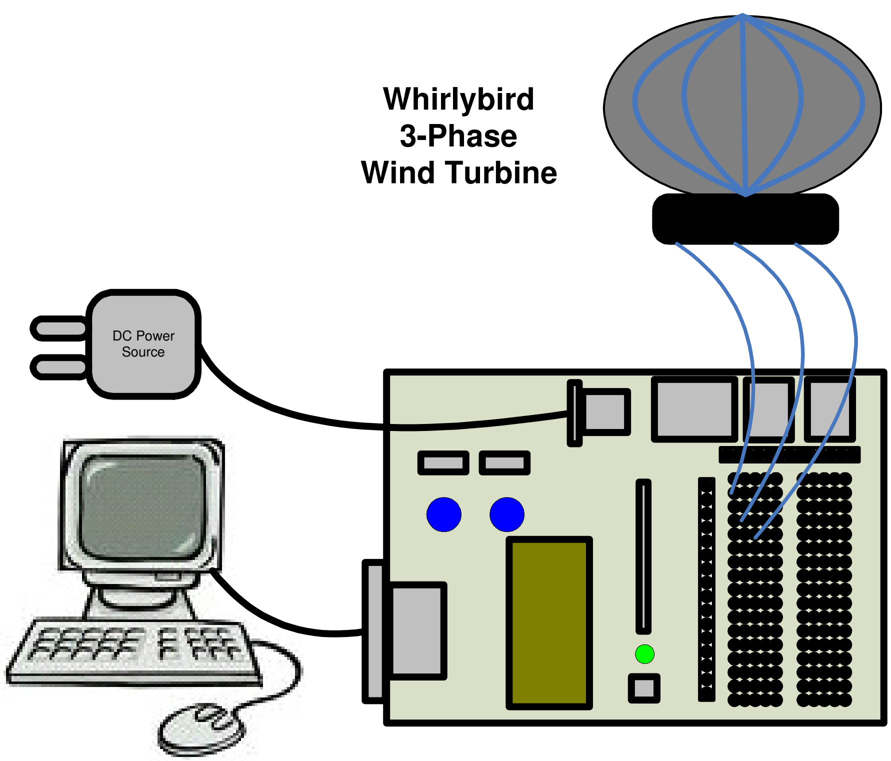
This will give you supplemental information on the wind experiment.

Equipment

Qty	Description
1	Whirlybird 3-Phase Wind Turbine
1	Parallax BOE or Homework Board
1	9-volt battery or +12 volt regulated DC supply
1	MCP3208 - 12-bit A/D converter chip
6	Diodes
1	1 ohm resistor
1	100 ohm potentiometer
10	Solid hookup wires
1	USB or RS232 cable
4	Clip leads
1	Table fan
1	Windows PC computer with **REEL Power** tm software (MACs must have Parallel's "Desktop 3.0 for Windows")
1	Printer (optional)

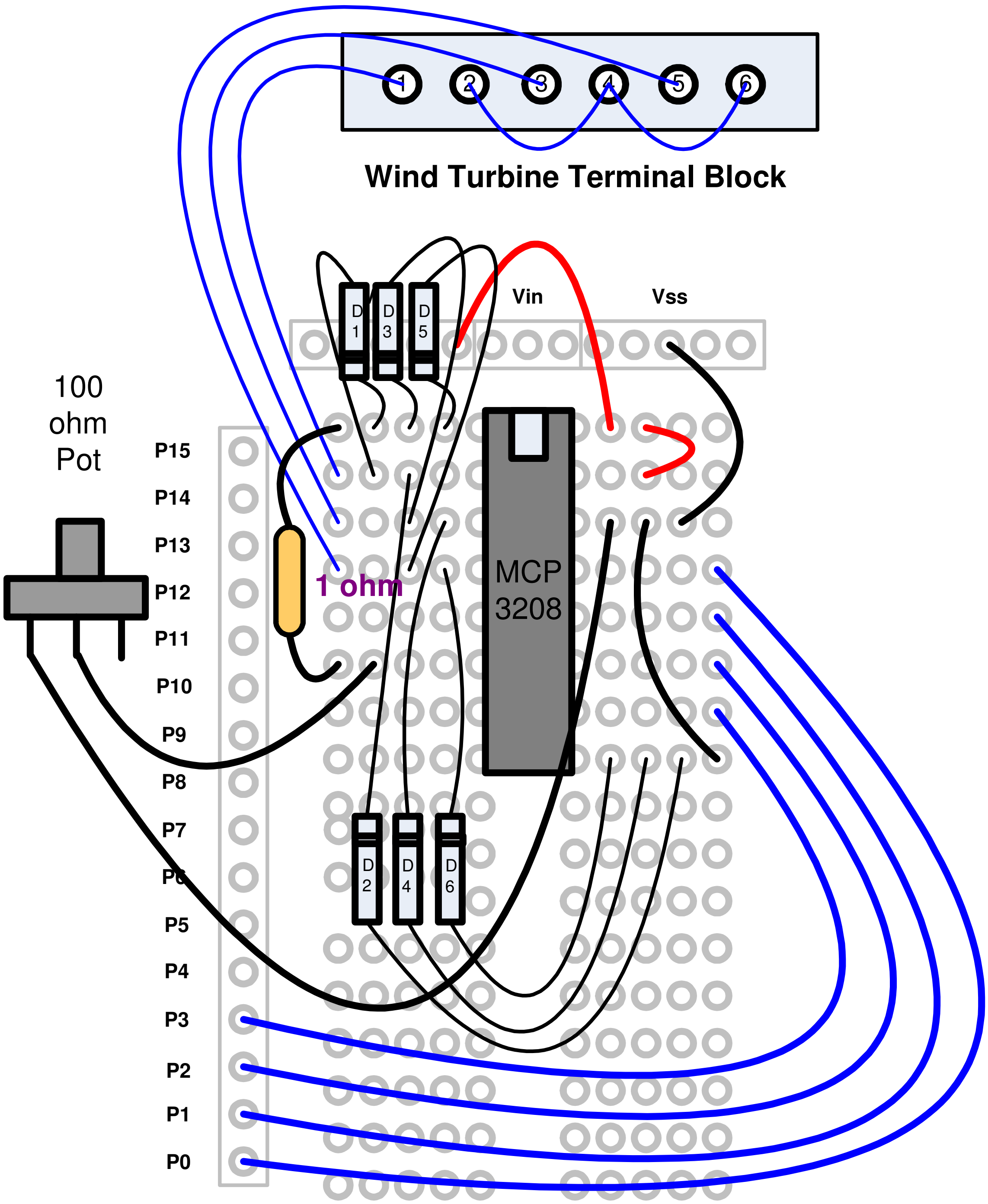
General Hardware Hookup for Whirlybird Wind Turbine

Setup the equipment as shown here, and then examine the **Jumper Board Hookup** (next) for specific details.

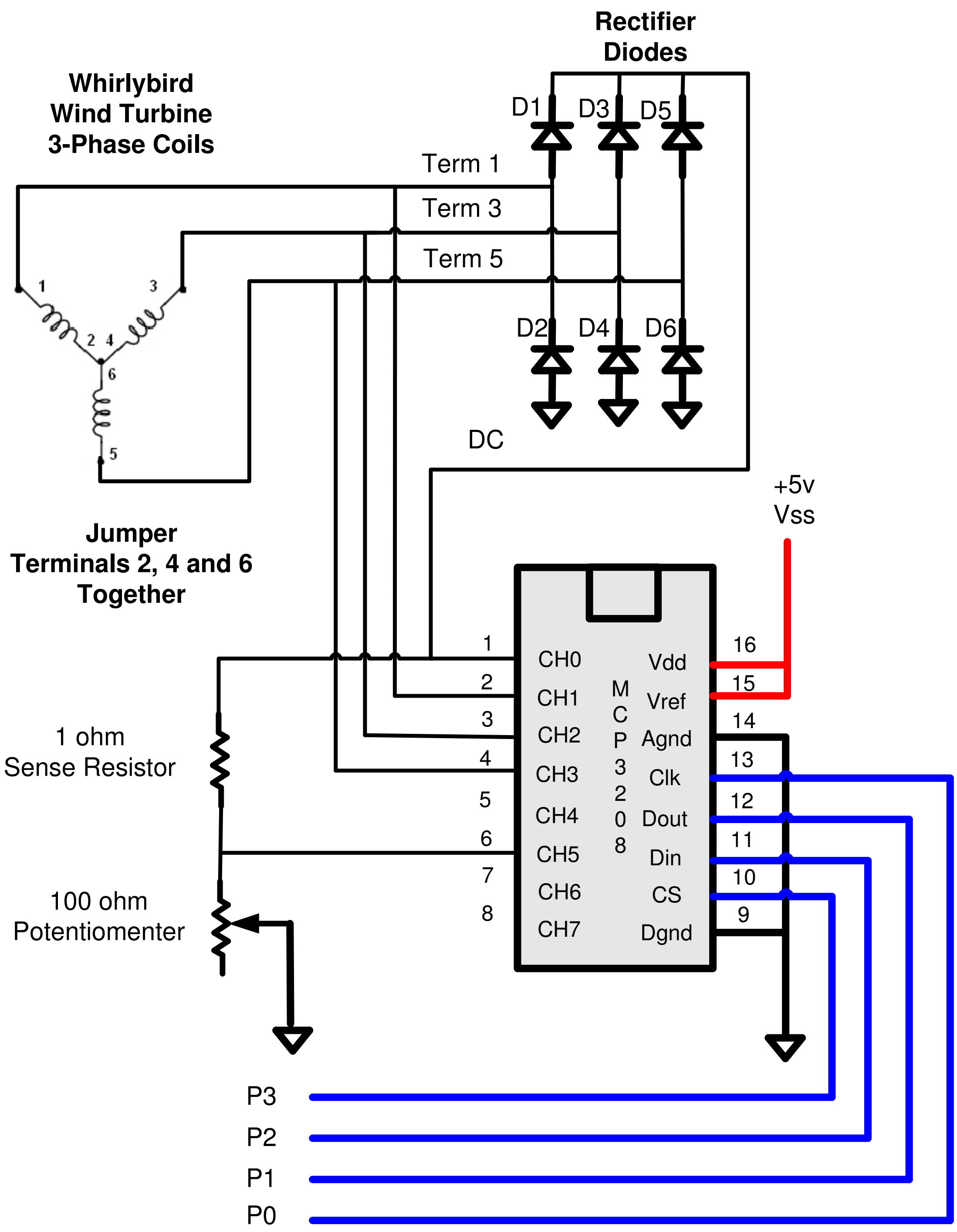


Jumper Board Hookup for Whirlybird Wind Turbine

Caution: This is a very dense hookup with many components whose wires can accidentally short together. Be careful in placing components so that they remain apart from one another.



Schematic for Whirlybird Wind Turbine



Code File

Download the following file to the BASIC Stamp:

Parallax_Wind_RPM_Exp.bs2

The code file can be found on the REEL Power CDROM that came with this lesson or on the LearnOnLine website at www.learnonline.com.

Code Algorithm

Here's how the code works to acquire and display the rectified voltage, current, power and RPM. For complete details refer to the above code file.

The Main loop looks like this…

```
Wind_RPM_Exp:
  GOSUB   Take_Samples
  GOSUB   Measure_RPM
  GOSUB   Transmit_Data_To_PC
  GOTO    Wind_RPM_Exp
```

The first subroutine acquires and averages samples of the rectified DC signal.

```
GOSUB   Take_Samples
```

Sixteen samples are taken one after the other then summed and averaged in an attempt to filter out the majority of the ripples. While somewhat effective, ripples still remain; however, the computed current is far more accurate doing it this way.

The second subroutine measures the RPM or revolutions per minute of the spinning wind turbine.

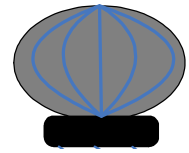
```
GOSUB   Measure_RPM
```

It does this by detecting the period of the phase1 signal and then computes the rate of rotation (RPM) using this time period number.

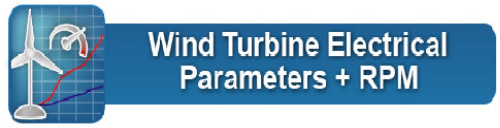
```
GOSUB   Transmit_Data_To_PC
GOTO    Wind_RPM_Exp
```

The final routine computes the checksum for the sampled data and transmits it to the computer. Then the entire routine repeats.

Procedure – Using the Whirlybird Wind Turbine



1. Click on the **REEL Power** tm icon to bring up the software menu. Then click on the **Wind Turbine Electrical Parameters + RPM** icon.



2. On the graphic display, click on the Connect button at the lower-left of the screen. Verify that the connected icon appears validating the Comm port selection. Make sure to click on the arrow and select the highest comm port number.

3. On the computer adjust the voltage (vertical) scale on the **REEL Power** tm software to 5.00 volts.

4. Adjust the potentiometer for maximum resistance – normally fully counter-clockwise. Temporarily remove the potentiometer from the circuit.

5. Set the fan to the highest speed setting and verify the following plot in Figure 1 below. This is a plot with no load applied. A small amount of current is displayed, but this is due to sampling the sense resistor after sampling the primary voltage, both of which are varying at different times.

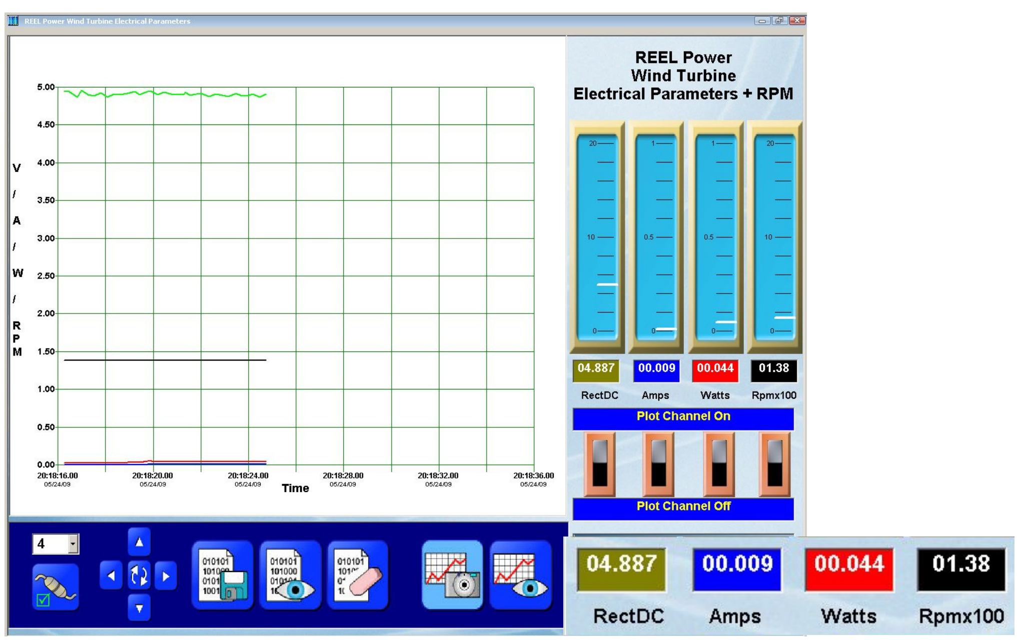


Figure 1– Filtered Rectified DC with No Load

6. Add the potentiometer back into the circuit and decrease the vertical range until the current and power plots are better visible. Your plot should like that in Figures 2. Note the drops in voltage and RPM.

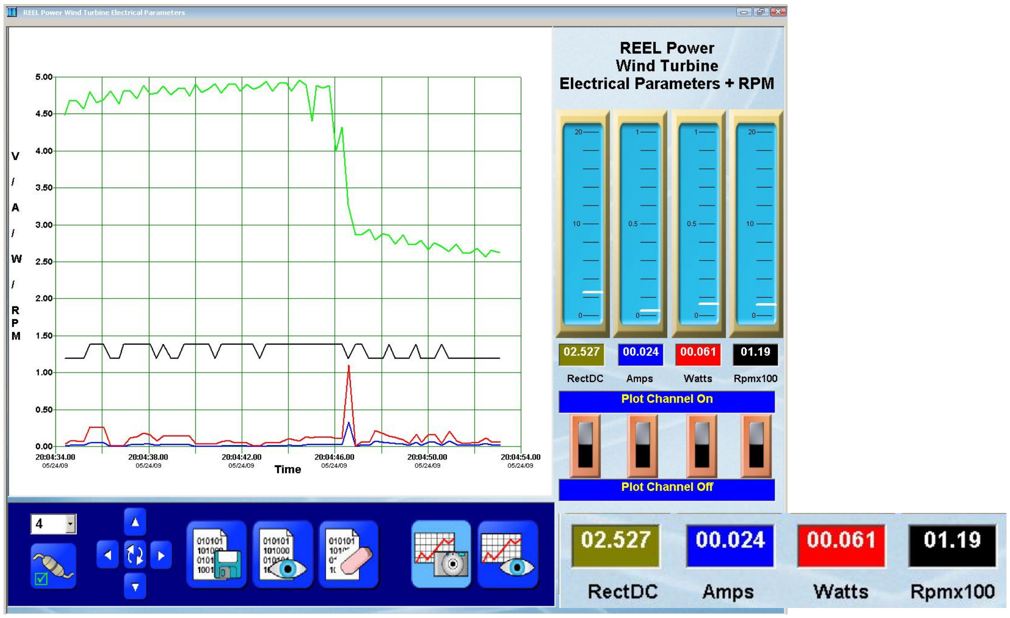
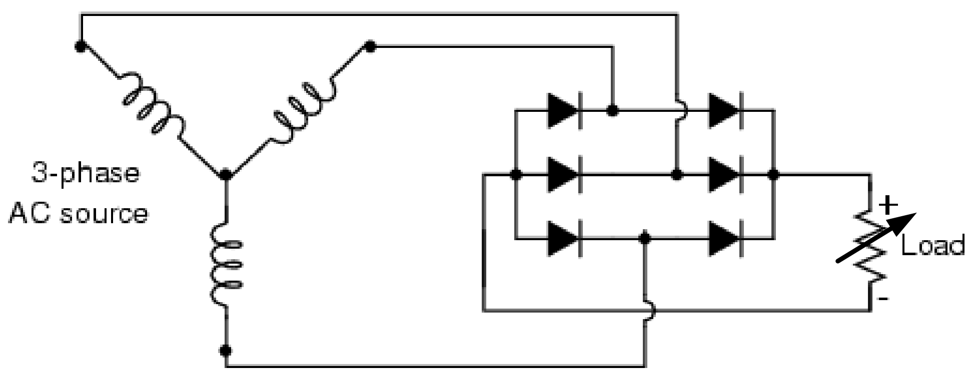


Figure 2 – Plot with 100 ohms as Load

Pre-Analysis

RPM and Corresponding Voltage Drop

The RPM drop is a result of applying the 100 ohm "Load" potentiometer across the rectifier diodes as illustrated below.



The wind turbine is now trying to supply power to the resistor load, but its' only source of power comes from the wind blowing across its rotor blades. If the fan's wind output stays constant, something has to give! In this case, it's the speed of the wind turbine rotation caused by the applied load, since it is working harder to supply power to the resistor load and not just spinning freely. The result is slower rotation.

For example, when you maintain the same peddling force riding a bicycle from a horizontal road to an up slope, the speed of the bicycle is reduced. The reduced speed is to compensate for the extra work load of climbing. The same analogy can be used here for the wind turbine's slower speed.

Current and Power Production

With a load attached, the wind turbine now has a path to deliver current and power. As an example take the readings from Figure 2 above and with Ohm's Law calculate the current generated by the alternator into the 100 ohm resistor load.

The equation for computing the association among voltage, current and resistance (load) is as follows:

$$V = I*R$$

Where V = Voltage in volts
I = Current in amps
R = Resistance in ohms

By algebraic substitution, current can be calculated as follows:

$$I = V / R$$
$$I = 2.527 / 100$$
$$I = 0.025$$ (actual is 0.024 amps)

With the current known, the power can be computed. The equation for power is shown below:

$$P = V * I$$

Where P = Power in watts
V = Voltage in volts
I = Current in amps

$$P = 2.527 * 0.025$$
$$P = 0.063 \text{ watts}$$ (actual is 0.061 watts based on 0.024 amps)

While the computed values in this example nearly match the displayed values, slight differences in actual versus computed current and power values are the result of rounding errors in software. In other words, you may not see the exact computed values displayed on the computer in every instance.

Because the wind turbine turns at slightly different rates while it spins, it generates slightly more, or less, voltage. This, in turn, produces more or less current and power. The wiggly lines of voltage, current and power represent both the 3-phase rectified DC signal along with the slight imbalance in the rotor blades plus any turbulence in the wind blowing across them. Wind is the result of the movement of air from the fan, and the movement of air is never steady – especially with a fan where the airflow is not laminar. Therefore, slight changes in wind speed will be reflected in the output voltage. You may have better results outdoors in natural wind.

7. Next, adjust the resistor for less resistance – about half of the entire rotation of the potentiometer. Now capture another plot of voltage, current and power as in Figure 3 below. Notice the increase in current but the drop in power and RPM.

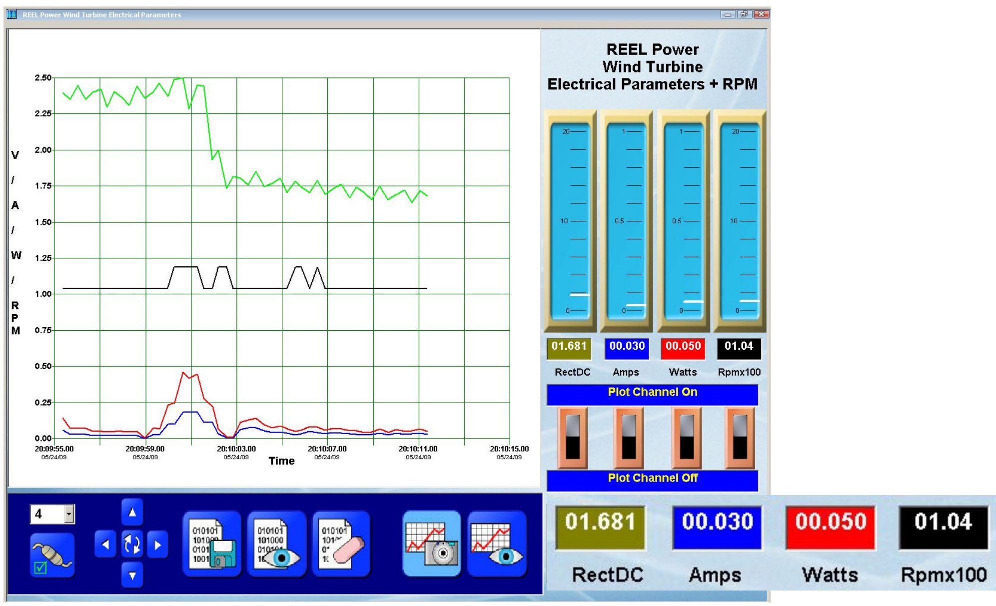


Figure 3 – Plot with 50 Ohm Load

Analysis

This experiment demonstrates that the wind turbine's ability to produce power is primarily dependent on the wind speed and the load. While the wind speed was kept constant, the load was reduced from 100 ohms to 50 ohms. While the current increased with the heaver load the resulting power levels decreased due to lower voltages since the wind turbine could not create enough power with the supplied wind speed. Wind turbine slowing or braking is done by dumping energy from the generator into a lower and lower resistance, thereby converting the kinetic energy of the turbine rotation into heat. This is what we did to make the turbine slow down. This is an alternative to mechanical breaking and is safe since the heat generated by the power dump is minimal.