Remote Combined Solar and Wind Renewable Energy Power Grid

New Mexico

Supercomputing Challenge

Final Report

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Table Of Contents

Executive Summary

In today's world, electrical power production based on traditional fossil fuels damages the environment and has become very expensive. All efforts to switch power production to renewable & clean energy sources should be undertaken. Remote locations do not have access to existing electrical power grids.   Examples: remote deserts, islands, wilderness, and arctic regions. Solar powered photovoltaic and wind-powered systems are ideal for generating remote electricity.

Project Overview

Project Overview Phase I

Learn the basic physics and equations of work, energy, power, electrical current & battery storage needed to develop and analyze an isolated electrical power grid for a system with both a photovoltaic component and a wind energy component. System variables include voltage, current, power, battery storage potential, etc. Develop floor plan and electrical grid schematic.

Determine type and quantity of electrical devices needed in a remote lab station that includes living, eating and sleeping quarters. Then determine the power needs of each device and the total power needs depending on the time of day or night. Develop a spreadsheet of these power needs for the lab station. (See Table I.)

This project will focus on the electrical power needs of the lab station. This project will assume that a solar water heating system is available during the sunny months of the year to heat water. Plus propane will be the primary source of energy for cooking, as well as heating water and heaters during cold seasons.

Learn C++ computer programming skills to write a program to simulate and monitor the power grid.

Project Overview Phase II

Develop the mathematical and physics equations for an isolated solar-powered photovoltaic power grid with its many functions -- voltage, current, power, battery storage, etc. Convert our mathematical model into a C++ computer program that will simulate and monitor the power grid

Project Overview Phase III

Develop the mathematical and physics equations for an electrical power grid with its many functions -- voltage, current, power, battery storage, etc., for a system that contains both a photovoltaic component and a wind energy component. Then, we want to convert our mathematical model into a C++ computer program that will simulate and monitor the power grid.

Project Phase I Assumptions

Remote facility, house or laboratory does not have access to existing commercial power grid. The structure is 600 ft^2 with lab/sleeping room, kitchen/dining room, bathroom, storage room. A minimum of three 30. amp circuits are needed: 1) Lab/sleeping room; 2) kitchen, microwave oven 3) dining room, bathroom, storage room, misc. (See Figure 1.)

Solar-powered electrical grid will need enough solar panels to produce on-demand electricity, plus charge up batteries for night time, stormy weather, winter season, etc.

Table I
Lab Station Power Source and Lab Station Power Needs

Power Source Area (Solar Panel Area)	Power Output (Watts)	Power Demand Device	Quantity	Power Need (Watts)
4.0 sq. meters	400	Fluorescent Light 40 W	10	400
8.0 sq. meters	800	Refrigerator	1	100
12.0 sq. meters	1200	Air Conditioner (1/2 HP)	1	375
16.0 sq. meters	1600	Computer	1	300
20.0 sq. meters	2000	Printer	1	300
24.0 sq. meters	2400	Television 26"	1	400
28.0 sq. meters	2800	Microwave Oven	1	1400
32.0 sq. meters	3200	Coffee Pot	1	200
36.0 sq. meters	3600	Lab device 1: Hot Plate	1	700
40.0 sq. meters	4000	Lab device 2: Centrifuge	1	200
44.0 sq. meters	4400	Lab device 3: Microscope	1	100
48.0 sq. meters	4800	Lab device 4: Mass Spectrometer	1	200
52.0 sq. meters	5200	Lab device 5: Gas Chromatograph	1	200
56.0 sq. meters	5600	Lab device 6: Motion Sensor	1	50
60.0 sq. meters	6000	Lab device 7: T.B.D…	1	???
64.0 sq. meters	6400	Lab device 8: T.B.D…	1	???
		Total Power Needed		**4875**

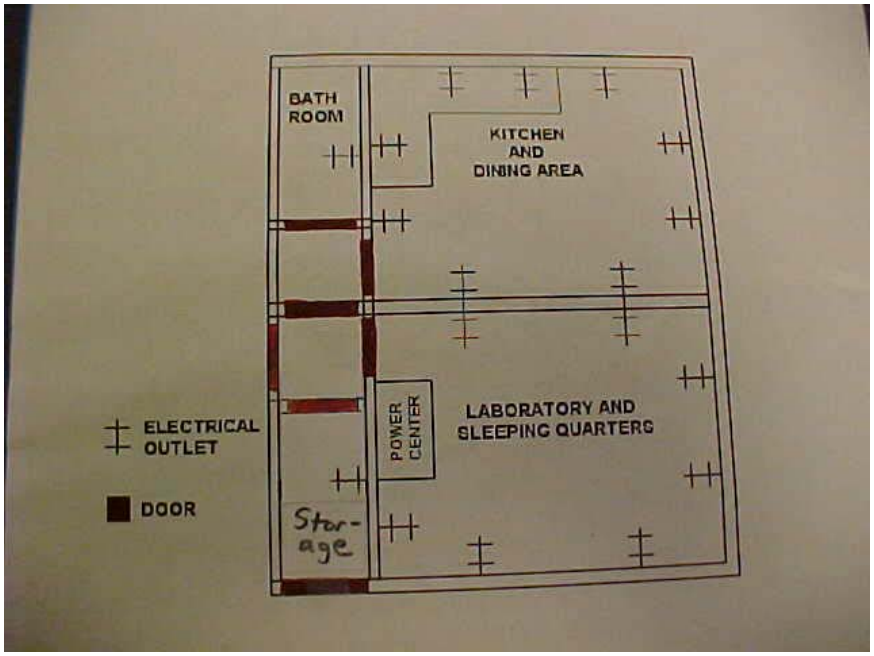

Figure 1. Remote Laboratory Floor Plan

Research and Physics of Photovoltaic Systems

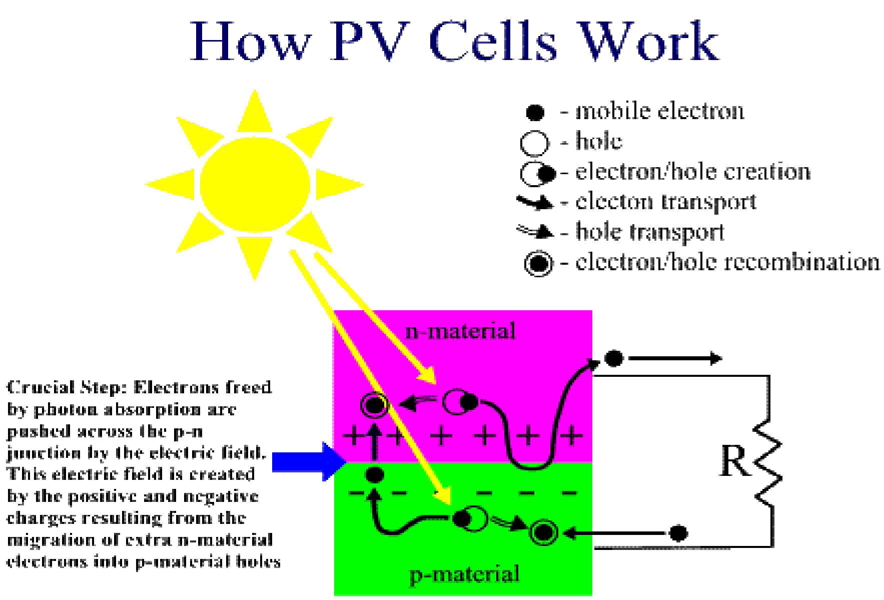

Figure 2. “Exploring Photovoltaics” Online Article: [NMSEA_ExploringPhotovoltaics.doc]

Because of the properties of semiconductor, when the sun's shine, the light fall into n-,and p- material. It emit an energy that strong enough to let the electron out of its atom by explanation: The number of electrons emitted by the metal depends on the intensity of the light beam applied on the metal; more intense the beam, higher the number of electrons emitted. The emitted electrons move with greater speed if the applied light has a higher frequency. No electron is emitted unless the light is greater than some basic frequency is called threshold frequency, no matter how intense the light is. Go back to semiconductors, free electron on n material and positive hole on p-material are created by the light . Then creates an electric field at p-n junction and never have recombination. This electric field is strong enough to move the free electron on p-material to n material and move positive hole from n material to p material separately. Finally we have a source of emf. In which – side is n matarial and + side is p-material. If you connect it to a circuit, the current will flow on the outside of the material. The light keep adding energy to p-n junction and it creates electricity over and over again.

The maximum kinetic energy K_{max} of an ejected electron is given by

$$K_{\text{max}} = hf - \varphi$$

Where h is the Planck constant, f is the frequency of the incident photon, and $\varphi = hf_0$ is the work function (sometimes denoted W), which is the minimum energy required to remove an electron from the surface of any given metal.

Research and Physics of Wind Energy

As the night time goes on, there is no light to make photoelectric effect, also there contain another sources that can convert to electric energy : wind power. We try to convert the wind energy to the electric energy. Suppose that the lap have …….. And the total current that required for a standard lab is 200 A. According to Ohm's law:

P=I.V

(the standard electric potential different for the AC circuit at home is 120V)

So the total power that need to be produced is

P= (200A)*(110V) = 22000 Watts.

- The wind turbine's is a device that can turn the wind energy to mechanical energy then electrical energy.

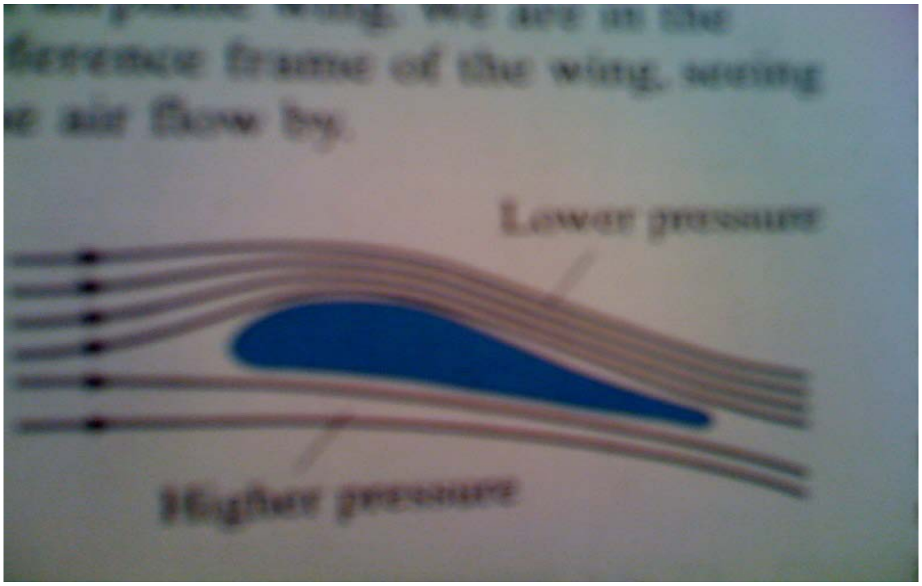

Figure 3. Bernoulli's Principle? (renewable-sources-of-energy.com)

- As the wind flow through the wind blade, the air speed at the top of the blade is greater than the bottom, the pressure on the top of the blade is less than the bottom. Hence it create a net upward force on the wind called aerodynamic force.

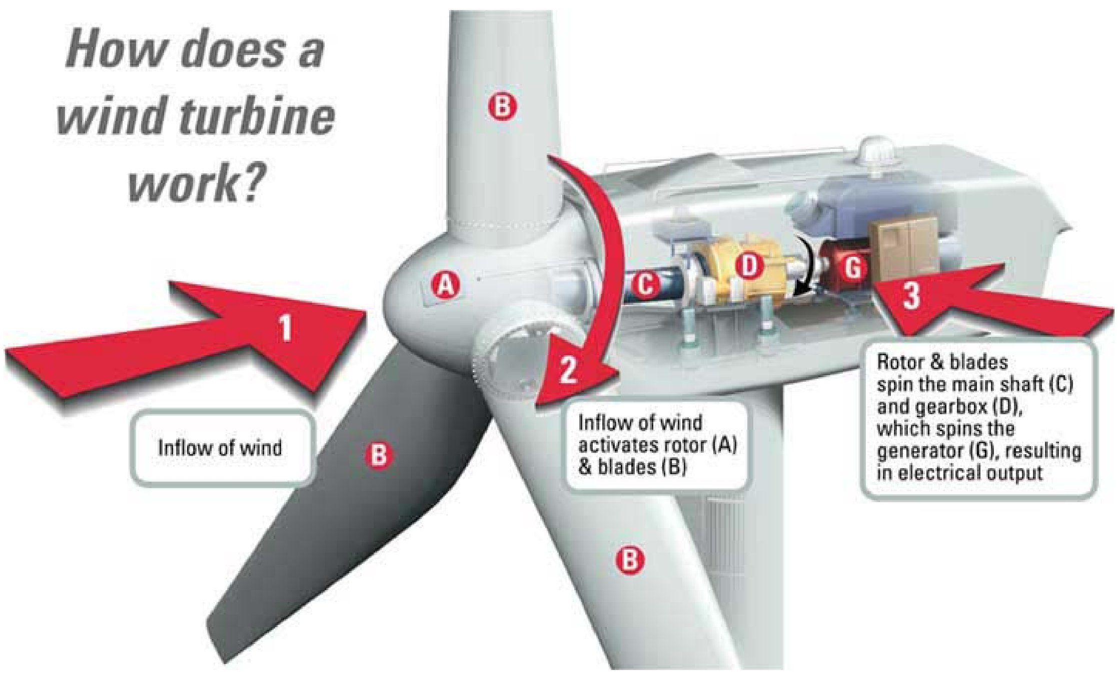

Figure 4. How Does a Turbine Work? (renewable-sources-of-energy.com)

Using the right hand rule the torque is created and makes the wind blade spin.

As the wind turbine spins, it makes the gear that connects with the generator spin also.

When a generator is spinning, the magnetic flux changes in time and creates electricity according to Faraday's law:

$$\mathcal{E} = -\frac{d\Phi_B}{dt},$$

Dealing with the aerodynamics of wind turbines. In real life, the air fluid passing through the blades is different from the air fluid far away from the turbine. Energy is transferred by the air which is deflected by the turbine. In an experiment in 1919, Albert Betz said that, for any wind energy machine, the basic of conservation of mass and energy is less than 59.3% of the maximum kinetic energy possible to be converted. This is known as Betz's Law. Today, new technologies can allow modern turbine designs to achieve 70-80% of the Betz's Law limit

Table 3 (www.eia.doe.gov)

Table 3. Classes of Wind Power Density at Heights of 10 m and 50 m [(a)]

	10 m (33 ft)		50 m (164 ft)	
Wind Power Class*	Wind Power Density (W/m^2)	Speed [(b)] m/s (mph)	Wind Power Density (W/m^2)	Speed [(b)] m/s (mph)
1	0	0	0	
	100	4.4 (9.8)	200	5.6 (12.5)
2	150	5.1 (11.5)	300	6.4 (14.3)
3	200	5.6 (12.5)	400	7.0 (15.7)
4	250	6.0 (13.4)	500	7.5 (16.8)
5	300	6.4 (14.3)	600	8.0 (17.9)
6	400	7.0 (15.7)	800	8.8 (19.7)
7	1,000	9.4 (21.1)	2,000	11.9 (26.6)

[a] Vertical extrapolation of wind speed based on the 1/7 power law.
[b] Mean wind speed is based on Rayleigh speed distribution of equivalent mean wind power density. Wind speed is for standard sea-level conditions. To maintain the same power density, speed increases 3%/1000 m (5%/5000 ft) elevation.
* Note: Each wind power class should span two power densities. For example, Wind Power Class = 3 represents the Wind Power Density range between 150 W/m^2 and 200 W/m^2. The offset cells in the first column attempt to illustrate this concept.

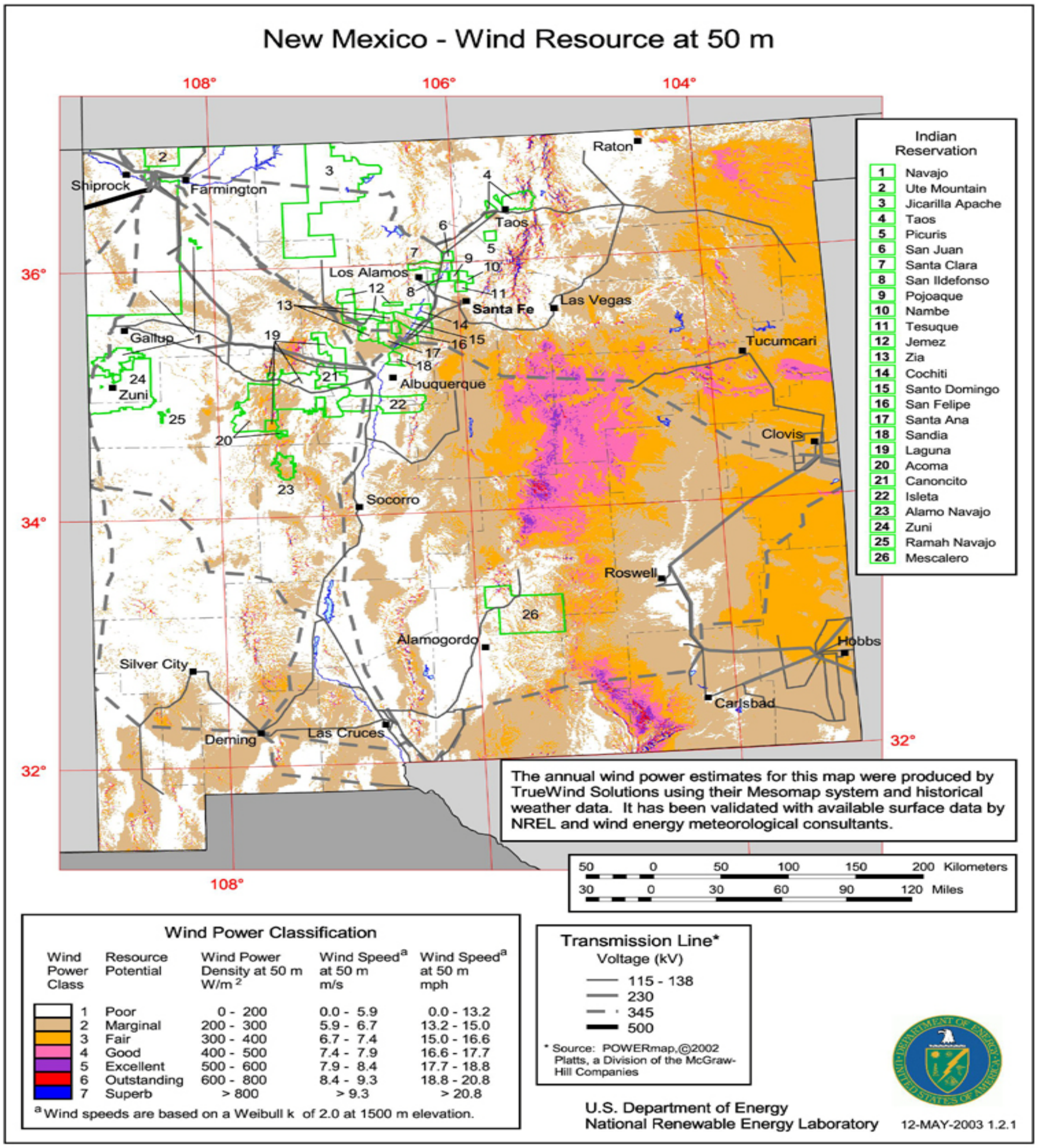

Figure 5 (http://www.environmentalsafeguards.org/air.html)

According to the picture to the right side, I chose the fair wind speed is about 7.2 m/s. and the total area of the wind blades (10m*(2+2+2)) = 60 m^2 The power that the wind turbine create is ($60m^2$)*($400w/m^2$) = 24000 Watts. Totally, we can create more power than the lab needs.

Math Variables and Symbols For Current and Power Formulas

- V = Voltage (volts)
- I = Current (amps)
- R = Resistance (ohms)
- P_o = Power Output (Watts)
- R_s = Solar Radiation (Watts/Square Meter)
- A = Area of solar panels (Square Meter)

Electric Current & Power Output Formulas

- Ohm's Law: V = I x R
- Power = V x I
- Example: P = (110 V)(30. amps) = 3300 watts
- Power Output = P_o = A x R_s
- Example: $P_o = (10.\ m^2)(300\ watts/m^2) = 3000$ W

Results

This year we learned much physics about mechanical motion work, energy, power, and static and current electricity. We researched and learn much about stand-alone photo-voltaic power supplies and wind-generated power. We then developed a created a floor plan and electrical schematic for a 600 square foot remote lab station. Then we determined the power needs and number of solar panels needed to supply power to this remote lab station. We wrote a simple C++ program to determine the current needed to supply power to the electrical devices in this lab station based.

Conclusions

We still have much left to do to finish the project. We need to learn more C++ computer programming skills to write a program to simulate and monitor the power grid.

For Phase II, we plan in the future to develop the mathematical and physics equations for an isolated solar-powered photovoltaic power grid with its many functions -- voltage, current, power, battery storage, etc. Convert our mathematical model into a C++ computer program that will simulate and monitor the power grid

For Phase III, we plan in the future to develop the mathematical and physics equations for an electrical power grid with its many functions -- voltage, current, power, battery storage, etc., **for a system that contains both a photovoltaic component and a wind energy component**. Then, we want to convert our mathematical model into a C++ computer program that will simulate and monitor the power grid.

In summary,we need to do the following:

- We need to learn more about solar-powered photovoltaic (PV) electrical systems.
- We need to learn more about wind-powered electrical systems.
- We need to learn how to tie the two systems together.
- We need to develop the complete math model.
- We need to develop the complete C++ program.

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Our team would like to acknowledge the NM Supercomputing Challenge Program for 2009-2010 and Mr. Stephen Schum for teaching the Pre-Engineering Electronics program here at Manzano High School and for helping us problem solve throughout the duration of the project. We would also like to give a special thanks to the MHS Administration for supporting the Pre-Engineering Electronics class.

Appendix:

C++ Code

```
// Team 82 NMSCC 2009-10  Power Grid C++ Program

// Filename: powergrid.cpp   Last Updated: 2010-April-6

// C++ brings other programs to your program via #include <filename> syntax

#include <iostream.h>   // Allows input and output to screen and/or file.

#include <math.h>       // Allows math functions (power, sine, cos, tan, etc)

#include <iomanip.h>    // Allows program to manipulate data.

int main(void)

{

   int c, rchoice;                  // int means integer variable

   float i, v, R, R1, R2, R3;      // float means "real number" variable

   float iR, iR1, iR2, iR3;        // float means "real number" variable

   cout << '\nEnter the number of resistors that are connected in parallel (from 1 to 3)."endl;

   cin >> rchoice;

   cout.precision(1);

   cout.setf(ios::showpoint |ios::fixed);
```

```
switch(rchoice)

{

 case 1:

 {

  cout << "\nEnter the voltage of the circuit." <<endl ;

  cin  >> v;

  cout << "\nEnter the resistance of the resistor in ohms." << endl ;

  cin  >> R1;

  i = v / R1;                // This uses Ohm's Law to compute current.

  cout << "\nVoltage = " << v << " volts."

       << "\nResistance = " << R1 << " ohms."

       << "\nCurrent = " << i << " amperes." << endl;

  Return 0;

  break;

  }

  case 2:

  {
```

```
cout << "\nEnter the voltage of the circuit." << endl;

cin  >> v;

cout << "\nEnter the resistance of the first resistor in ohms." << endl;

cin  >> R1;

cout << "\nEnter the resistance of the second resistor in ohms." << endl;

cin  >> R2;

iR1 = 1/ R1;

iR2 = 1/ R2;

iR = iR1 + iR2;

R = 1 / iR;

i = v / R;

cout << "\nVoltage = " << v << " volts."

     << "\nTotal Resistance= " << R << " ohms."

     << "\nCurrent = " << i << " amperes." << endl;

return 0;

break;

}
```

```
case 3:

{

cout << "\nEnter the voltage of the circuit." << endl;

cin  >> v;

cout << "\nEnter the resistance of the first resistor in ohms." << endl;

cin  >> R1;

cout << "\nEnter the resistance of the second resistor in ohms." << endl;

cin  >> R2;

cout << "\nEnter the resistance of the third resistor in ohms." << endl;

cin  >> R3;

iR1 = 1 / R1;

iR2 = 1 / R2;

iR3 = 1 / R3;

iR = iR1 + iR2 + iR3;

 R = 1 / iR;

 i = v / R;

cout << "\nvoltage = " << v << " volts".
```

```
      << "\nTotal Resistance = " << R << " ohms."
      << "\nCurrent = " << i << " amperes." << endl;
  return 0;
  break;
 }
}
```