Project Overview

The circuit simulator Python project simulates a basic circuit with a resistance in series with a grounded load. Possible circuit components include a voltage source, buses to represent nodes, resistors that dissipate power traveling towards the load, and loads that behave similarly to resistors with rated voltage and power. Important to note is that this simulation is for purely ohmic, DC circuits with no complex impedance nor AC functionality. This simulator can be used to calculate circuit current and bus voltages based on Kirchhoff’s Voltage Law.

The simulator is not very generalized, but it reliably allows for the calculation of bus voltage and circuit current with one resistor in series with one load. In other words, the only parameters of concern are the resistance of the resistor (denoted by the variable r in the script), the rated power and voltage of the load (p and v respectively), and the voltage source’s voltage (v_in). These parameters are in the main.py file, which when run will generate a solution based on user-generated inputs.

The primary application of this simulator is that it offers insight into the relationship between changing parameters of a basic circuit. Seeing how the voltage and current changes with respect to various input parameters demonstrates the connections each variable has in the system. Since the simulation is limited to real components and performs KVL only with one resistor and one load, the real-world applications are limited. However, it does demonstrate fundamental relationships that are at the core of power engineering and can be built to model more complex power simulations.

Class Diagram and Documentation

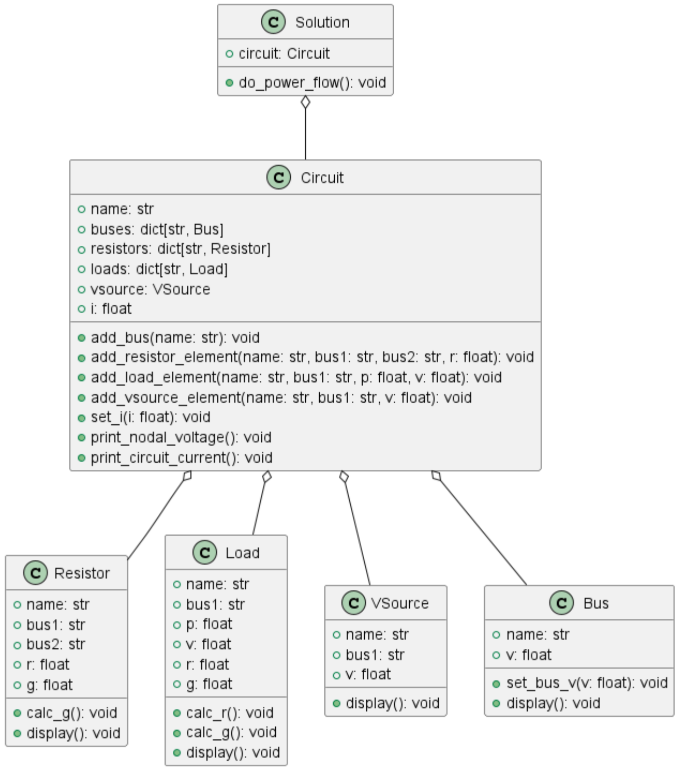

Figure 1 – PlantUML class diagram for the circuit simulator project.

The project utilizes class-based architecture for improved organization. Each component has a built-in class: Resistor, Load, Bus, and VSource. The resistor class is constructed with a name, bus 1 name, bus 2 name, and resistance value. The resistor class also has a function to calculate the attribute g for conductance. The load has a name, rated power, rated voltage, and bus 1 name. The load has internal methods for calculating resistance r and conductance g and storing them as attributes, like the resistor class. The bus has only a name and a function to set voltage. Finally, the voltage source is constructed with a name, bus 1 connection, and voltage. All classes also have a display function to display attributes. Each of these classes are used in a Circuit object to represent an entire circuit. The construction of a circuit object requires a name. The Circuit class has many methods for adding each of the classes mentioned above, requiring the same parameters that each class requires. The Circuit class also has methods to display the current attribute as well as each bus voltage. The Solution class is constructed with a Circuit object and built to solve the specific case mentioned in the paragraph above by leveraging the relevant equations mentioned below. The use of the Solution class is for the power flow method, which calculates the circuit current and bus voltage of the input Circuit object.

Relevant Equations

For conductance calculations used in the Resistor class, the given resistance of a resistor can be used with equation (1) is used.

$$G = \frac{1}{R} \tag{1}$$

To find derived equations for resistance and conductance of a Load object, we start with the basic power equation (2) and Ohm's Law (3). Using substitution, we can find power in terms of voltage and resistance in (4). Finally, we can easily solve equations (5) and (6) with algebraic manipulation for use in the Load class.

$$P = IV \tag{2}$$

$$V = IR \tag{3}$$

$$P = \frac{V^2}{R} \tag{4}$$

$$R = \frac{V^2}{P} \tag{5}$$

$$G = \frac{P}{V^2} \tag{6}$$

The Solution class uses KVL analysis of a single branch to find circuit current and bus voltages. A simple way to find current is to begin by finding the total equivalent resistance via equation (7). With this, we can use Ohm's Law (3) and solve for the current of the total circuit (8) since the user provides the VSource object's voltage and we know the equivalent resistance from (7). Now that we know the current for the single branch, we can find the voltage at each bus with equation (9) by treating the circuit as a voltage divider.

$$R_{tot} = \sum_{i=0}^{N} R_{i,series} \tag{7}$$

$$I_{tot} = \frac{V_{source}}{R_{tot}} \tag{8}$$

$$V_n = \sum_{i=n}^{N} I_{tot} R_{i,series} \tag{9}$$

Example Case

Problem Definition

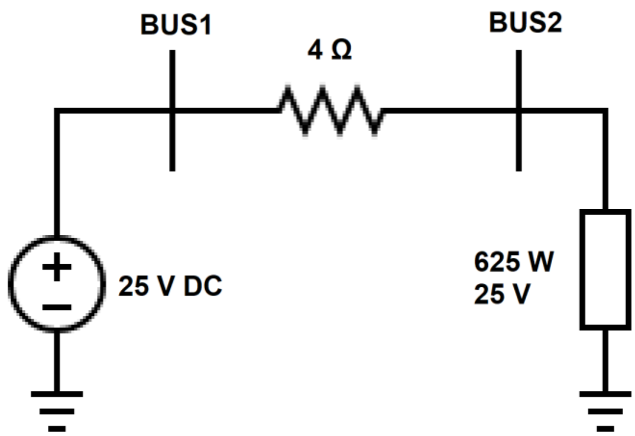

Figure 2 – Computer-drawn circuit diagram for example.

The circuit comprises one 4 Ω resistor, a load rated for 625 W at 25 V, and a DC voltage source of 25 V. A computer-drawn schematic of this circuit description can be seen in Figure 2. The user wishes to solve their circuit's current and bus voltages. How can this circuit simulator be utilized to solve the circuit in question?

Solution Process

First, in the main.py file the user inputs the desired variables. The r variable is to be set to 5 for the resistance of the resistor, p is 2000, v is 100, and v_in is 100. Note that v is associated with the rated voltage of the load and v_in associates with the voltage source. This is all the data necessary, as the circuit can be built with two buses, one resistor, one load, and a voltage source. The simulator achieves this by creating a circuit object and calling internal methods to add each component appropriately.

Before the main solution, the rated resistance of the load must be found. Utilizing equation (5) via an internal method, this calculation is saved as an attribute for the Load class automatically. The Solution class first solves the current. The current is found by utilizing relevant equations (7) and (8) above. Under different conditions we might expect to have multiple resistors and a load, but the user only has one resistor in their circuit. A built-in for loop iterates only once through the single resistor and through the calculated resistance of the load and via equation (7) determines total ohmic resistance. Back to equation (8), the Solution class utilizes the input voltage of the VSource object to find the total current.

To determine bus voltages, the Solution class relies on equation (9). Again, we only have one resistor and one load, so only one iteration of KVL is required. The first bus – the one connected to the voltage source – will have a voltage that matches the voltage source's voltage.

For every bus beyond the first one, the solution is given by equation (9). In this case, we only have one iteration with the load's resistance to consider. With this, the solution is given, and the circuit has been solved.

Expected Output

To solve this circuit, first the resistance of the load must be determined. Following equation (5) we find that the load resistance is 1 Ω.

$$R_L = \frac{V_L^2}{P} = \frac{(25\,V)^2}{625\,W} = 1\,\Omega$$

Now that the load resistance is known, the total series resistance can be determined by summing the resistance of the resistor and the previously calculated load via equation (7).

$$R_{tot} = R_L + R_{resistor} = 1\,\Omega + 4\,\Omega = 5\,\Omega$$

Through equation (8), the circuit current can now be calculated with the previous result. Determining the circuit current will also allow us to determine the voltages at each bus.

$$I_{tot} = \frac{V_{in}}{R_{tot}} = \frac{25\,V}{5\,\Omega} = \mathbf{5\,A}$$

$$V_0 = V_{in} = \mathbf{25\,V}$$

$$V_1 = I_{tot}R_L = 5\,A * 1\,\Omega = \mathbf{5\,V}$$

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Circuit Current:
    Current: 5.0000
Bus Voltages Attributes:
    Name: BUS1      Voltage: 25.0000
    Name: BUS2      Voltage: 5.0000
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Figure 3 – Values returned by program's calculations.

Comparing the work above with the values given in Figure 3, it is confirmed that the program functions as intended.