Project 1 - Simple Circuit Simulator
Milestone 5: Documentation Creation

1 Project Overview

1.1 Introduction

The Simple Circuit Simulator (SCS) is a Python-based tool designed to model and solve a direct current (DC) circuit that includes a voltage source, a series resistor, and a load resistor connected between buses A and B, as shown in **Figure 1**. The purpose of this simulator is to facilitate the analysis of the DC circuit.

The key features and functionalities of this simulator are:

- **Model DC Circuit:** Users can construct simple DC circuits by adding multiple circuit elements such as voltage source, buses, resistors, and load and specifying component values.
- **Solve DC Circuit:** The simulator calculates and displays the voltage at each bus and the current flowing through the circuit, providing instant output on the circuit's behavior.

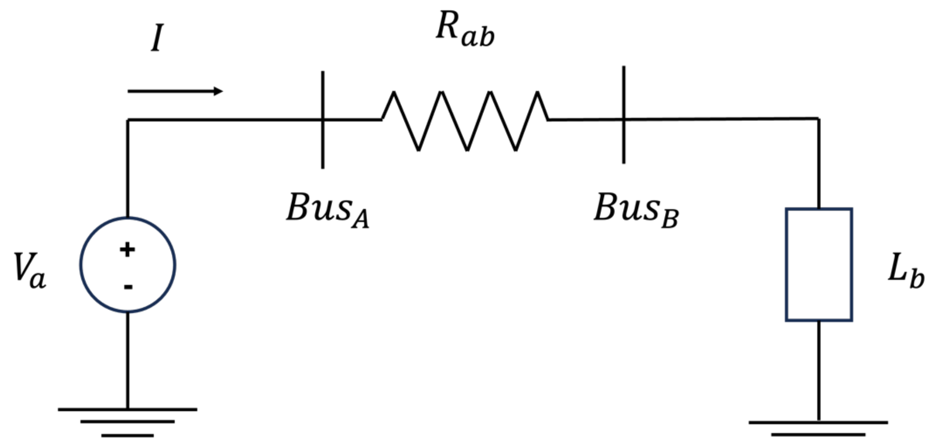

Figure 1. Schematic of the DC Circuit

1.2 Problem Solving and Real-World Applications

The SCS provides a virtual environment where users can experiment with circuit configurations and instantly observe the outcomes. Its real-world applications are:

- **Educational Tools**: Acts as a teaching aid in classrooms to demonstrate the fundamental principles of DC circuit design and analysis.
- **Prototype Testing**: Allows engineers to test DC circuit configurations before building physical prototypes, saving time and resources.
- **Troubleshooting**: Helps in diagnosing issues with DC circuit designs by allowing for hypothetical modifications and observing potential impacts on circuit functionality.

2 Class Diagrams

Figure 2 shows the class diagrams of the SCS. The diagrams are generated using the diagram.puml file, which is processed by the PlantUML plugin in PyCharm.

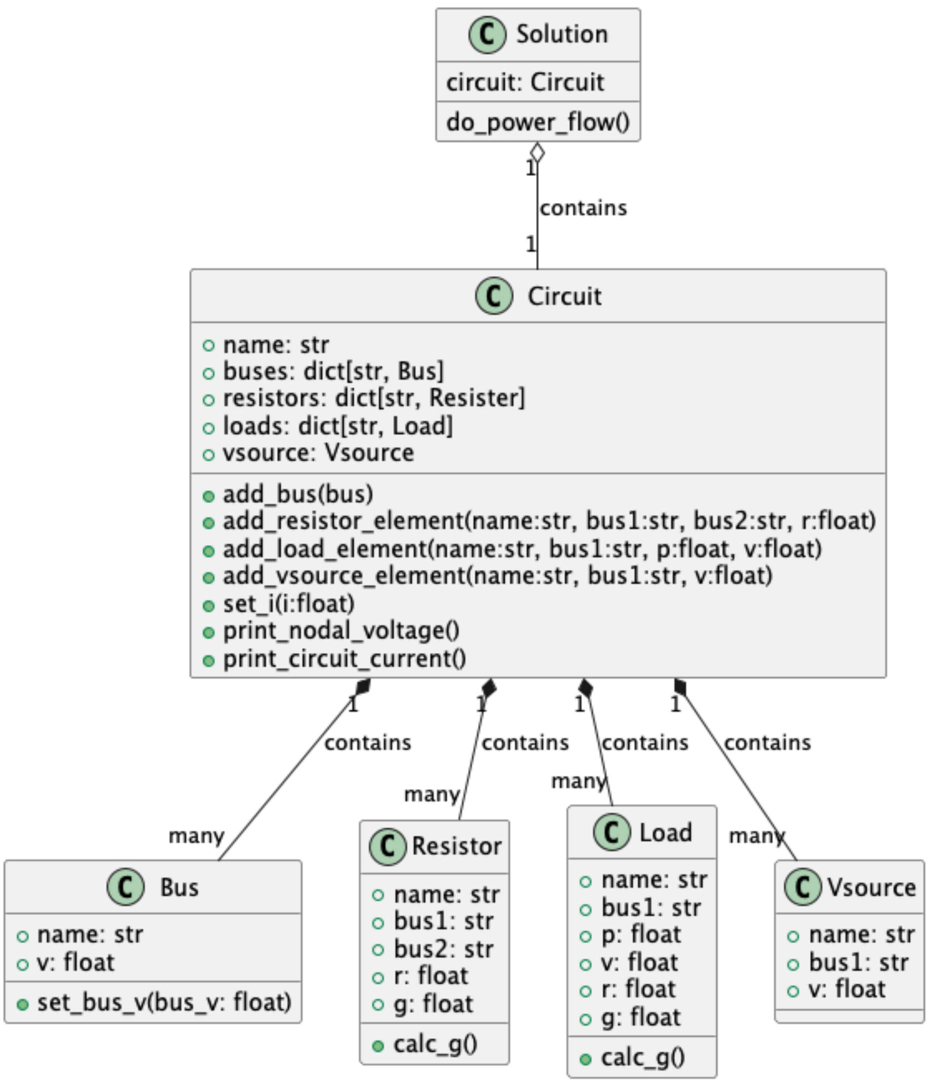

Figure 2. Diagram of the DC Circuit

3 Relevant Equations

The equations used in the SCS include Ohm's law, power-voltage relationship, conductance calculations, and KVL to solve for circuit voltages and current.

3.1 Ohm's Law

Ohm's Law is for determining the current flowing through a component in an electrical circuit. It is expressed as:

$$\boldsymbol{I = \frac{V}{R}}$$

Where $\boldsymbol{I}$ is the current through the component (in amperes, A), $\boldsymbol{V}$ is the voltage across the component (in volts, V), and $\boldsymbol{R}$ is the resistance of the component (in ohms, Ω).

3.2 Power-Voltage Relationship

The power consumed by a component in a DC circuit can be calculated using the power-voltage relationship, which is given by:

$$\boldsymbol{P = VI}$$

Where $\boldsymbol{P}$ is the power (in watts, W), $\boldsymbol{I}$ is the current through the component (in amperes, A), and $\boldsymbol{V}$ is the voltage across the component (in volts, V).

By combining Ohm's law and power-voltage relationship, the resistance $\boldsymbol{R}$ of a component can be calculated using its voltage $\boldsymbol{V}$ and power $\boldsymbol{P}$:

$$\boldsymbol{R = \frac{V^2}{P}}$$

3.3 Conductance Calculations

The conductance of a component is the inverse of its resistance:

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

Where $\boldsymbol{G}$ is the conductance (in siemens, S), and $\boldsymbol{R}$ is the resistance of the component (in ohms, Ω).

3.4 Kirchhoff's Voltage Law (KVL) to Solve for System Voltages and Current

KVL ensures the sum of the voltage drops around the circuit equals the voltage of the source. KVL can be represented as:

$$\boldsymbol{V_{source} = V_1 + V_2 = IR_1 + IR_2}$$

Where $\boldsymbol{V_{source}}$ is the voltage of the source, $\boldsymbol{I}$ is the current, $\boldsymbol{V_1, V_2}$ are voltages of all the other components of the circuit, and $\boldsymbol{R_1, R_2}$ are the resistors.

4 Example Case

4.1 Problem Definition

The circuit in **Figure 1** is defined as:

1. Buses A and B are added to the circuit.
2. Voltage source $\boldsymbol{V_a}$ is connected at bus A with 120 V.
3. Resistor $\boldsymbol{R_{ab}}$ is connected between buses A and B with 50 Ohms.
4. Load $\boldsymbol{L_b}$ is connected to bus B with power $\boldsymbol{P} =$ 1000 W and nominal voltage of $\boldsymbol{V_{load}} =$ 100 V. The load model is constant impedance.

The problem is to solve the current of the circuit, and the voltages of bus A and B.

4.2 Solution Process

The solution details are in the Solution class in solution.py file. The total resistance along the circuit is computed by summing the resistances of the resistor element and the load element:

$$\boldsymbol{R_{total} = R_{ab} + R_{load} = R_{ab} + \frac{{V_{load}}^2}{P} = 50 + \frac{100^2}{1000} = 60\ Ohms}$$

Using Ohm's Law, the current ($\boldsymbol{I}$) flowing through the circuit is calculated as:

$$\boldsymbol{I = \frac{V_a}{R_{total}} = \frac{120}{60} = 2\ A}$$

The voltage at bus A ($\boldsymbol{V_{busA}}$) is set equal to the source voltage since it is directly connected to the voltage source:

$$\boldsymbol{V_{busA} = V_a = 120\,V}$$

The voltage at bus B ($\boldsymbol{V_{busB}}$) is calculated using the current through the circuit and the resistance of the load:

$$\boldsymbol{V_{busB} = IR_{load} = 2 \times 10 = 20\,V}$$

4.3 Expected Output

In the main.py file, create a DC circuit instance my_circuit named "Simple DC Circuit" and add variables using the given example:

```
def main():
    my_circuit = Circuit("Simple DC Circuit")
    my_circuit.add_bus("Bus A")
    my_circuit.add_bus("Bus B")
    my_circuit.add_vsource_element("Va", "Bus A", 120)
    my_circuit.add_resistor_element("Rab", "Bus A", "Bus B", 50)
    my_circuit.add_load_element("Lb", "Bus B", 1000, 100)
```

Next, pass the created circuit my_circuit to the Solution class and call the do_power_flow() function to solve the problem:

```
    solution = Solution(my_circuit)
    solution.do_power_flow()
```

Then, run the main function:

```
if __name__ == '__main__':
    main()
```

Finally, the expected output would be displayed:

```
Circuit Current = 2.0 A
Bus A Voltage = 120.0 V
Bus B Voltage = 20.0 V
```