Rabia Nur Ünsal 2376051
Erdem Canaz 2374676

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EE443 Numerical Methods and Introduction to Optimization

Project Work Proposal Report

Development of a Numerical Simulation Script for Nonlinear Time-Varying Circuits

Introduction:

In most real-life scenarios circuit components can be approximated as linear where their L, C and R parameters are constant. However, there are cases that the circuit's components may exhibit nonlinearity. The inductance of inductors, for instance, varies depending on the current passing through them, influenced by the saturation of the core material. Similarly, the capacitance of capacitors changes due to the dielectric properties, affecting the voltage-charge relations across them. Consequently, the differential equation solutions used for linear circuits, where L (inductance) and C (capacitance) are assumed constant, cannot be applied to nonlinear problems. Therefore, employing numerical solutions becomes highly practical when components cannot be considered linear. This project aims to tackle this issue by developing a numerical solution script for such circuits.

Components to be Simulated:

1)Active Voltage Source: Time-dependent voltage function

2)Active Current Source: Time-dependent current function

3)Resistor: Temperature is considered a state.

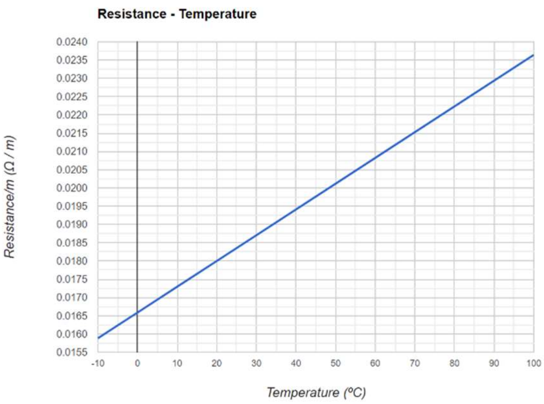

Figure 1 Resistor vs Temperature Graph

4)Inductor: Flux linkage is considered a state.

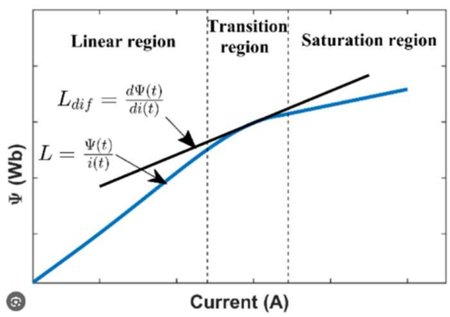

Figure 2 Flux Linkage vs Current Graph

5)Capacitor: Charge is considered a state.

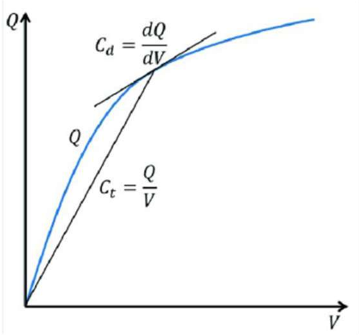

Figure 3 Charge vs Voltage Graph

Algorithm:

1) Setup:

- Define component characteristics.
- Specify the circuit to be solved (define initial values for flux, charge, and temperature; identify node connections).

2) Simulation:

- Define the simulation duration and tolerance.
- Set simulation timestep (Δt) and maximum timestep.
- Begin solving the circuit.
- Check if the simulation is complete (elapsed time).
- Linearize the circuit for time 't' (assume the timestep small enough so that capacitor voltage and inductor current values do not change significantly, and they can be replaced by voltage and current sources respectively).
- Formulate node equations.
- Solve node equations using a Python library.
- Update states (flux, charge, temperature).
- Check if the tolerance for inductor current and capacitor voltage change is met.
- If not met, reduce Δt and rerun the simulation with old states; if met, update Δt using $\Delta t = \min(2 * \Delta t, \text{max timestep})$.

3) Output:

- Plot desired results (node voltages and branch currents).

4) Comparison:

- Compare simulation results with LTspice.

Conclusion:

In conclusion, this proposal presents a framework for developing a numerical simulation script adept at handling the intricacies of nonlinear time-varying circuits. The systematic approach outlined not only facilitates accurate circuit analysis but also accommodates dynamic characteristics inherent in real-world electronic components.