ECE 433 Project #1– Due February 26, 2024

1) Given the following specifications for a converter circuit: The output is to have an average of 400 V with a maximum peak-peak ripple of 10 V for a load range of 50 kW to 250 kW. The input to the converter is 800 V. A switching frequency of 10 kHz is desired.
   a. Determine an inductance $L = 1.10L_{crit}$ and the minimum C needed to satisfy these requirements.
   b. Use approximation techniques presented in class, analytically determine the expected steady-state current and voltage waveforms expected for each component under both light and heavy load. Plot these values. You can plot via hand, provided it is neat. Key values on the plots are the expected currents and voltages (including amplitude and time scale).
   c. Use a **Forward Euler** Integration algorithm that you program in Matlab to simulate the ideal circuit behavior by numerically solving the differential equations. There are a few specifications for your code.

- You should create 4 files (sw.m, buck.m, buckproc.m, aver.m) .
- The first file (sw.m) contains a function (sw) that accepts the duty cycle D, and a single instant of time as an input, and outputs the state (on/off) of the transistor at that time instant as an output. A Fourier series-based triangle wave that you create within this function should be compared with the duty cycle D to determine the state of the transistor. The output of the function is a 1 if the transistor is to be turned on. It is a value of 0 if it is turned off.
- The file (buck.m) contains the Forward Euler integration algorithm within a while loop (FOR LOOPS ARE NOT ALLOWED). buck is not a function. The file buck.m only contains a single while loop (i.e. while (t(k)<tend)) to solve for all circuit voltages and currents of your buck converter. Within the while loop, you will call the function sw at each time instant to determine the value of your transistor gate (on or off). Voltages of currents and voltages of circuit components must be determined within the while loop.
- The file buckproc.m first contains the circuit parameter values (i.e. L, C, fsw, time step, initial conditions etc.). Only the initial value of your circuit voltages and currents should be pre-established (i.e. Vload(1)=0). It then invokes buck. Finally, it performs your plotting and any post-processing calculations that are done using the simulated data (such as computing average values, efficiency, etc.).

- The fourth file (aver.m) contains a function you create to compute the average of a waveform. Specifically, the function is of the form

  function av = aver(x,T,dt)

where x is the waveform to be averaged, T is its period, and dt is the period of time between samples. This function must use the last period of the input waveform to calculate the average.

d. Using your code, perform the following simulations:
   i. With D set to a value to achieve the desired output, simulate the startup of the circuit under heavy load. Specifically, set the initial conditions of the inductor current and capacitor voltage to zero. Run your simulation until the output voltage reaches steady-state. Plot the output voltage, inductor current, switch current, and diode current over the time period simulated.
   ii. With D set to achieve the desired output, set your initial conditions for the inductor current and capacitor voltage to values you expect to see in the steady-state under heavy load. Run your simulation until the circuit reaches a steady-state and then obtain plots of the voltage and current of each component over 2 cycles. Use your aver function to compute the average output voltage and the efficiency of the circuit. In the final report these should be compared to those obtained in b.
   iii. Repeat part d (ii) for the light load conditions.

e. Analytically determine the effect of non-ideal switches. Specifically, assume the switch and diode have on-state voltage drops and resistances (both have the same) of 1 V and 0.01 Ω, respectively. Solve for the duty cycle to have an output of 400 V, the expected values of I1 and I2, and the efficiency under the heavy power condition.

f. Edit the model you created in c) to include the non-idealities in e). Set D to the value needed to obtain the required output voltage. Then use your code to simulate the circuit under heavy load conditions. Plot the output voltage, the inductor current, and the power loss across the diode and transistor over 2 cycles. Finally, compute the simulated efficiency of your circuit using your aver function. In the final report these should be compared to expected values.

2) Write a report that documents your analytical and numerical results. Make sure all plots are well labeled and explanations contain solid analytical foundations. Attach your Matlab Code to your report.