ECE 433 Project #2– Due April 4, 2022

1) Create a Matlab function named *fourser* that is invoked to provide the coefficients of the fourier series up to the user-defined Nth value. Specifically, the function header should have a form

function [avg,ak,bk,rw,err] = fourser(t,x,T,N)

where t is time, x is the waveform that is being analyzed, T is its fundamental period of the waveform, and N is the number of terms of the fourier series that is desired. ak and bk are the Fourier coefficients. rw is the waveform produced by evaluating your N term series, err is the rms error between rw and the x. Note the avg is the average value of x.

2) Prove your function works by inputting the waveform:

$x = 10\cos(2\pi 100t) + 30\sin(2\pi 300t) - 5\cos(2\pi 1000t) + 17\sin(2\pi 1500t) - 5\cos(2\pi 5000t)$

and verifying your rw matches x and that the coefficients match what you expect. Express the error in your ak and bk values.

3) Create a function THD that computes the total harmonic distortion of a waveform, based upon equation 8.17. The input to the function are the Fourier coefficients of the waveform, an and bn, the number of coefficients, N, and the output is the calculated distortion.

4) Assume a single-phase inverter operating is operating under 180 switching. Assume the load is an rl load with $r = 0.5\ \Omega$ and $L = 1mH$ and the desired fundamental component of AC voltage is $V_{as} = \frac{400}{\pi}\cos(\theta_{ac})$ where $\theta_{ac} = 377t$. Analytically determine the steady state AC current waveform, DC current waveform, the transistor and diode currents, and the THD you would expect to observe over a single period. Plot these (you can do so by hand) versus θ_{ac}.

5) Simulate the system of problem 4 using a backward Euler integration algorithm. Obtain a plot of all transistor and diode voltages and currents and output voltage and current and dc current over 1 cycle to validate the model is correct. Use the spectrum analyzer developed in Problem 1 to plot the frequency spectrum of the output voltage from 0 to 1800 Hz. Use the THD calculator to determine the THD of your AC voltage. Validate the waveforms, spectrum, and THD matches the values expected.

6) Use the h-bridge inverter operated under sine-triangle modulation to create a digital amplifier circuit. The amplifier circuit is to be used to provide 1 kW of power to an 8 Ohm speaker. The switching frequency you may use is 30 kHz. The THD of the voltage applied to your speaker (calculated using the fundamental and the harmonics at the switching frequency, the switching frequency + fundamental and the switching frequency-fundamental) must be less than 1%. You will need to provide an LC filter between the output of the inverter and the speaker to achieve this THD. Select the L and C values, ensuring sufficient justification for their values. Using Matlab simulate the system using a backward Euler integration routine simulate the system assuming the music to be played is the note 'A'. For the 1 kW output, d = 0.95sin(2*pi*440t). Plot the output voltage provided to the speaker over one cycle and also generate its frequency spectrum using Fourier to show that the intended amplitude is as you expected. Calculate its THD as well to show that your circuit matches spec. Next plot the transistor and diode voltages and currents along with the output current over 1 cycle of the fundamental.

7) Using the model in 5) vary the amplitudes of m in the duty cycle to create 100 W, 200 W, 300 W, 400 W, 500 W and 1000 W at the speaker. For each value of duty cycle use the spectrum analyzer to determine the amplitude of the fundamental frequency component of the output voltage. Then plot the amplitude as a function of m. Validate that the amplitude versus m is what you would expect.

8) Using Matlab simulate (using a backward Euler algorithm) a 3-phase inverter operating under sine-triangle control. Assume the load is an rl load with $r = 0.5\Omega$ and $L = 5mH$ and the desired ac currents are of the form:

$$i_{as} = 20\cos(2\pi 60t)$$
$$i_{bs} = 20\cos(2\pi 60t - \frac{2\pi}{3})$$
$$i_{cs} = 20\cos(2\pi 60t + \frac{2\pi}{3})$$

Prior to running the simulation, determine the minimum DC voltage necessary to obtain the currents with no low frequency harmonics. Express the duty cycle you would use for this value of Vdc. Simulate the circuit, including the voltage and current of all switches and the dc-link current. Plot the output current and voltage and ensure it has no low frequency harmonics. Also, plot the DC current and the phase-a leg transistor and diode voltages and currents over 1 cycle of the fundamental to validate the model is correct.