1. Load resistance:

$$R_L = \frac{V_0}{I_0} = 2\Omega$$

2.

2. **state space model:**

$i(t) = i_1(t) + i_2(t)$, $V_c(t) + R_c i_1(t) = R_L i_2(t)$, Therefore $i_1(t) = \dfrac{R_L i(t) - V_c(t)}{R_c + R_L}$

q(t)=1:Switch on

$$L\frac{di(t)}{dt} = -\frac{R_c R_L}{R_c + R_L} i(t) - \frac{R_L}{R_c + R_L} V_c(t) + V_{in}(t)$$
$$C\frac{dV_c(t)}{dt} = \frac{R_L}{R_c + R_L} i(t) - \frac{1}{R_c + R_L} V_c(t)$$

q(t)=0:Switch off

$$L\frac{di(t)}{dt} = -\frac{R_c R_L}{R_c + R_L} i(t) - \frac{R_L}{R_c + R_L} V_c(t)$$
$$C\frac{dV_c(t)}{dt} = \frac{R_L}{R_c + R_L} i(t) - \frac{1}{R_c + R_L} V_c(t)$$

The derivation equation is:

$$\frac{di(t)}{dt} = \frac{1}{L} d(t)\left[-\frac{R_c R_L}{R_c + R_L} i(t) - \frac{R_L}{R_c + R_L} V_c(t) + V_{in}(t)\right] + \frac{1}{L}(1 - d(t))\left[-\frac{R_c R_L}{R_c + R_L} i(t) - \frac{R_L}{R_c + R_L} V_c(t)\right]$$
$$\frac{dV_c(t)}{dt} = \frac{R_L}{C(R_c + R_L)} i(t) - \frac{1}{C(R_c + R_L)} V_c(t)$$

transfer into state-space mode is:

$$\begin{pmatrix} \dfrac{di(t)}{dt} \\ \dfrac{dV_c(t)}{dt} \end{pmatrix} = \begin{pmatrix} -\dfrac{R_c R_L}{L(R_c + R_L)} & -\dfrac{R_L}{L(R_c + R_L)} \\ \dfrac{R_L}{C(R_c + R_L)} & -\dfrac{1}{C(R_c + R_L)} \end{pmatrix} \begin{pmatrix} i(t) \\ V_c(t) \end{pmatrix} + \begin{pmatrix} \dfrac{d(t)}{L} \\ 0 \end{pmatrix} V_{in}(t)$$

$$V_0(t) = R_L i_2(t) = \frac{R_c R_L}{R_c + R_L} i(t) + \frac{R_L}{R_c + R_L} V_c(t) = \left(\frac{R_c R_L}{R_c + R_L}, \frac{R_L}{R_c + R_L}\right) \begin{pmatrix} \dfrac{di(t)}{dt} \\ \dfrac{dV_c(t)}{dt} \end{pmatrix}$$

3. Steady-state Values:

Let the nominal signals be: $V_{in}(t) = V_{in};\ d(t) = D$

Let the right-hand sides of the state equations equal to 0. Then solve for $i = L,\ V_c = V$.

Together, these values will be the nominal signals.

$$\frac{D}{L}\left[-\frac{R_c R_L}{R_c + R_L} I - \frac{R_L}{R_c + R_L} V + V_{in}\right] + \frac{(1-D)}{L}\left[-\frac{R_c R_L}{R_c + R_L} I - \frac{R_L}{R_c + R_L} V\right] = 0$$

$$\frac{R_L}{C(R_c + R_L)} I - \frac{1}{C(R_c + R_L)} V = 0$$

Steady state value is $I = \dfrac{(R_c + R_L) D V_{in}}{R_L (R_c + R_L)},\ V = \dfrac{(R_c + R_L) D R_L V_{in}}{R_L (R_c + R_L)}$

4. Linearized System around the nominal signal:

$$\begin{pmatrix} I \\ V \end{pmatrix} = \begin{pmatrix} -\dfrac{R_c R_L}{L(R_c + R_L)} & -\dfrac{R_L}{L(R_c + R_L)} \\ \dfrac{R_L}{C(R_c + R_L)} & -\dfrac{1}{C(R_c + R_L)} \end{pmatrix} \begin{pmatrix} I \\ V \end{pmatrix} + \begin{pmatrix} \dfrac{1}{L} \\ 0 \end{pmatrix} V_{in}$$

$$\begin{pmatrix} I \\ V \end{pmatrix} = \begin{pmatrix} -\dfrac{R_c R_L}{L(R_c + R_L)} & -\dfrac{R_L}{L(R_c + R_L)} \\ \dfrac{R_L}{C(R_c + R_L)} & -\dfrac{1}{C(R_c + R_L)} \end{pmatrix} \begin{pmatrix} I \\ V \end{pmatrix} + \begin{pmatrix} 0 \\ 0 \end{pmatrix} V_{in}$$

$$A_1 = A_2 = \begin{pmatrix} -\dfrac{R_c R_L}{L(R_c + R_L)} & -\dfrac{R_L}{L(R_c + R_L)} \\ \dfrac{R_L}{C(R_c + R_L)} & -\dfrac{1}{C(R_c + R_L)} \end{pmatrix}; B_1 = \begin{pmatrix} \dfrac{1}{L} \\ 0 \end{pmatrix}; B_2 = \begin{pmatrix} 0 \\ 0 \end{pmatrix}$$

$$A = DA_1 + (1-D)A_2 = A_1 = \begin{pmatrix} -\dfrac{R_c R_L}{L(R_c + R_L)} & -\dfrac{R_L}{L(R_c + R_L)} \\ \dfrac{R_L}{C(R_c + R_L)} & -\dfrac{1}{C(R_c + R_L)} \end{pmatrix}$$

$$B = (A_1 - A_2)x_0 + (B_1 - B_2)V_{in} = B_1 V_{in} = \begin{pmatrix} \dfrac{V_{in}}{L} \\ 0 \end{pmatrix}$$

Local Linearization: $\tilde{x}(t) = x(t) - x_0, where\ \tilde{i}(t) = i(t) - I; \widetilde{V_c}(t) = V_c(t) - V$

$$\frac{d\tilde{x}(t)}{dt} = A\tilde{x}(t) + B\tilde{d}(t) = \begin{pmatrix} -\frac{R_c R_L}{L(R_c + R_L)} & -\frac{R_L}{L(R_c + R_L)} \\ \frac{R_L}{C(R_c + R_L)} & -\frac{1}{C(R_c + R_L)} \end{pmatrix} \tilde{x}(t) + \begin{pmatrix} \frac{V_{in}}{L} \\ 0 \end{pmatrix} \tilde{d}(t)$$

5. Transfer Function:

$$Z(s) = Ls + \frac{R_L(R_c + \frac{1}{Cs})}{R_L + R_c + \frac{1}{Cs}} = Ls + \frac{R_L(R_cCs+1)}{(R_L+R_c)Cs+1} = \frac{Ls\left[(R_L+R_c)Cs+1\right] + R_L(R_cCs+1)}{(R_L+R_c)Cs+1}$$

$$P(s) = \frac{1}{Z(s)} \times \frac{R_L(R_cCs+1)}{(R_L+R_c)Cs+1} = \frac{R_LR_cCs + R_L}{(R_L+R_c)CLs^2 + (L+R_LR_cC)s + R_L}$$

The transfer function : $\frac{V_0(s)}{D(s)} = \frac{R_LR_cCs + R_L}{(R_L+R_c)CLs^2 + (L+R_LR_cC)s + R_L}$

$$= \frac{1\times10^{-4}s+2}{1.005\times10^{-6}s^2 + 2\times10^{-4}s + 2}$$

6. What should be V_{set} :

To derive the competitor value that make V_{OUT}=12V, I_{OUT}=6A, while V_{SET} is the reference value to compare with inductor current, I_{OUT}=6A Rt=0.2Ω therefore V_{SET}=1.2V.

7. System analyses:

Following in the report.

Design Project 2, ECE5330/EVE5430/AET5330

Course Number: ECE 5330/EVE 5430/AET 5330

Title: Modeling and Control of Power Electronics and Electric Vehicle Powertrains

Instructor: Le Yi Wang, Professor

Student Name: Zhenyu Qu

Student ID: 004298218

I have not received, nor have I given, any help and assistance on this project.

Signature: Date: