IIT ROORKEE

NPTEL ONLINE CERTIFICATION COURSE

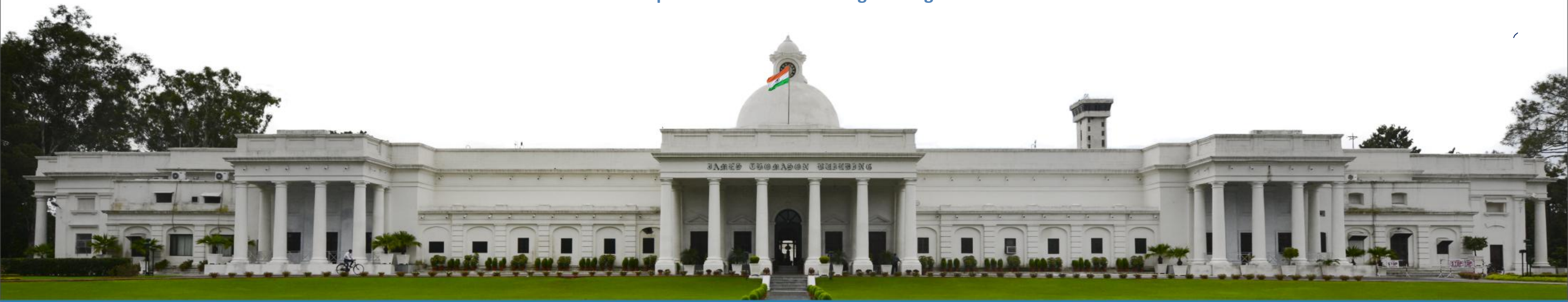
Charging Infrastructure

Lecture-14

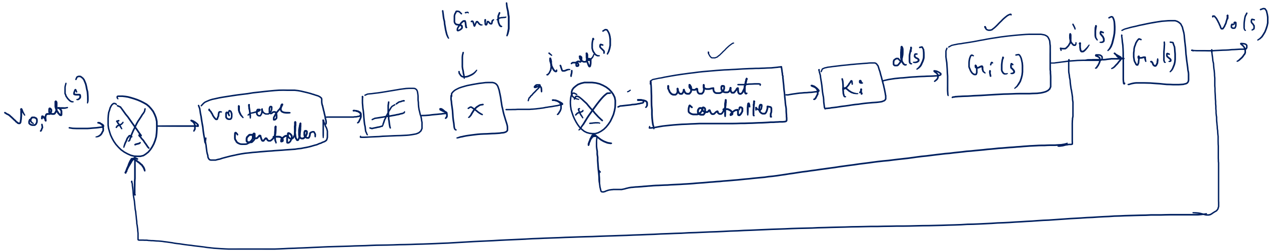
Closed Loop Control of Single-phase Boost PFC Converter-II

Dr. Apurv Kumar Yadav

Department of Electrical Engineering



Recap



$$G_i(s) = \frac{i_L(s)}{d(s)}$$

$$G_v(s) = \frac{V_o(s)}{i_L(s)} \approx \frac{V_c(s)}{i_L(s)}$$

Small Signal Model

Average large signal model using state equations

↓

perturbation

↓

linearize the state equation around the operating point

↓

time-domain to s-domain

State variables : i_L, v_c

Input : d, v_s

output : v_o

In one of the switching period,

the duty ratio of $S_1' = D$

the $v_d = |v_s|$

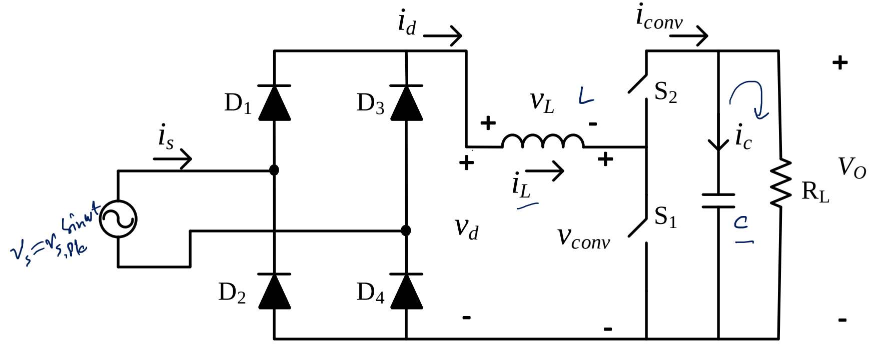
In the positive half-cycle

During DT_s period,

$$\Rightarrow \quad L\frac{di_L}{dt} = |v_s| \quad \Rightarrow \quad \frac{di_L}{dt} = \frac{|v_s|}{L}$$

$$v_c = -i_c R_L$$

$$\Rightarrow \quad C\frac{dv_c}{dt} = -\frac{v_c}{R_L}$$



$f_{sw} >> f_s$

$v_d = |v_s(t)|$

$$\frac{dv_c}{dt} = -\frac{v_c}{R_L C}$$

input $= |v_s|$

$$V_o = v_c$$

$\Rightarrow$ i_L, v_c are the state variable $\Rightarrow$ $x = \begin{bmatrix} i_L \\ v_c \end{bmatrix}$

$$\underbrace{\begin{bmatrix} \frac{di_L}{dt} \\ \frac{dv_c}{dt} \end{bmatrix}}_{\dot{x}} = \underbrace{\begin{bmatrix} 0 & 0 \\ 0 & -\frac{1}{R_L C} \end{bmatrix}}_{A_1} \underbrace{\begin{bmatrix} i_L \\ v_c \end{bmatrix}}_{x} + \underbrace{\begin{bmatrix} \frac{1}{L} \\ 0 \end{bmatrix}}_{B_1} \underbrace{|V_s|}_{|v_s|}$$

$$v_o = \underbrace{\begin{bmatrix} 0 & 1 \end{bmatrix}}_{C_1} \underbrace{\begin{bmatrix} i_L \\ v_c \end{bmatrix}}_{x} + \underbrace{[0]}_{D_1} \underbrace{|v_s|}_{|v_s|}$$

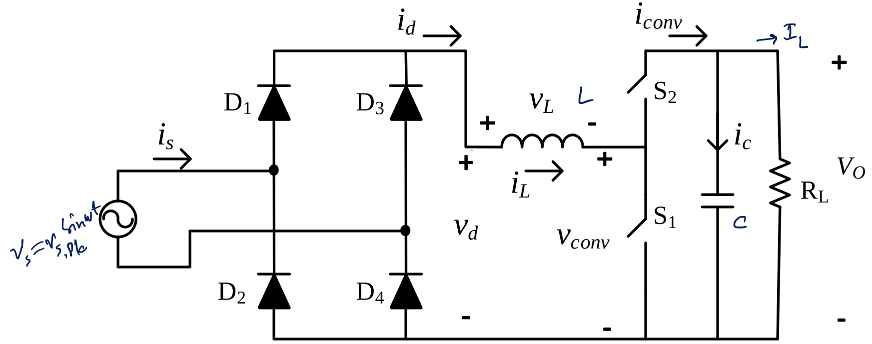
$(1-D)T_s$,

$$\frac{di_L}{dt} = \frac{1}{L}(|v_s| - v_c)$$

$$i_{conv} = i_L$$

$$\Rightarrow i_L = i_c + I_L$$

$$\Rightarrow i_L = i_c + \frac{v_c}{R_L}$$



$$\Rightarrow \quad i_c = i_L - \frac{v_c}{R_L}$$

$$\Rightarrow \quad \frac{dv_c}{dt} = \frac{1}{C} i_c$$

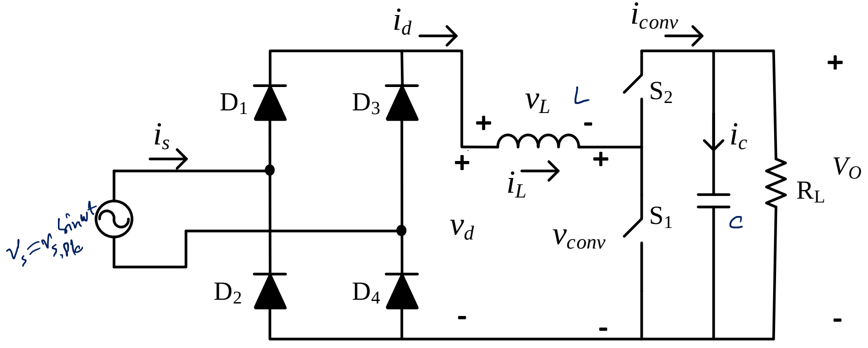
$$= \frac{1}{C}\left[i_L - \frac{v_c}{R_L} \right]$$

$$\Rightarrow \quad \frac{dv_c}{dt} = \frac{1}{C} i_L - \frac{1}{R_L C} \cdot v_c$$

$$\Rightarrow \quad V_o = v_c$$

$$\underbrace{\begin{bmatrix} \frac{di_L}{dt} \\ \frac{dv_c}{dt} \end{bmatrix}}_{\dot{x}} = \underbrace{\begin{bmatrix} 0 & -\frac{1}{L} \\ \frac{1}{C} & -\frac{1}{R_L C} \end{bmatrix}}_{A_2} \underbrace{\begin{bmatrix} i_L \\ v_c \end{bmatrix}}_{x} + \underbrace{\begin{bmatrix} 1/L \\ 0 \end{bmatrix}}_{B_2} \underbrace{|v_s|}_{|v_s|}$$

$$V_o = \underbrace{\begin{bmatrix} 0 & 1 \end{bmatrix}}_{C_2} \underbrace{\begin{bmatrix} i_L \\ v_c \end{bmatrix}}_{x} + \underbrace{\begin{bmatrix} 0 \end{bmatrix}}_{D_2} \underbrace{|v_s|}_{|v_s|}$$



$$\dot{x} = \frac{(A_1 x + B_1|v_s|)DT_s + (A_2 x + B_2|v_s|)(1-D)T_s}{T_s}$$

$$\Rightarrow \dot{x} = (A_1 x + B_1|v_s|)D + (A_2 x + B_2|v_s|)(1-D) \longrightarrow ①$$

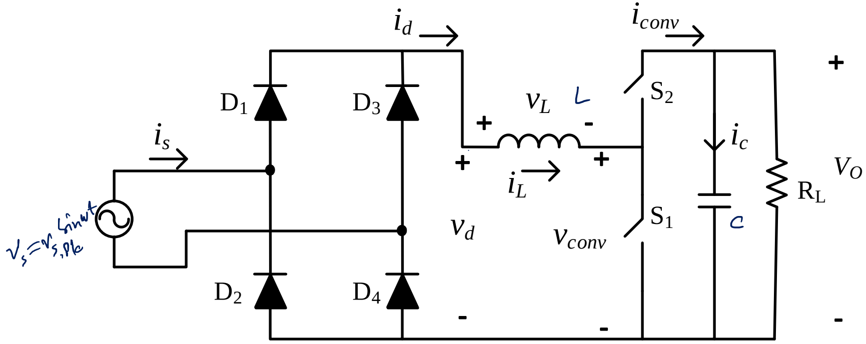
$$v_o = [C_1 x]D + [C_2 x](1-D) \longrightarrow ②$$

Rearranging eq. ① & ②

$$\Rightarrow \dot{x} = [\underbrace{A_1 D + A_2(1-D)}_{A}]x + [\underbrace{B_1 D + B_2(1-D)}_{B}]|v_s|$$

$$\Rightarrow v_o = [\underbrace{C_1 D + C_2(1-D)}_{C}]x$$

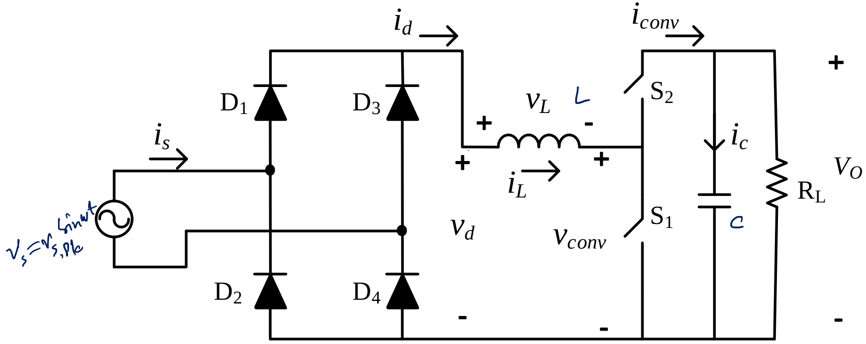
$$\Rightarrow \left.\begin{aligned} \dot{x} &= Ax + B|v_s| \\ v_o &= Cx \end{aligned}\right\} \rightarrow$$ Average large signal model using state space representation



$$A = \begin{bmatrix} 0 & -\frac{(1-D)}{L} \\ \frac{1-D}{C} & -\frac{1}{R_L C} \end{bmatrix} ; \quad B = \begin{bmatrix} 1/L \\ 0 \end{bmatrix}$$

$$C = \begin{bmatrix} 0 & 1 \end{bmatrix}$$

$$\Rightarrow \left.\begin{aligned} \begin{bmatrix} \frac{di_L}{dt} \\ \frac{dv_c}{dt} \end{bmatrix} &= \begin{bmatrix} 0 & -\frac{(1-D)}{L} \\ \frac{1-D}{C} & -\frac{1}{R_L C} \end{bmatrix} \begin{bmatrix} i_L \\ v_c \end{bmatrix} + \begin{bmatrix} 1/L \\ 0 \end{bmatrix} |v_s| \\ V_o &= \begin{bmatrix} 0 & 1 \end{bmatrix} \begin{bmatrix} i_L \\ v_c \end{bmatrix} \end{aligned} \right\}$$



Thank You