IIT ROORKEE

NPTEL ONLINE CERTIFICATION COURSE

Charging Infrastructure

Lecture-21

Flyback based PFC Converter

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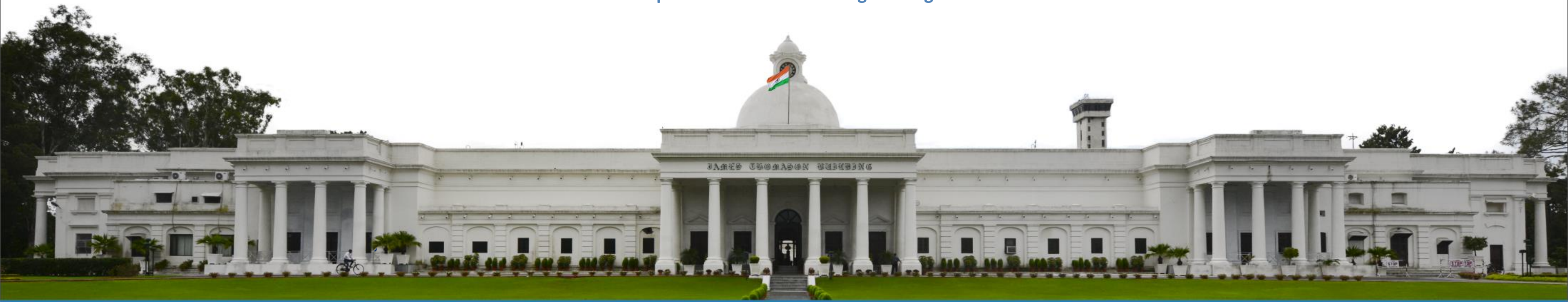
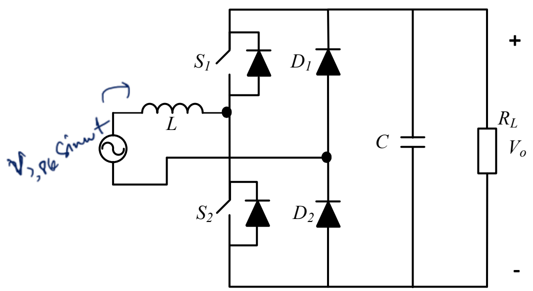
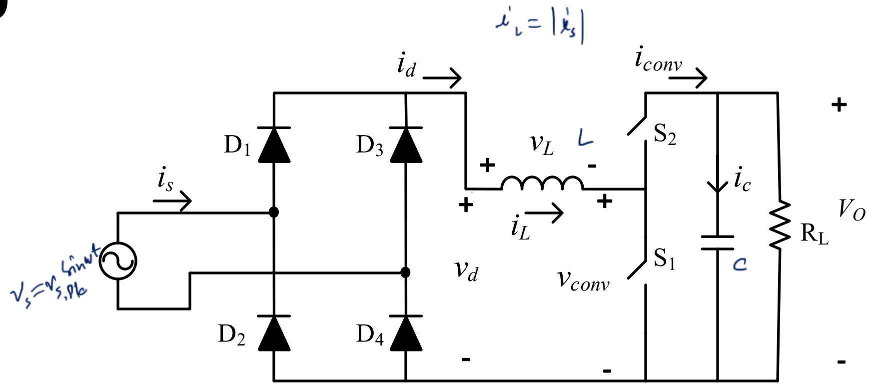


Recap



Totempole PFC

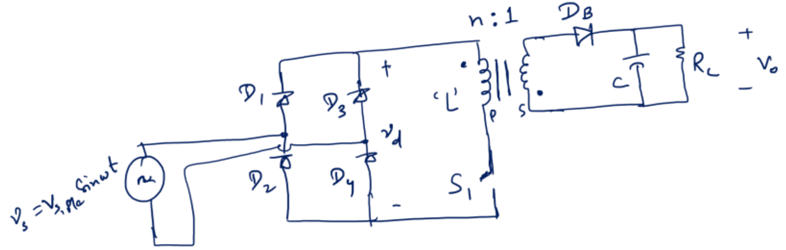


diode bridge rectifier

DC-DC Boost Converter

DCM mode

Flyback based PFC Converter



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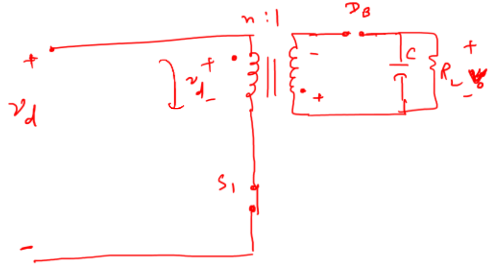


$v_d = |v_s|$

$d(t) \rightarrow$ duty ratio of switch 'S_1' that varies with time 't'

$S_1 \rightarrow$ is switching with frequency f_{sw}

$\Rightarrow f_{sw} \gg f_s$

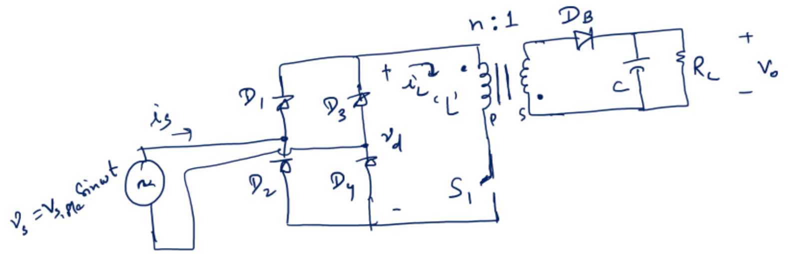
$\Rightarrow$ during $\underline{d(t)T_s \text{ period}}$ $\Rightarrow$ the 'S_1' is ON

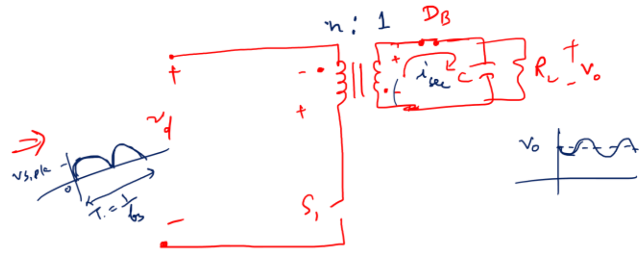
$\Rightarrow \quad v_L = |v_s|$

Flyback based PFC Converter

$(1-d(t))T_s$

$T_s = \frac{1}{f_{sw}}$





$(1-d(t))T_s \rightarrow$ the S_1 is off $\Rightarrow$ D_B is forward biased

$\Rightarrow$ Core is deenergized, as the flux in the core comes back

$\Rightarrow v_L = -nV_o$

$\Rightarrow$ Then, apply volt-sec balance in half-line cycle

$$\frac{1}{T/2}\left[\int_0^{T/2}\left[d(t)\cdot T_s\cdot |v_s| + (1-d(t))\cdot T_s\cdot -nv_o\right]\cdot dt\right] = 0$$

$$\Rightarrow \quad d(t)\cdot \cancel{T_s}|v_s| - nv_o\,(1-d(t))\cancel{T_s} = 0$$

Flyback based PFC Converter

$$|v_s| \cdot d(t) = nV_o(1-d(t))$$

$$\Rightarrow \quad |v_s|\,d(t) + nV_o\,d(t) = nV_o$$

$$\Rightarrow \quad d(t) = \frac{nV_o}{|v_s| + nV_o}$$

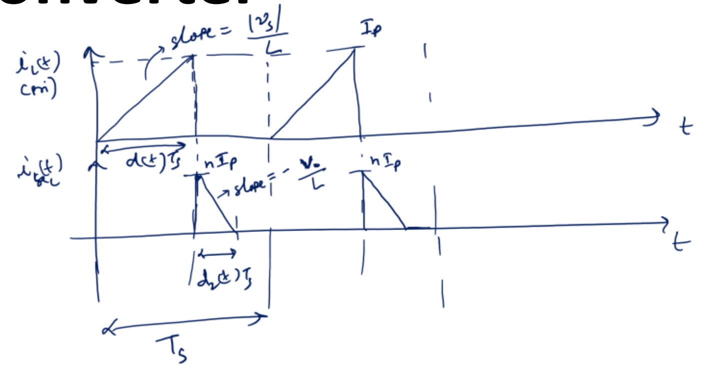
$$\Rightarrow \quad d(t) = \frac{1}{1 + \frac{|v_s|}{nV_o}}$$

$$\Rightarrow \quad \boxed{d(t) = \frac{1}{1 + \frac{V_{s,pk}|\sin\omega t|}{nV_o}}}$$

Flyback based PFC Converter

DCM operation of flyback based PFC converter

$\Rightarrow d_2(t) < 1 - d(t)$



$d(t)T_s$ period

$$|v_s(t)| = \frac{L I_p}{d(t)T_s}$$

($L \rightarrow$ referred to primary side)

$$\Rightarrow I_p = \frac{d(t)T_s}{L}|v_s(t)|$$

I_p varies with $|v_s(t)|$

$$\Rightarrow \langle i_L \rangle_{T_s} = \frac{1}{T_s} \times \frac{1}{2} \times \frac{d(t)T_s|v_s(t)|}{L} \times d(t)T_s$$

$$= \frac{1}{2}\frac{d^2(t)T_s|v_s(t)|}{L}$$

Flyback based PFC Converter

$$\langle i_L \rangle_{T_s} = \frac{|v_s(t)|}{R_e} \qquad \Rightarrow \quad R_e = \frac{2L}{d^2(t)\, T_s} \longrightarrow (1)$$

$$\Rightarrow \quad P_o = \frac{V_o^2}{R_L}$$

$$\Rightarrow \quad P_{in} = \frac{V_{s,pk}^2}{2\, R_e}$$

Assume, the loss less converter

$$\Rightarrow \quad P_o = P_{in}$$

$$\Rightarrow \quad \frac{R_L}{R_e} = \frac{2 V_o^2}{V_{s,pk}^2} \longrightarrow (2)$$

$\Rightarrow$ from (1) & (2)

$$\frac{R_L \cdot T_s \cdot d^2(t)}{2L} = \frac{2 v_o^2}{V_{s,pk}^2}$$

$$\Rightarrow \quad d^2(t) = \frac{4 V_o^2}{V_{s,pk}^2} \frac{L}{R_L T_s}$$

$$\Rightarrow \quad d(t) = \sqrt{\frac{4 V_o^2}{V_{s,pk}^2} \cdot \frac{L}{R_L T_s}}$$

$$\Rightarrow \quad d(t) = \frac{2 V_o}{V_{s,pk}} \sqrt{\frac{L}{R_L T_s}} \longrightarrow (3)$$

In worst case scenario

$$d(t)_{(worst)} = \frac{1}{1 + \frac{V_{s,pk}}{n V_o}} \longrightarrow (4)$$

Substitute (4) in (3)

$$\Rightarrow \quad \frac{1}{1 + \frac{V_{s,pk}}{n V_o}} = \frac{2 V_o}{V_{s,pk}} \sqrt{\frac{L}{R_L T_s}}$$

$$\Rightarrow \quad L = \frac{n^2 R_L T_s}{4\left(1 + \frac{n V_o}{V_{s,pk}}\right)^2} \Rightarrow L_{critical}$$

$\Rightarrow L < L_{critical} \rightarrow$ DCM operation

$\Rightarrow L > L_{critical} \rightarrow$ CCM operation

$$L_{critical} = \frac{n^2 R_L T_s}{4\left(1 + \frac{n v_o}{v_{s,pk}}\right)^2}$$

referred to primary side

$L < L_{critical} \longrightarrow$ DCM is possible

if we can ensure, the 'L' value to be smaller than the minimum $L_{critical}$ value, then we can always ensure the DCM operation

$L_{critical,min} \Rightarrow$ R_L is min & $v_{s,pk}$ is at Min.

full load power

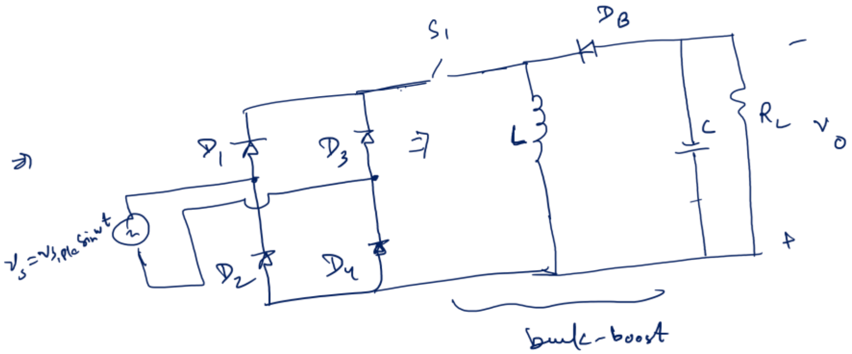
$L_{critical,min}$ has to be calculated for peak power demand and at Min value input pk voltage

$L < L_{critical,min} \Rightarrow$ DCM is ensured

Advantage

(1) Isolation is incorporated

(2) voltage follower mode



⇒ buck-boost or Flyback operated in DCM has the resistive effective input impedance and thus, the current drawn from the source will be having sinusoidal variation.

Thank You