IIT ROORKEE

NPTEL ONLINE CERTIFICATION COURSE

Charging Infrastructure

Lecture-11

Single-phase Boost PFC Converter-III

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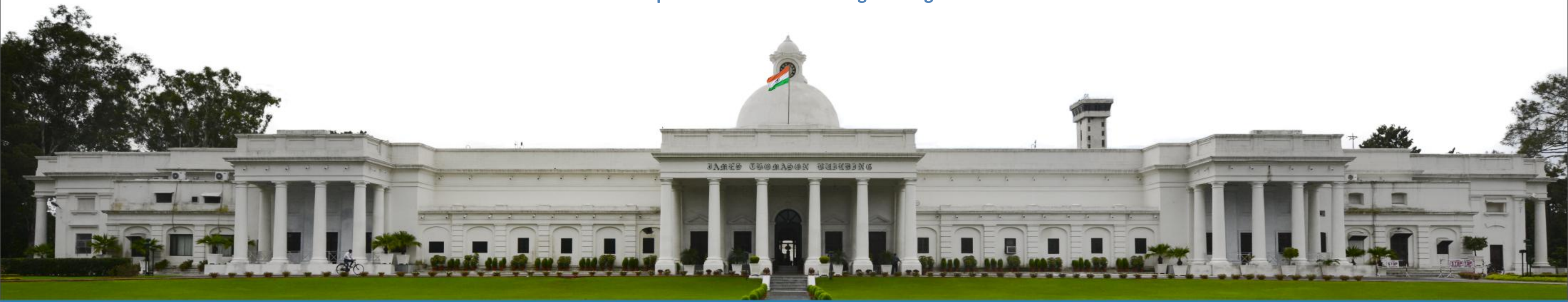
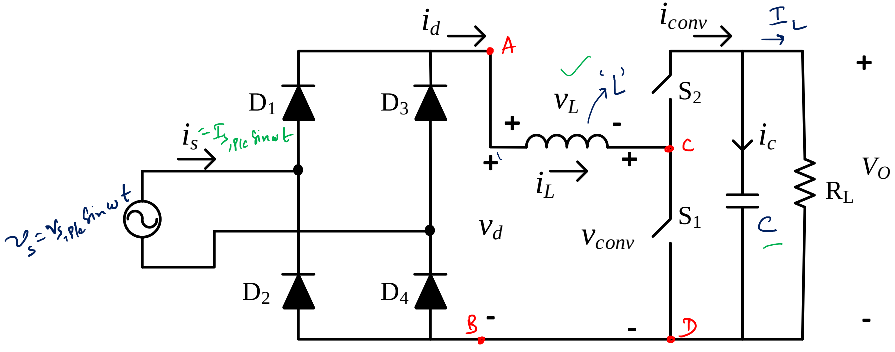
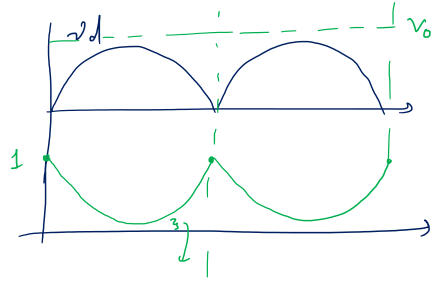


Recap



full-bridge diode rectifier

Boost converter



$$1 - \frac{V_{s,pk}}{V_o}$$

for $S_2 \rightarrow d(t)_{,S_2} = 1 - d(t) = \dfrac{|v_{s,pk}\sin\omega t|}{V_o}$

for $S_1 \rightarrow d(t)_{,S_1} = d(t)$

$v_d = |v_s(t)|$

$v_d = v_{s,pk}|\sin\omega t| \Rightarrow f_{sw} \gg f_s$

$$d(t) = 1 - \frac{|v_{s,pk}\sin\omega t|}{V_o} \Rightarrow 0 < d(t) < 1 \Rightarrow V_o > V_{s,pk} \rightarrow$$

$230V \rightarrow 325V$

$\Rightarrow V_o > 325V$

$\simeq V_o \simeq 400V$

$$L = \frac{V_o}{4\,\Delta i_{L,max}\, f_{sw}} \Rightarrow$$

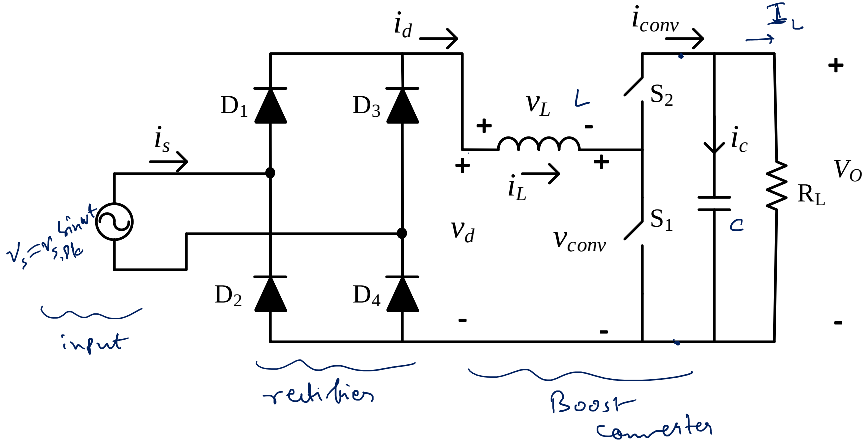
$\Delta i_{L,max}$ → allowable ripple current → 10% of $I_{s,pk}$

Sizing of 'C'

Assumption, the converter is operated in such a manner that the upf current is drawn from the grid

$\Rightarrow \quad i_s = I_{s,pk} \sin\omega t$

$v_s = V_{s,pk} \sin\omega t$



Power at the input

$$P_{in}(t) = (V_{s,pk} \sin\omega t)(I_{s,pk} \sin\omega t)$$

$$= V_{s,pk} I_{s,pk} \sin^2\omega t$$

$$= V_{s,pk} I_{s,pk} \frac{(1-\cos 2\omega t)}{2}$$

$$P_{in}(t) = \frac{V_{s,pk} I_{s,pk}}{2} - \frac{V_{s,pk} I_{s,pk} \cos 2\omega t}{2} \longrightarrow (1)$$

Power at the output of half bridge

$$P_d(t) = i_{conv}(t) \cdot V_o \longrightarrow (2)$$

Assume, the losses in rectifier & boost converter is negligible

$\Rightarrow \quad Eq(1) = Eq(2)$

$\Rightarrow \quad P_{in}(t) = P_d(t)$ (By doing the power balance)

$$\Rightarrow \quad i_{conv}(t) \cdot V_o = \frac{V_{s,pk} I_{s,pk}}{2} - \frac{V_{s,pk} I_{s,pk}}{2} \cos 2\omega t$$

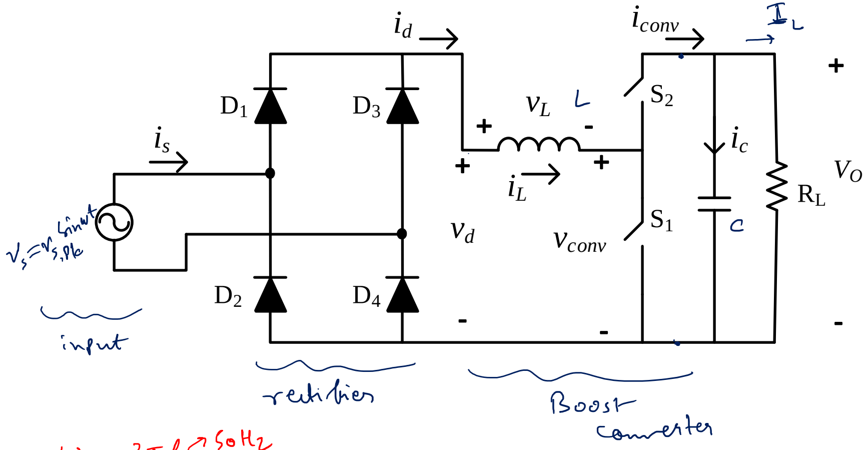
$$\Rightarrow \quad i_{conv}(t) = \frac{V_{s,pk} I_{s,pk}}{2 V_o} - \frac{V_{s,pk} I_{s,pk} \cos 2\omega t}{2 V_o}$$

will be flowing to the load 'R_L' ← DC quantity

2nd harmonic current → will be flowing through the capacitor

⇓ 2nd line harmonic current

$$i_{conv}(t) = i_c(t) + I_L$$



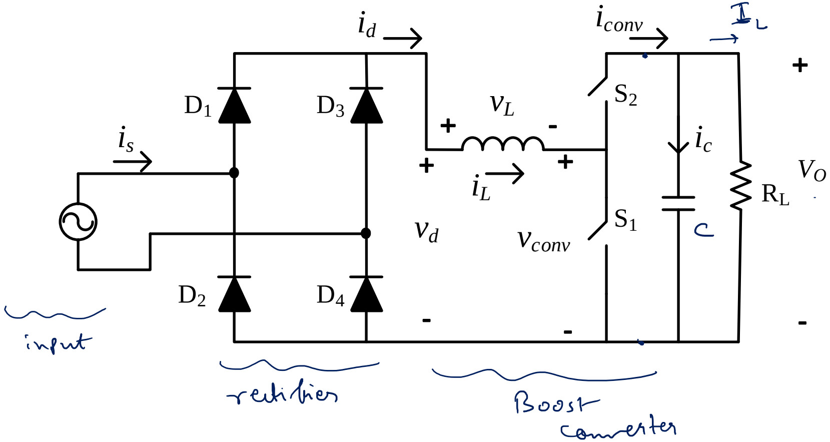
$\omega = 2\pi f_s \rightarrow 50\,Hz$

$$i_c(t) = \frac{-V_{s,pk} I_{s,pk} \cos 2\omega t}{2 V_o}$$

the ripple generated by the $i_c(t)$

$$\Rightarrow V_{o,ripple} = \frac{1}{C} \int i_c(t) \cdot dt$$

$$V_{o,ripple} = \frac{1}{C} \int -\frac{V_{s,pk} I_{s,pk}}{2 V_o} \cos 2\omega t \cdot dt \longrightarrow (3)$$



we can write,

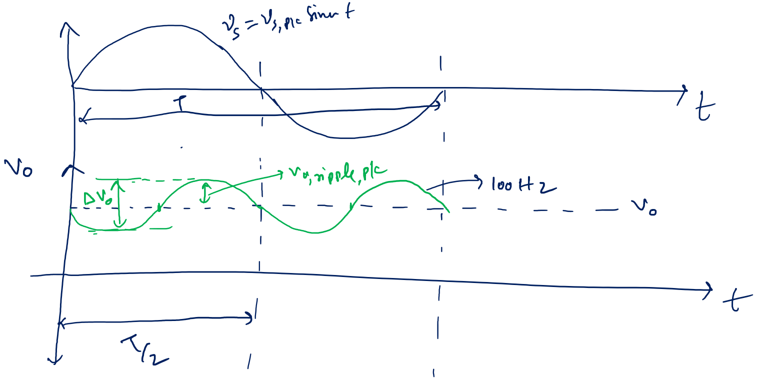
$$\frac{V_{s,pk} I_{s,pk}}{2 V_o} = I_L \longrightarrow (4)$$

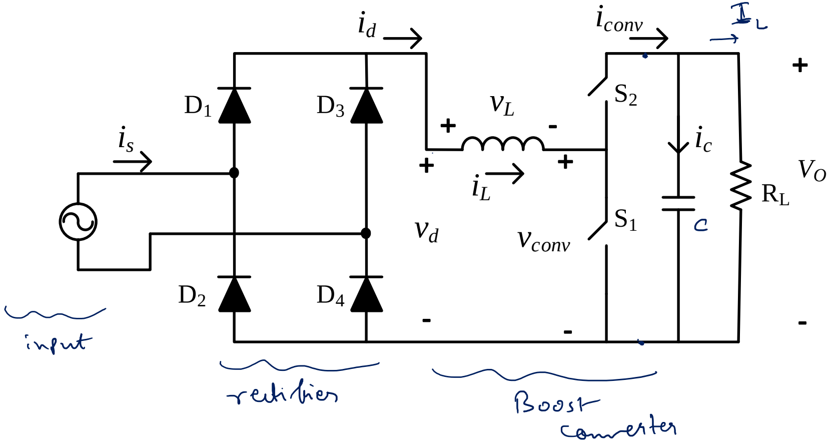
Eq. (4) in (3)

$$\Rightarrow V_{o,ripple} = -\frac{I_L}{C} \int \cos 2\omega t \cdot dt$$

$$V_{o,ripple} = \frac{-I_L}{2C\omega} \sin 2\omega t \longrightarrow (5)$$

$$V_{o,ripple,pk} = \frac{I_L}{2\omega C} \longrightarrow (6)$$





$$C = \frac{I_L}{2\omega\, V_{o,ripple,pk}}$$

$$C = \frac{I_L}{\omega\, \Delta V_o}$$

$\Rightarrow \quad C = \dfrac{P_L}{\omega \Delta V_0 \cdot V_0}$

$\Rightarrow \quad C = \dfrac{P_L}{2\pi f_s \Delta V_0 \cdot V_0}$

P_L → specification

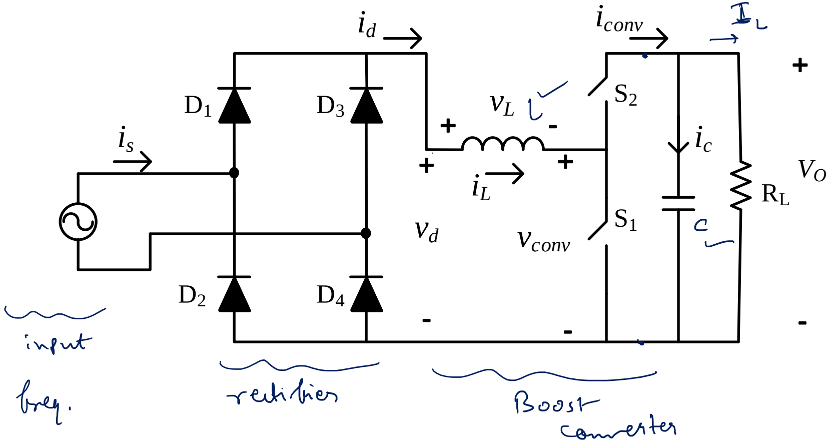
f_s → specification ← the line freq.

ΔV_0 → allowable voltage ripple

V_0 → specification

⇒ Capacitor 'C' sees the 2nd line harmonic current & has ripple which is of 2nd line harmonic freq

⇒ C is of large size because of 2nd line harmonic freq. component



Switch ratings

for 'S_1'

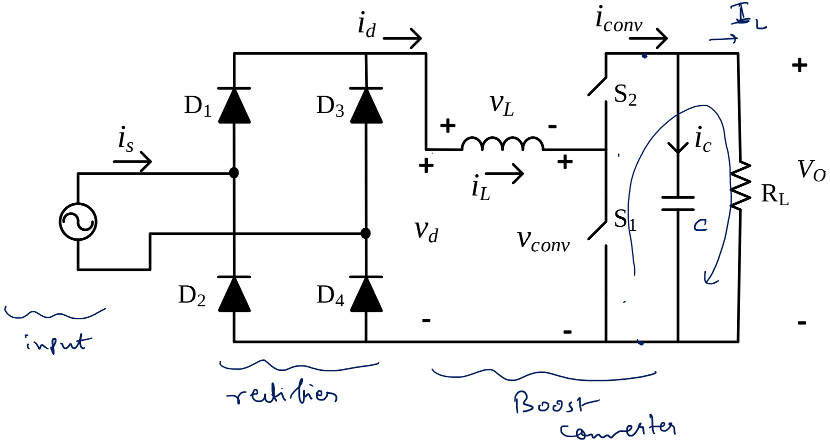
The voltage rating of S_1, $V_{S_1} = V_0$

$\Rightarrow V_{S_1} = 1.4\, V_0$ (40% – 60%)

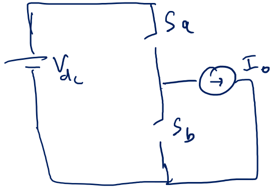
$V_0 = 400\,V$

$V_{S_1} \simeq 650V - 700V$

$\rightarrow 600V$



RMS current of 'S_1'



$$\text{The } I_{rms,S_a} = \sqrt{\frac{1}{T_s}\int_0^{T_s} (i_{Sa})^2\, dt}$$

$$= \sqrt{\frac{1}{T_s}\left[\int_0^{DT_s} I_0^2 + \int_{DT_s}^{T_s} 0\right] \cdot dt}$$

$$= \sqrt{\frac{1}{T_s} I_0^2 \int_0^{DT_s} dt}$$

$\Rightarrow$ when S_a is ON $\rightarrow$ $D\,T_s$

Duty ratio

Switching period

$= 1/f_{sw}$

The current through $S_a = I_o$

$\Rightarrow$ when S_a is off, $(1-D)\,T_s$

The current through $S_a = 0$

$$\Rightarrow I_{rms,sa} = \sqrt{\frac{1}{T_s} \cdot I_o^2 \; t \Big]_0^{DT_s}}$$

$$= \sqrt{\frac{1}{T_s} I_o^2 \cdot D T_s}$$

$$I_{rms,sa} = I_o \sqrt{D}$$

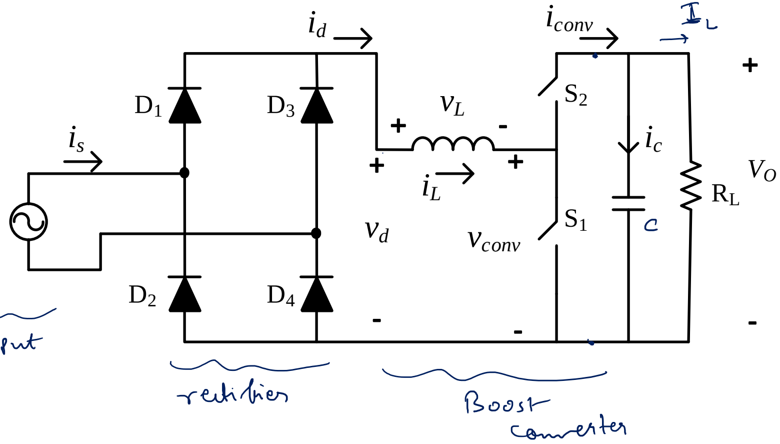
$P_L = \cdot$

$\Rightarrow P_{in} = 3.3k$

$\Rightarrow \frac{V_{s,pk} \cdot I_{s,pk}}{2} = 3.3kW$

$\Rightarrow I_{s,pk} = \frac{3.3kW \times 2}{V_{s,pk}}$

$\Rightarrow I_{s,pk} = \frac{P_L \times 2}{V_{s,pk}}$ input



Rms current of switch 'S1'

$$i_s(t) = I_{s,pk} \sin\omega t$$

$$i_L(t) = i_d(t) = I_{s,pk} \sin\omega t \rightarrow \text{in the half cycle}$$

$$\Rightarrow I_{S1,rms} = \sqrt{\frac{1}{T/2} \int_0^{T/2} (i_s(t))^2 \cdot d(t) \cdot dt}$$

(as during '$d(t)T_s$' period 'S_1' is ON)

$$I_{s1,rms} = \sqrt{\frac{2}{T} \int_0^{T/2} I_{s,pk}^2 \sin^2\omega t \left[1 - \frac{|V_{s,pk}\sin\omega t|}{V_o}\right] \cdot dt}$$

Thank You