DESIGN AND SIMULATION OF SERIES RESONANT CONVERTER FOR EV CHARGING

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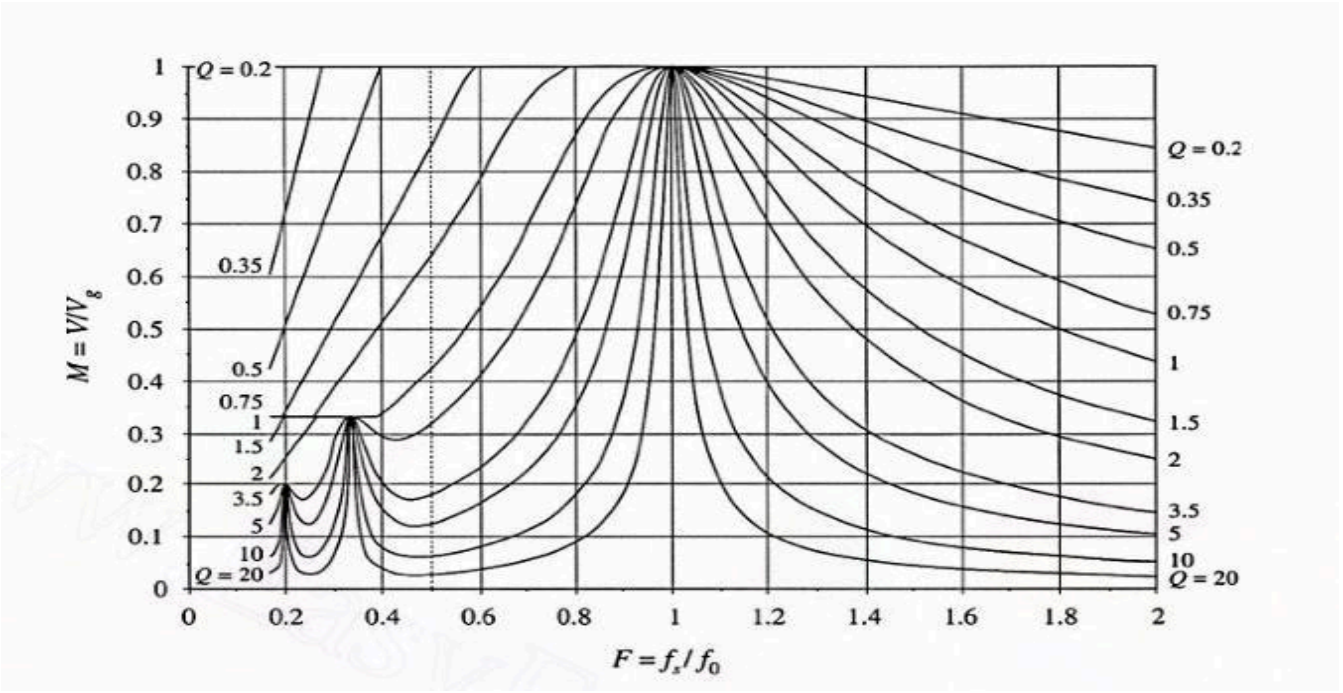
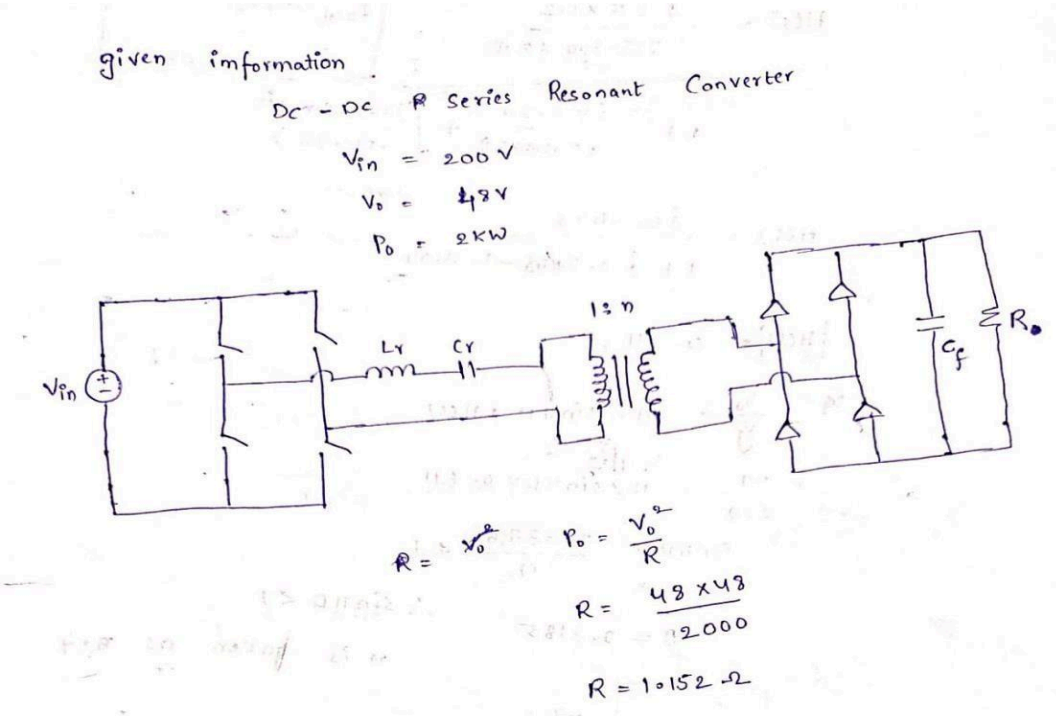


Figure 1 : M vs F for different Q values

Theoretical Calculations



DC voltage gain

$$\frac{V_o}{V_{in}} = n \cdot H(s) * \sin(\pi D)$$

$$H(s) = \frac{\frac{s}{Q_e \omega_o}}{1 + \frac{s}{Q_e \omega_o} + \left(\frac{s}{\omega_o}\right)^2}$$

take $Q_e = 25$

$f_o = 100 \times 10^3$ Hz

$\omega_o = 2\pi f_o$

$= 2\pi \times 100 \times 10^3$

$= 6.28 \times 10^5$ rad/sec.

$F = f_s / f_o = \frac{102}{100} = 1.02$

$f_{sw} > f_o$

$f_{sw} = 102$ KHz

$$H(s) = \frac{\frac{j\, 2\pi \times 102}{25 \times 100 \times 2\pi}}{1 + \frac{j102 \times 2\pi}{25 \times 100 \times 2\pi} + \left(\frac{j102 \times 2\pi}{100 \times 2\pi}\right)^2}$$

$$H(s) = \frac{j\,0.0408}{1 + j\,0.0408 - 1.0404}$$

$$|H(s)| = 0.711$$

$$\frac{V_o}{V_g} = n \times \sin\pi D \times H(s)$$

$$\frac{48}{200} = n \times \sin\pi D \times 0.711$$

$$\sin\pi D = \frac{0.3376}{n} < 1$$

$\therefore \sin\pi D < 1$

$D = 0.3185$

n is taken as 0.4

$$n = 0.4$$

$$V_o = 0.4 \times 0.711 \times 200 \times \sin\pi D$$

$$(V_o)_{max} = 56.88\ V$$

$$Q_e = \frac{\omega_o L}{R_e}$$

$$L_r = \frac{Q_e R_e}{\omega_o}$$

$$= \frac{25 \times 5.844}{2\pi \times 10^5}$$

$$= 232.6\,\mu H$$

$$L_r \simeq 230\,\mu H$$

$$R_e = \frac{8}{\pi^2} R/n^2$$

$$= \frac{8}{\pi^2} \times \frac{1.152}{0.4^2}$$

$$= 5.844\,\Omega$$

$$\omega_o = \frac{1}{\sqrt{L_r C_r}}$$

$$C_r = \frac{1}{L_r \omega_o^2} \Rightarrow \frac{10^6}{232.6 \times (2\pi \times 10^5)^2}$$

$$= 10.9nf$$

$$\simeq 11nf$$

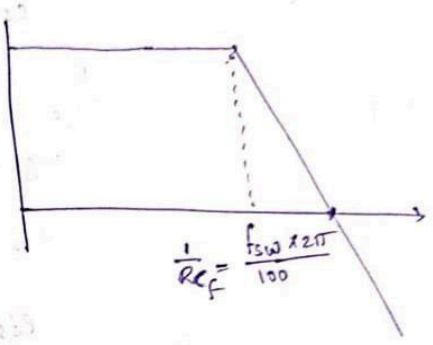
$$s = \frac{1}{R C_f}$$

$$C_f = \frac{1}{R \omega_{sw}/100}$$

$$= \frac{100}{1.152 \times 2\pi \times 102 \times 10^5}$$

$$= 135.5 \times 10^{-6}\ f$$

$$C_f \simeq 150\,\mu f$$



$$T(s) = 4V_g \cos\pi D \left(\frac{1}{SL_r + \frac{1}{SC_r}} + R_e \right) \times \frac{2n}{\pi (SC_f + \frac{1}{R_o})}$$

$$= 4 \times 200 \times \cos(\pi \times 0.3185) \left\{ \frac{S \times 11 \times 10^{-9}}{S^2 (11 \times 10^{-9} \times 230 \times 10^{-6}) + 5.844 \times 11 \times 10^{-9} S + 1} \right\}$$

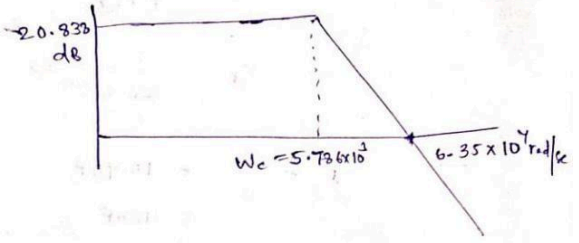
$S = 640.56 \times 10^3$ rad/sec

$$\cdot \times \frac{2 \times 0.4}{\pi \times \left(S\,150 \times 10^{-6} + \frac{1}{1.152} \right)}$$

$$= \frac{110.11 \times 867.82 \times 10^{-4} \angle 60}{S\,150 \times 10^{-6} + 0.868}$$

$$\boxed{T(s) = \frac{9.56 \angle 60}{S\,150 \times 10^{-6} + 0.868}}$$

Bode-plot of uncompensated system



take

$t_{ss} \leq 5$ ms

$e_{ss} \leq 1\%$

$$\frac{4}{\omega_{gc}} \leq 5 \times 10^{-3}$$

$\omega_{gc} \geq 800$ rad/sec

$$e_{ss} = \lim_{s \to 0} \frac{1}{1 + GH}$$

$$e_{ss} = \lim_{s \to 0} \frac{1}{1 + \cancel{G}}$$ DC Gain of $G = 11.01$

$$\frac{1}{1 + 11.01 H} = 0.01$$

dc gain of Compensator > 9

$H > 9$

$$\omega_{gc} \leq \frac{2\pi f_{sw}}{10}$$

~~Be~~ take

~~For~~ ~~Add~~ PI Controller, ~~Be~~ Add one zero at $\frac{w_c}{10}$

And integrator,

$$K\left(\frac{s+570}{s}\right)$$

take $w_{gc} = 10 \times 10^3$ rad/sec

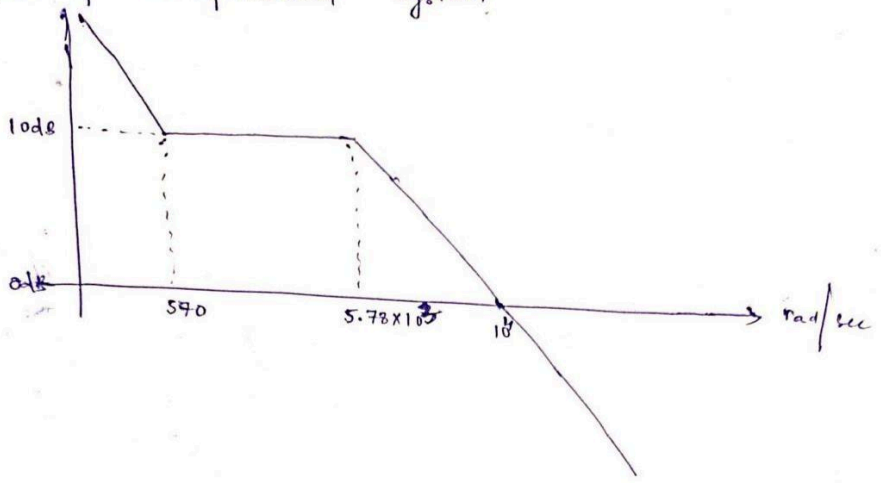
$$\left[\frac{K(s+570)}{s} \times \frac{9.56}{s+50 \times 10^{-6} + 0.868}\right] = 1$$

$w_{gc} = 10^4$

We get $K = 0.2$

$$H(s) = \frac{s+570}{5s}$$

Bode - plot of Compensated System

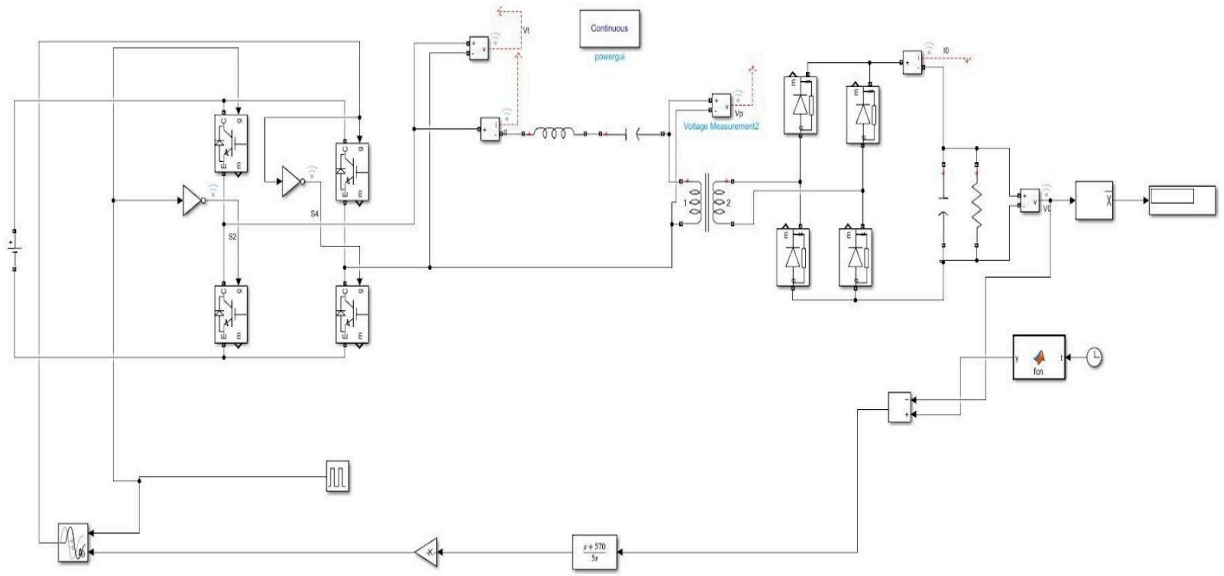


~~PM~~ Phase margin $= 180 + |G|$

$= 180 + (-6)$

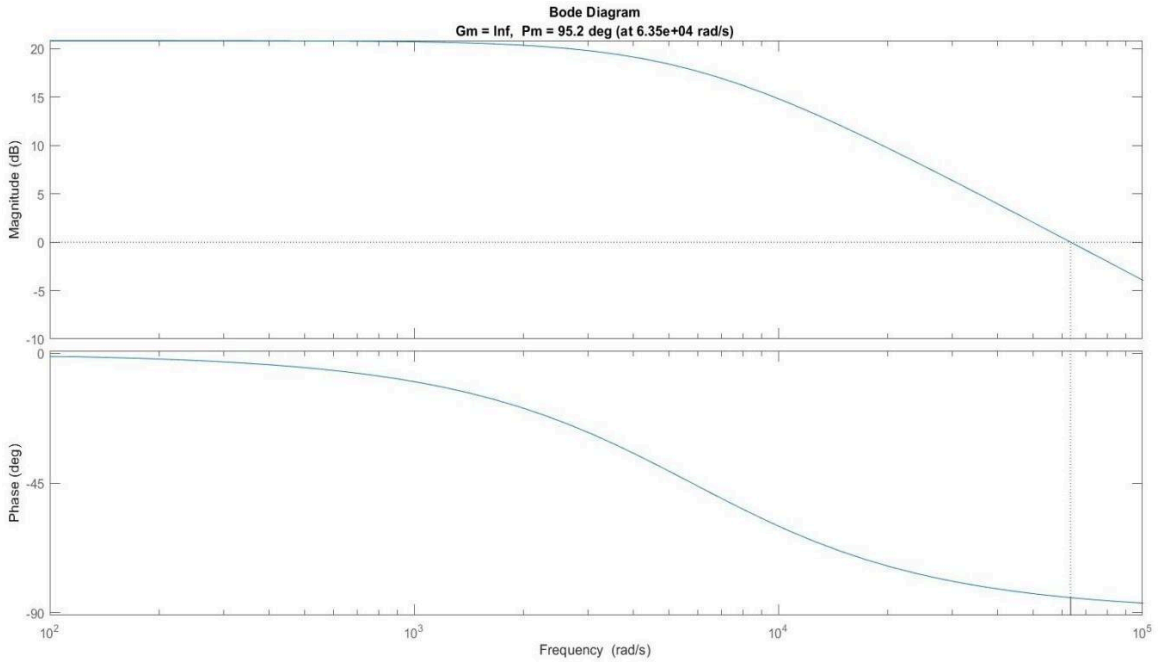
$= 174^\circ$

Simulink Model

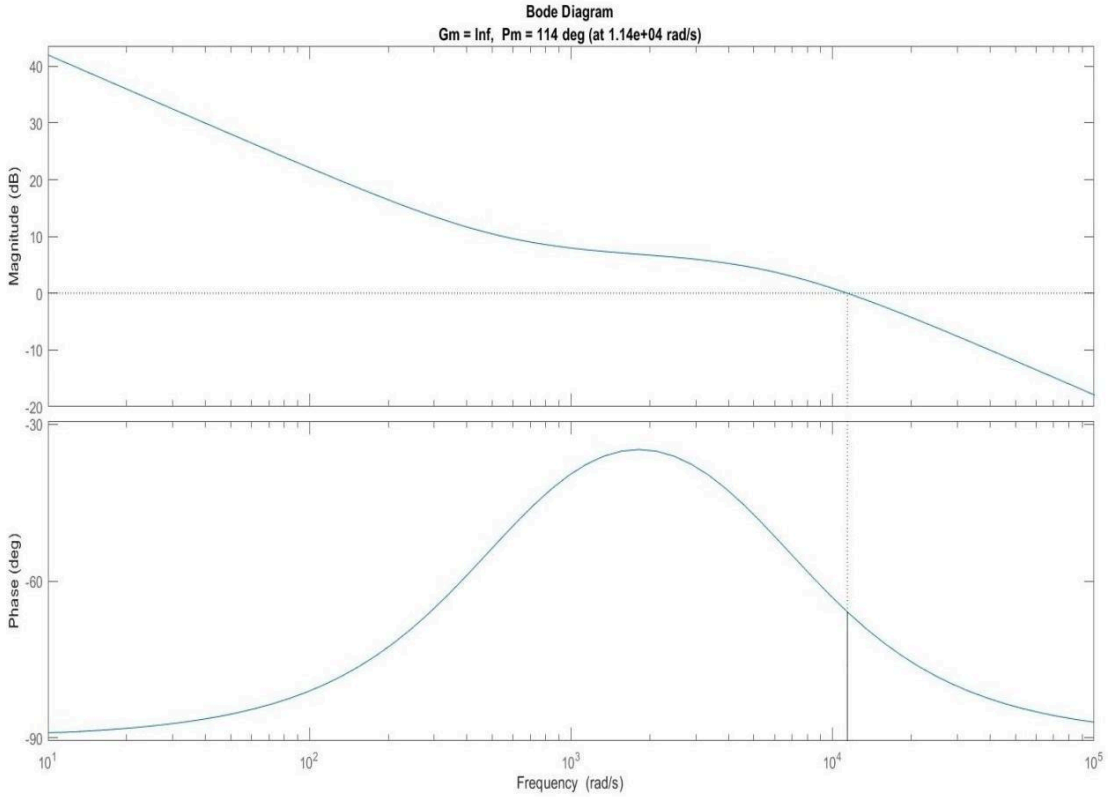


Bode Plots

Uncompensated System

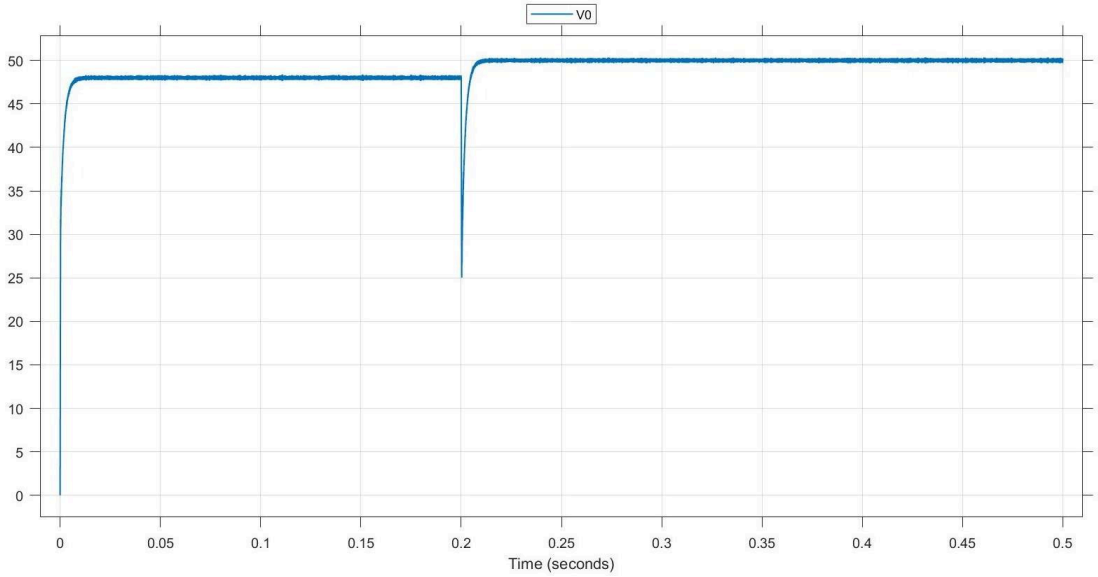


Compensated System

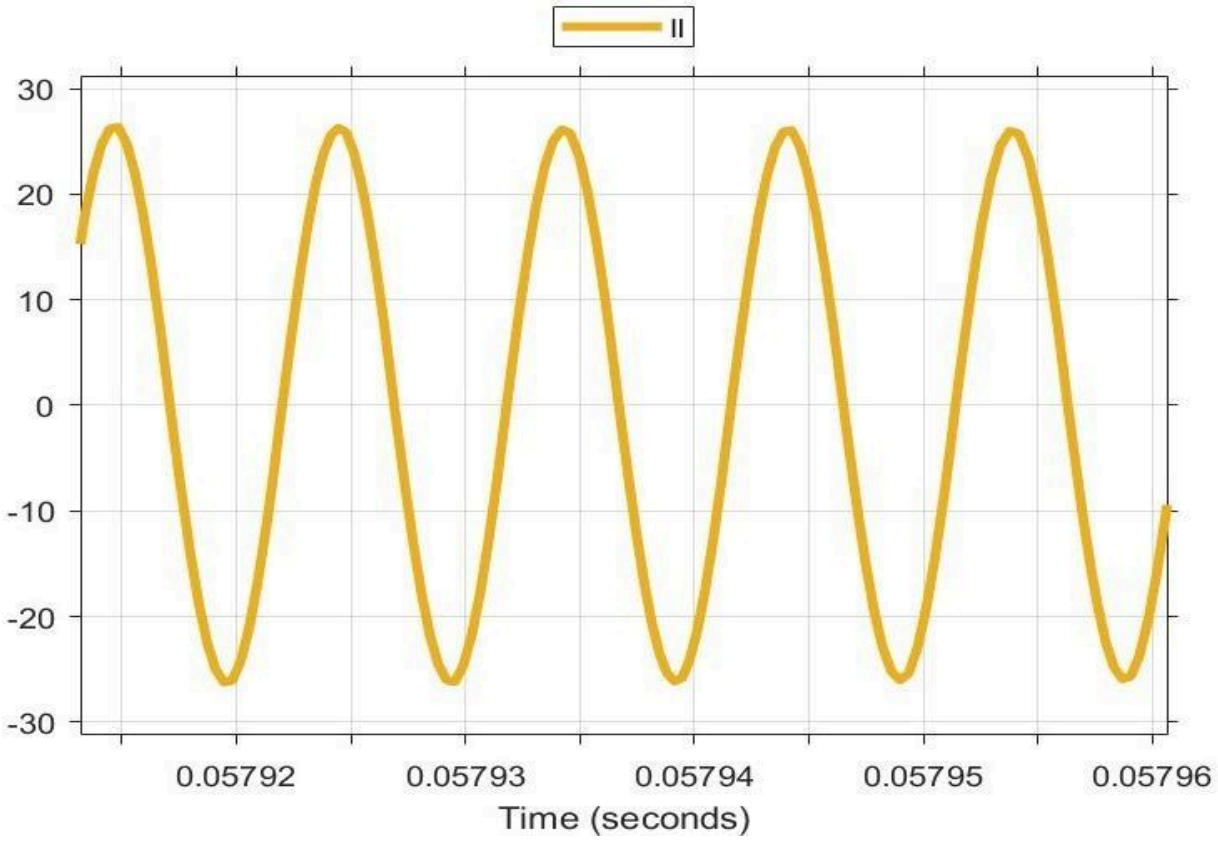


Waveforms

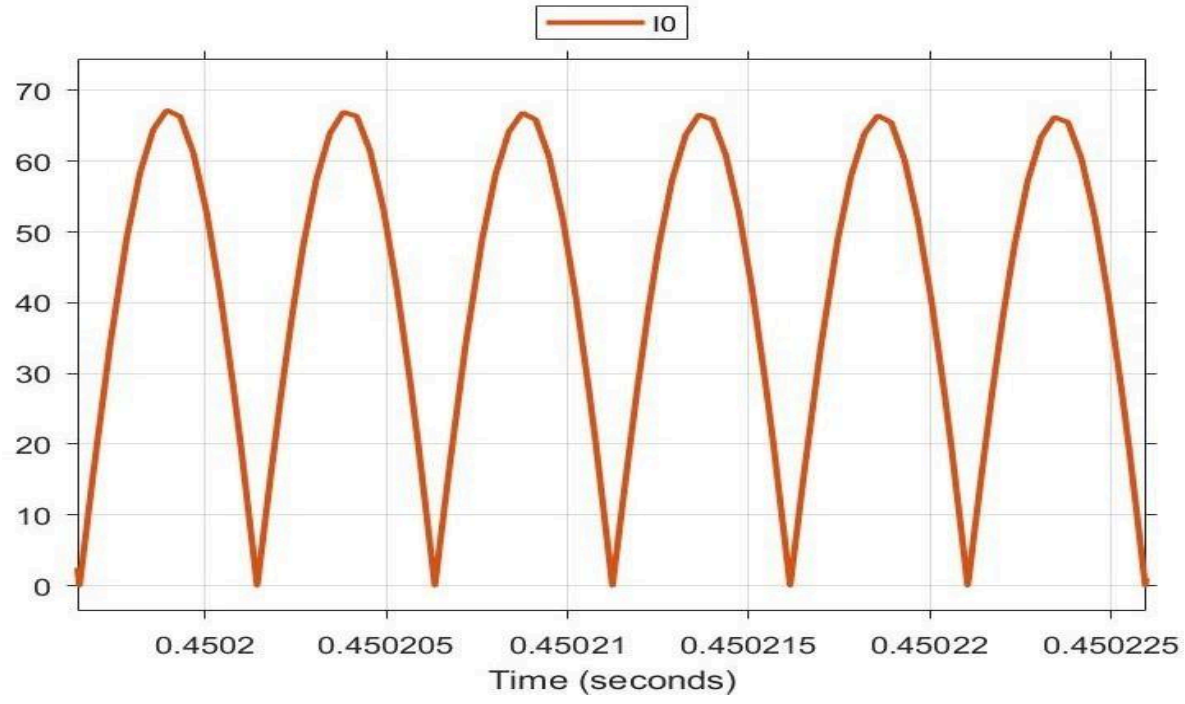
Output Voltage



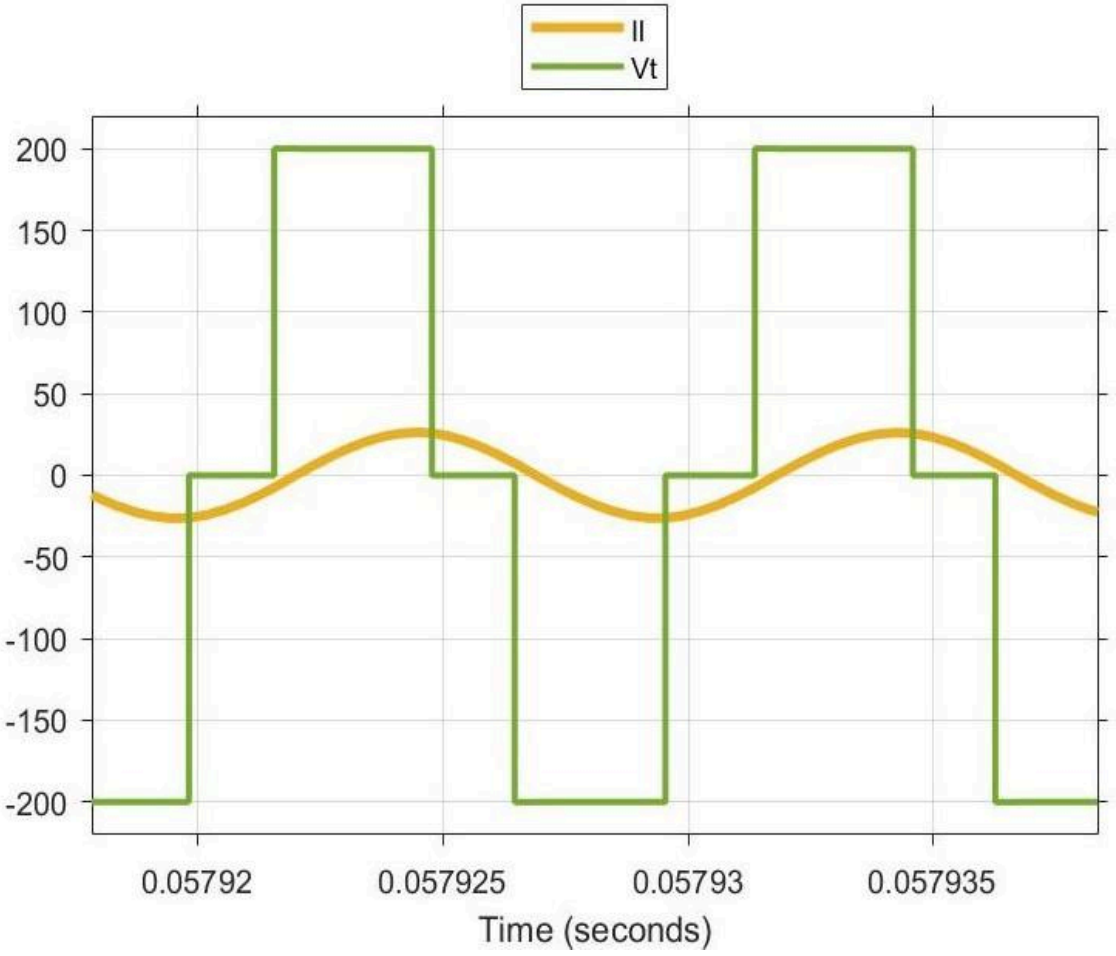
InductorCurrent



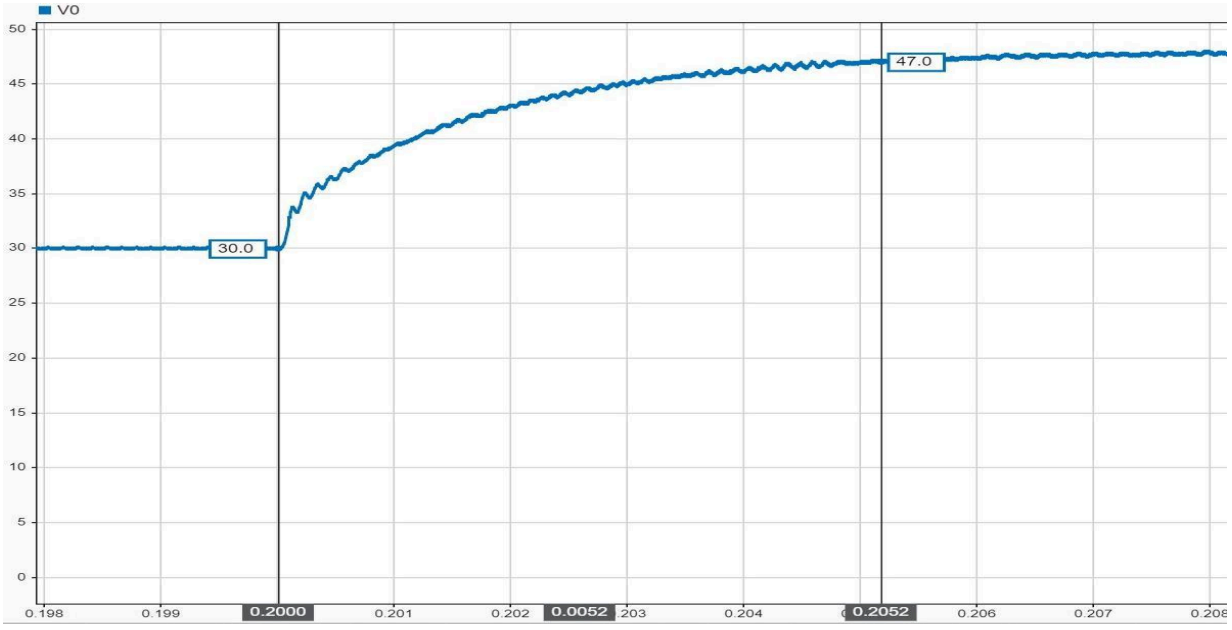
Output Current



Zero Voltage Switching



Settling Time



Selection of Switches

MOSFET

VDS(MAX) = 200V

Safety Factor = 1.5

VDS of switch >= 200*(1.5)

>= 300V

RMS Current of MOSFET = 26,5/2 = 13.25A

Safety Factor = 2

I RMS rating >= 13.25*2

>= 26.5A

Data Sheet :

https://www.mouser.in/datasheet/2/308/1/FDB28N30TM_D-2311897.pdf

Diode

PIV = 48V

Safety Factor = 1.5

Voltage rating of Diode >= 72V

Average current of Diode = 20.38A

Safety Factor = 1.5

I RMS rating >= 20.38*1.5

>= 30.57A

Data Sheet :

https://www.vishay.com/doc?89169