Load sharing & Balancing of Transformers University College of Engineering, KU Kothagudem-507101

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1 Objective:

Load analysis and balance for a transformer involves ensuring that the transformer is loaded evenly across its phases to prevent unbalanced conditions. Unbalanced loads can cause secondary voltage imbalances, additional transformer losses, and high neutral currents :

Sr.No.	Parameters	Value
1	Input Voltage	24V
2	Inductor	50μ H
3	Capacitor	100μ F
4	load Resistance	2 Ω
5	Switching Frequency	100kHz
6	Desired Gain Cross over Frequency	100Hz
7	Desired Phase margin	140°

Tabel 1: Input Parameters

2 Theory:

2.1 Duty Ratio:

Duty ratio represent the relation of input and putput voltage:

$$D = \frac{V_{in}}{V_o} \tag{1}$$

2.2 Transfer function

After performing small signal analysis function of the Buck converter we can easily get transfer:

$$G_p(s) = \frac{V_o(s)}{d(s)} = \frac{V_{in}}{LCs^2 + \frac{L}{R}s + 1} \tag{2}$$

3 Compensator Design:

For designing of compensator first we calculate phase and gain of the transfer function at desired gain crossover frequency.

$$\phi_p = \angle G_p(j\omega)|_{\omega=\omega_c} = -0.905^\circ$$

$$\phi_b = \phi_m - \phi_p - 90$$

$$\phi_b = 120 - (-0.905) - 90$$

$$\phi_b = 49.095^{\circ}$$

Here ϕ_b is less than 90° so, we will go for type-2 compensator. Transfer function for the type -2 compensator is-

$$G_c(j\omega) = G_{MB} * \frac{(1 + \frac{\omega_z}{j\omega_c})}{(1 + \frac{j\omega}{\omega_p})}$$

Calculation for the compensator parameters-

$$k = tan(45^\circ + \phi_b/2) = 2.68139$$

$$\omega_z = \frac{\omega_c}{k} = 234.3256 rad./sec$$

$$\omega_p = k * \omega_c = 1684.7670 rad./sec$$

$$G_{MB} = \frac{1}{|G_p(j\omega_c)|} = \frac{1}{23.98}$$

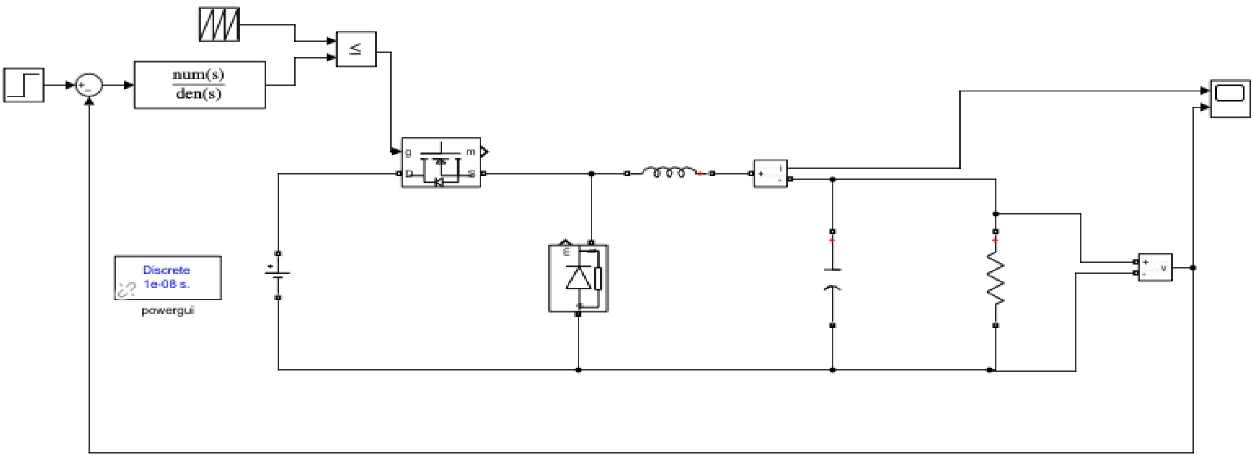
So finally the compensator is-

$$G_c = \frac{1684.77}{24} * \frac{s + 234.33}{s(s + 1684)}$$

MATLAB code for compensator is-

```
clc
clear all
close all
Vs=24; L=50*10^-6; C=100*10^-6; R=2;
num=[Vs ] ;
den=[L*C L/R 1 ] ;
Gp=tf (num, den )
bode (Gp)
grid on
%margin (Gp)
hold on
numc=[1 234.33] ;
denc =[1 1684.77 0 ] ;
Gc=( 1684.77/24 )*tf ( numc , denc ) %Compensator design
bode (Gc*Gp)
grid on
margin (Gc*Gp)
hold on
```

3.1 Simulation model of Buck Converter:



4 Waveforms and Results:

Bode plot of the compensated (closed loop buck converter) and uncompensated (open loop buck converter) is showing in red and blue colour respectively. Compensated system gives the phase margin 120° at the desired frequency 300Hz.

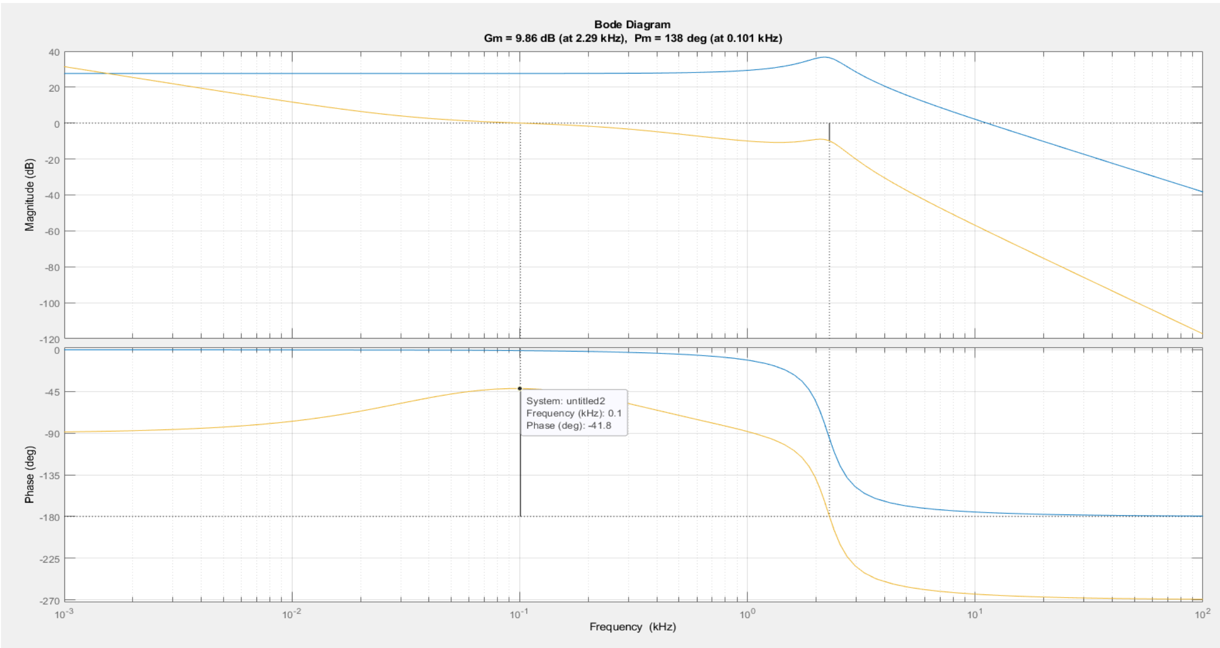


Fig. 1: Bode plot of compensated and uncompensated converter

By seeing the below waveforms we are giving inital reference signal 10V which is followed by output and giving step at 0.05 sec. to 15V again followed by the output of the converter.

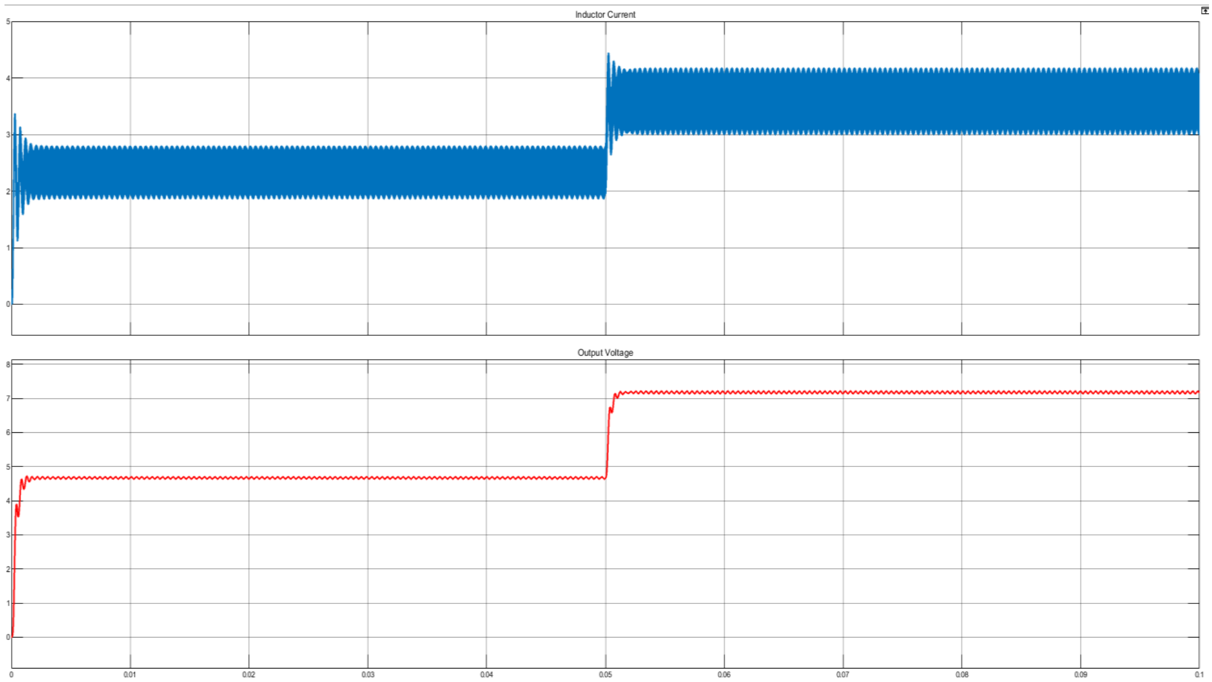


Fig. 2: Waveforms of output voltage and inductor current

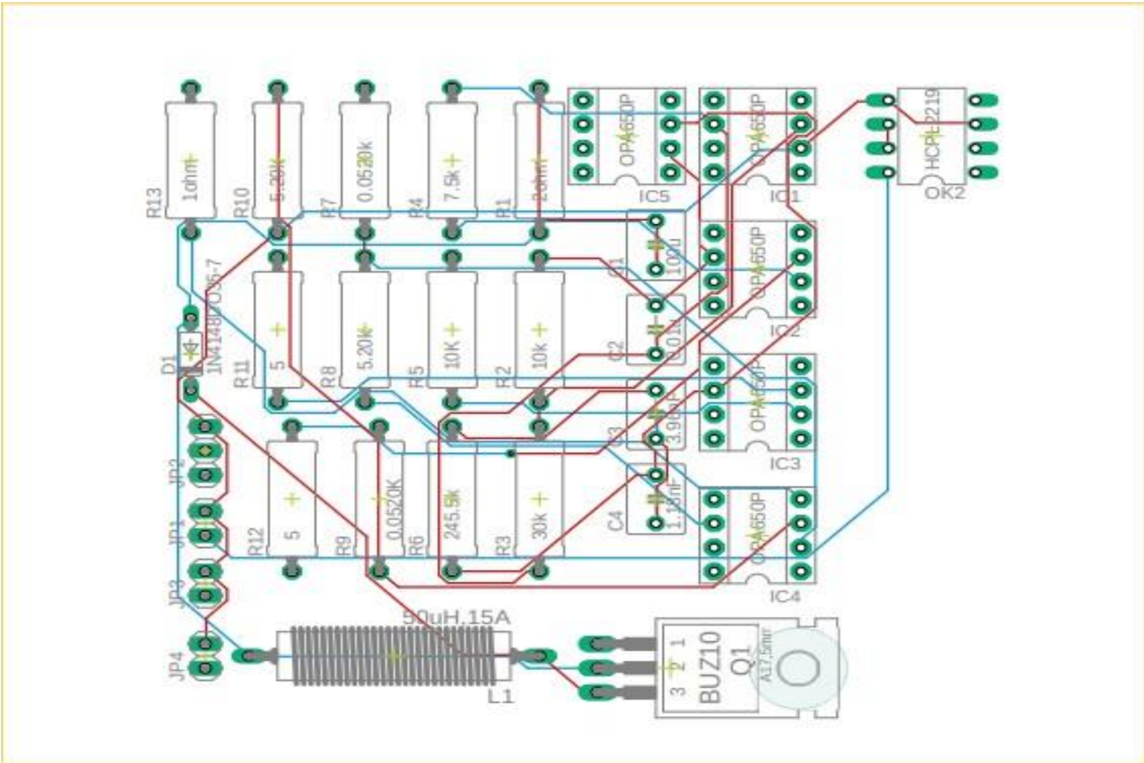
5 Transformer Effieciency :

- % Efficiency at UPF full load ($\cos \varphi_2 = 1$)

$$\%\text{Efficiency} = \frac{(\underbrace{x}_{\boxed{1}} \times \text{Full load VA}) \times \text{P.F}}{(x \times \text{Full load VA}) \times \text{P.F} + \underbrace{P_i}_{\boxed{60\ \text{W}}} + x^2 \underbrace{P_c}_{\boxed{60\ \text{W}}}}$$

$$P_c = W_s \frac{I_2^2}{I_s^2}$$

$$\%\text{Efficiency} = \frac{4000}{4120} \times 100 = 97.1\%$$


50uH,15A
L1
BUZ10
Q1
IC1
IC2
IC3
IC4
IC5
OK2
R13
R10
R7
R4
R1
R11
R8
R5
R2
R12
R9
R6
R3
C1
C2
C3
C4
D1
JP1
JP2
JP3
JP4