

MIDDLE EAST TECHNICAL UNIVERSITY

Electrical & Electronics Engineering

Simulation Project #2

EE 464 – Static Power Conversion - II

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# Introduction

In our hardware project of the EE464 course, we are asked to design an Isolated Power Supply. In this project, the design and simulations are to be performed for hardware project. As Anca Inc. group, we have chosen the project designing an Isolated Flyback Converter. The specifications are as follows;

|  |  |
| --- | --- |
| Minimum Input Voltage (V) | 210 Vac |
| Maximum Input Voltage (V) | 230 Vac |
| Output Voltage (V) | 15 |
| Output Power (W) | 15 |
| Output Volt. Peak-to-Peak Ripple (%) | 5 |
| Line Regulation (%) | 3 |
| Load Regulation (%) | 3 |

Table 1: Flyback Converter Specifications

# Question-1

## a)

Our input voltage is AC voltage with 210 V rms. Firstly, we establish the single phase full bridge rectifier to convert AC to DC and the DC voltage is filtered by DC-Link Capacitor. Then, a Flyback Converter is established by PI controller. PI controller is required to adjust the output power 15 V for not considering input voltages change.

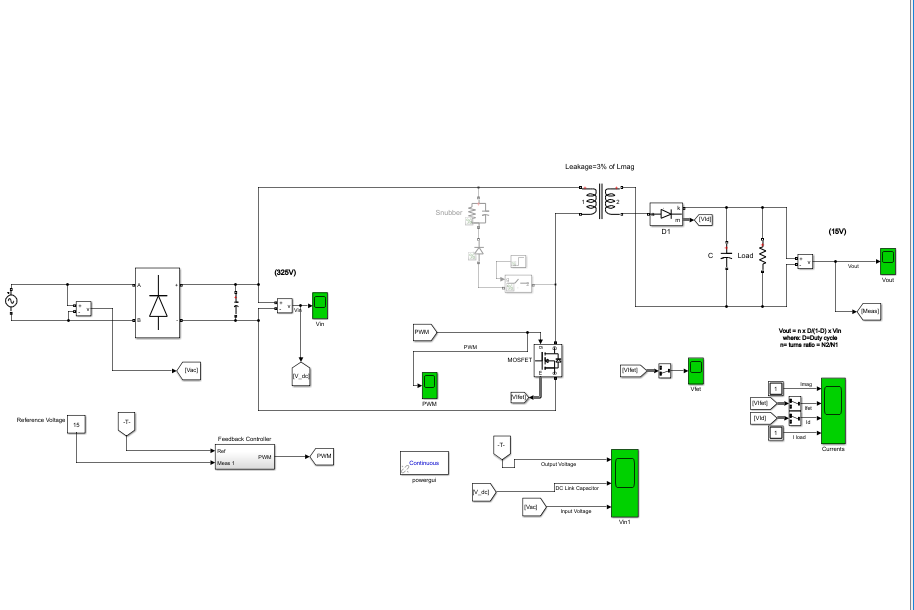


Figure 1: Simulink Setup of Flyback Converter

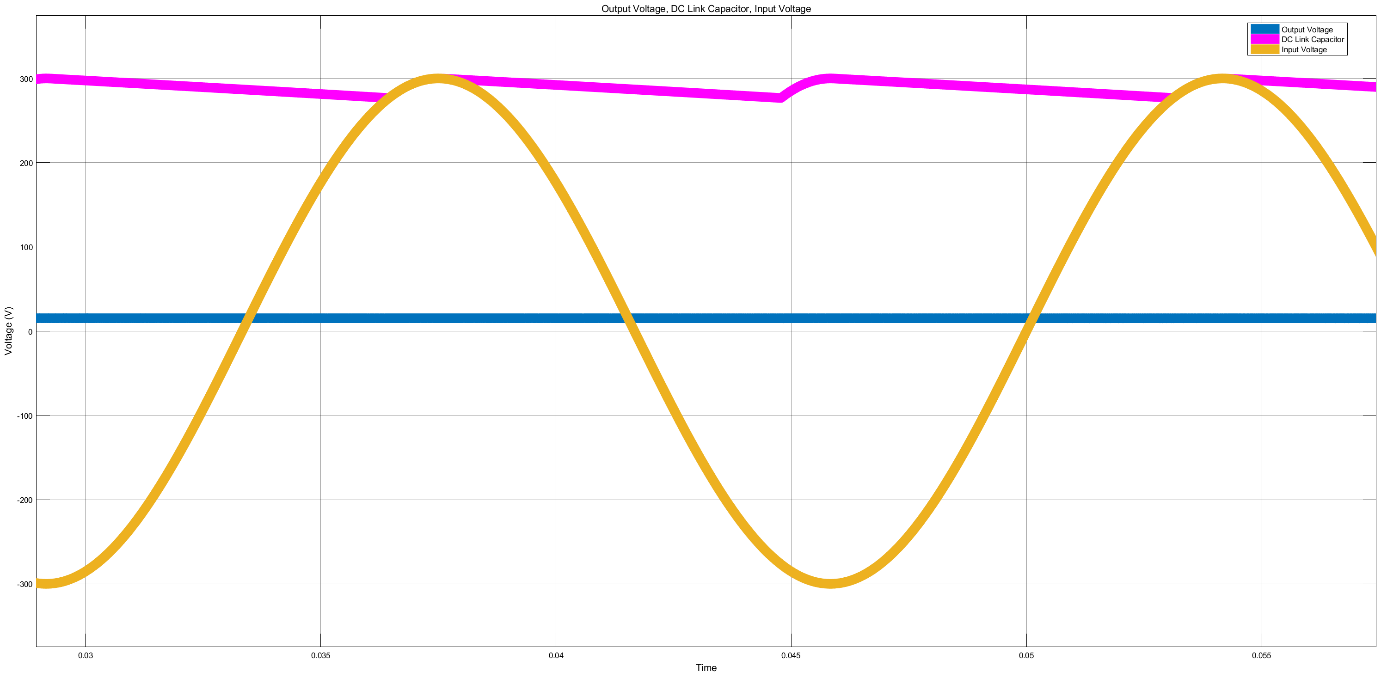


Figure 2: Inputs and Output Voltages of the Flyback Converter

## b)

At this part, we are supposed that transformer design for our Flyback Converters. There are some properties that are important for designing such as permeability, saturation flux and core loss. Geometry and core type of the transformers determines the properties.

Transformer geometry toroid changes with respect to applications and some geometries are E-core I-core and Toroid core. E- cores are easier to wind and mount by using transformer core former. We chose the core geometry as E-core for that reason. Saturation flux depends on current ratings. Our current rating is small, 1A and we can choose saturation flux density as small. Also, permeability affects the magnetizing inductance which is very important to Flyback design because transformer is used for energy storage elements in Flyback. In addition to this, core loss is very important to determine switching frequency because of the efficiency consideration.

We, as Anca Inc Team, made a Matlab Script to determine the design parameters with respect to our requirements. The script is given as APPENDIX.

By using this script, we found that:

Requirement Magnetizing Inductance: 66mH

Np/Ns= 26.7721 (maximum duty is determined as 0.6) and minimum Np=30 turns.

And core is chosen as ‘00K6527E060’. It has Kool Mu core and the area of core is 540mm^2. The properties meet our specifications and requirements.

## c)

There are 4 step to calculate the parameters to provide specification:

1. DC link capacitor determination for Single Phase Rectifier

DC link capacitor is determined by AC voltage and frequency with desired ripple at output of the single phase rectifier.

The DC link capacitor is calculated easily as 33uF, 400 V.

1. Magnetizing Inductance is calculated by formula:

Maximum duty can be selected for mode of converter. We want our converter to operates at continuous conduction mode. Thus, standard duty ratio is near the 0.5. Maximum duty is 0.6-0.7. Ripple factor (Krf) is 1 at DCM and it is between 0.2 and 0.5 at CCM. Switching frequency was determined as 45 kHz.

1. Calculation of Peak Current of Switch

The calculation is important to determine the CCM and DCM mode. Change in switch current is equal to half of peak current or equals to I\_eds.

1. Determination of primary side Turn number

Minimum turn number depends on core. The core area and saturation flux density.

They are found at our core datasheet.

1. Determination of primary side Turn number

Secondary side turn ratio depends on primary side voltage and secondary side voltage. Secondary side voltage includes output voltage and opening voltage of diodes.

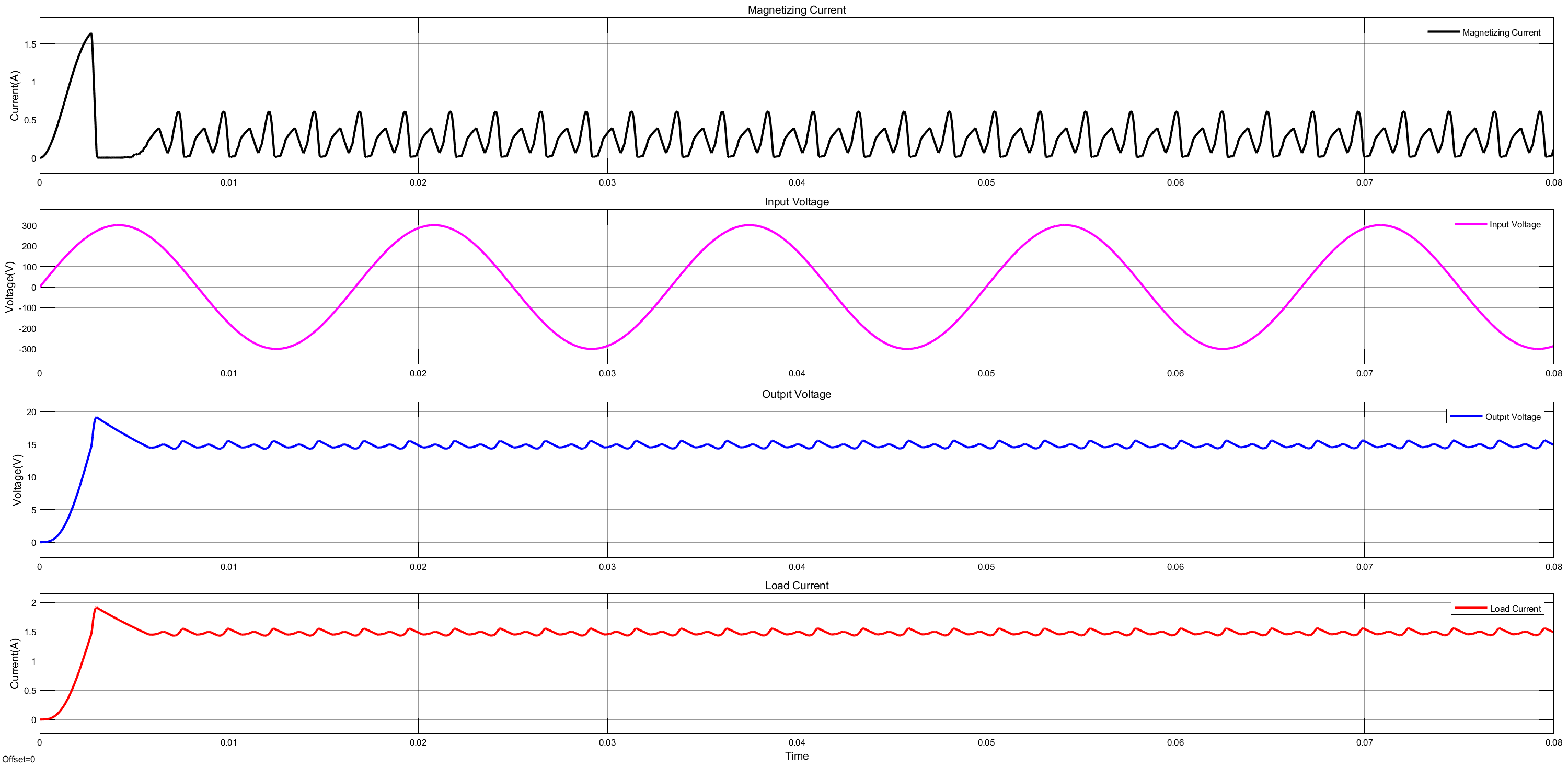


Figure 3:

## d)

Passing through DCM and CCM gives the minimum current of load. At question 3, half of peak current of switch current change in current.

Transformer current calculated by turns ratio:

## e)

Leakage inductance is taken as 3 percentage of magnetizing inductance. The mosfet conduction resistance is 10 ohms, and diode conduction resistance is 5 ohms. Switch Voltage and Switch current are taken at only conduction time.

Without Snubber Circuit:

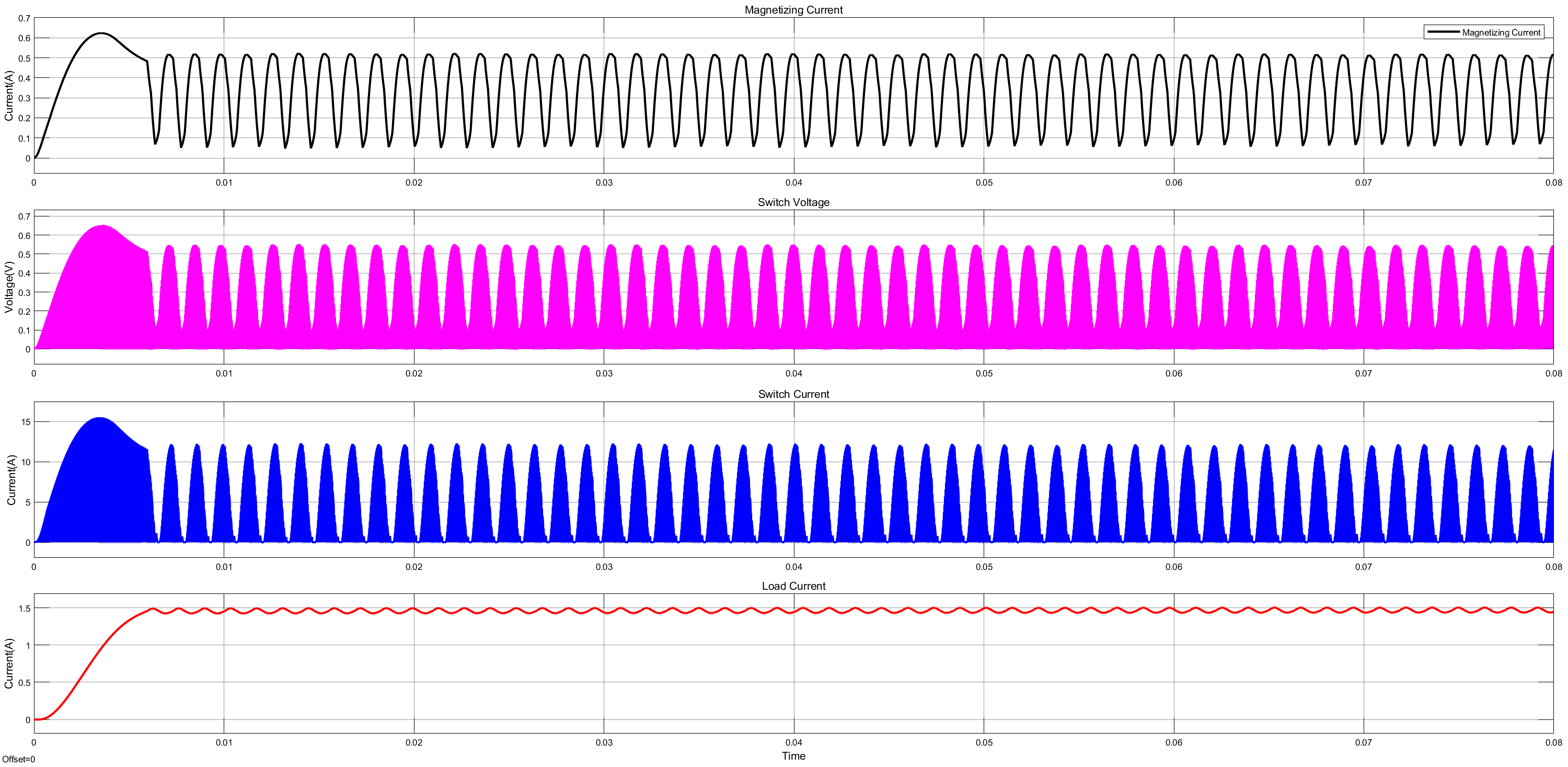


Figure 4:

With Snubber Circuit:

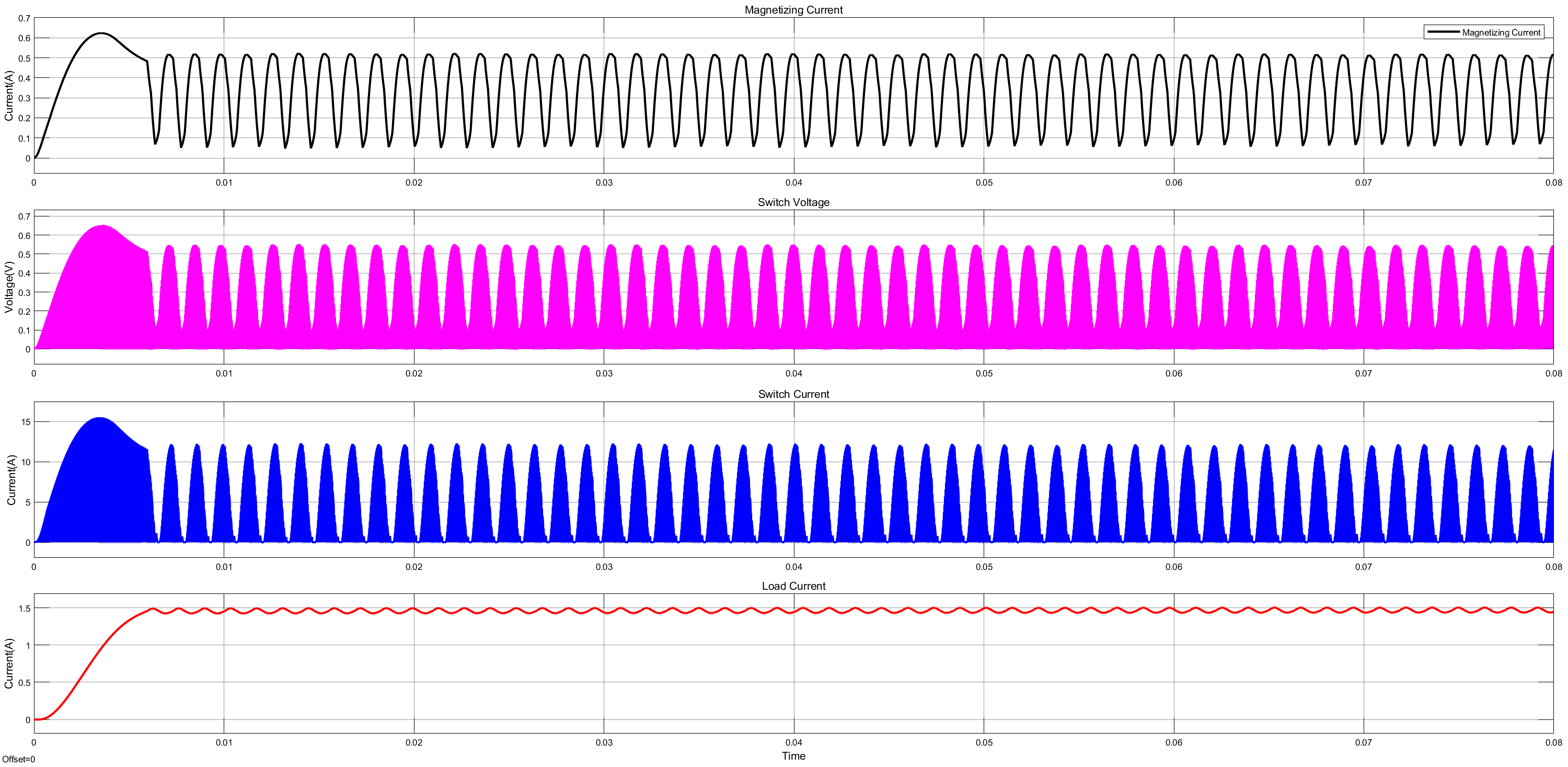


Figure 5:

Without snubber circuit, the energy storage is not transferred to load. Load current decreases and output voltage is not provided successfully.

RCD snubber circuit is established. The value of components can be found by considering reverse voltage.

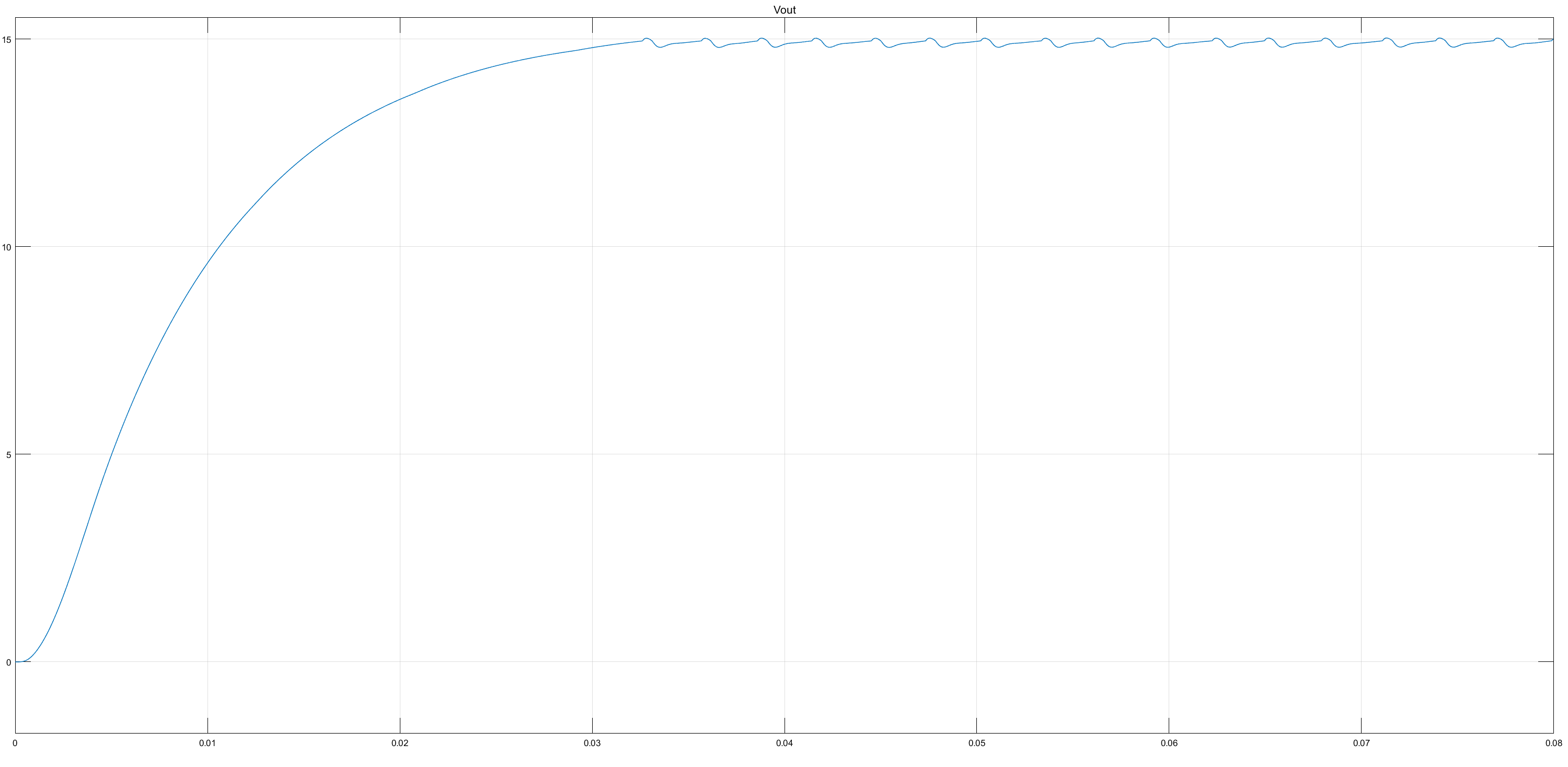
R=1k ohm

C= 47 nF

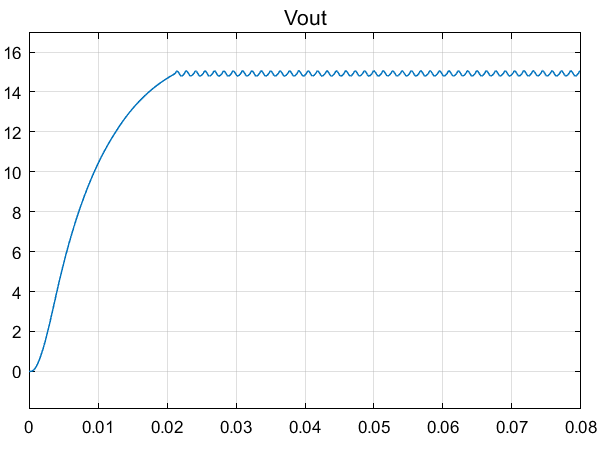
## f)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Input Power (W) | Output Power (W) | Efficiency (%) |
| %100 | 21.12 | 14.98 | 71 |
| %75 | 17.6 | 14.99 | 85 |
| %50 | 17 | 14.96 | 88 |
| %25 | 16.5 | 14.97 | 90 |

## g)



%1.3 ripple at 210 Vac



%1.6 ripple at 230 Vac

## h)

As calculated from part b, we found the capacitor value as 33 µf. We decided to use electrolytic capacitor since 33 µf is large value.

For switching and controller, we found an integrated circuit which is called TNY267[1]. This component has its mosfet and PWM generator with respect to feedback value. Also, we calculated Vds as 625 and the reverse voltage of the component is 700V. Ids is 0.12A in the calculation. Ids value of the component is 0.72 A. This component is proper for our application. For diode selection, we calculated Vro value in the part b and that is 400V. On the output side, maximum current will be 1 A. On the internet, we found a diode which is called 10A10[2]. For the output capacitor, 1mF is need and output voltage is 15 V. We can use more than capacitor to obtain that value.

# References

[1] Controller datasheet: <http://html.alldatasheet.com/html-pdf/139806/POWERINT/TNY267PN/5077/13/TNY267PN.html>

[2] Diode datasheet: <http://html.alldatasheet.com/html-pdf/56900/BYTES/10A10/124/1/10A10.html>

APPENDIX

Matlab Script for Calculations:

%%

clear all;

clc;

%% Flyback Parameters

V\_line\_minimum= 210; % V rms

V\_line\_max=230 ; % Vrms

V\_dc\_min= 280; % 5 percentage ripple

V\_dc\_max=sqrt(2)\*V\_line\_max;

Output\_power= 15; % Watt

Efficiency= 0.95 ; % between 0-1

Input\_power= Output\_power/Efficiency;

%% DC Link Capacitor Calculation

D\_ch=0.2; % for capacitor charging duty

F\_line= 50; % Line frequency

C\_DC = (Input\_power\*(1-D\_ch))/ ...

(F\_line\*((2\*V\_line\_minimum^2)-V\_dc\_min^2));

fprintf(' %f microFarad \n',C\_DC\*1e6);

%% Determination of Maximum Duty Cycle

D\_max= 0.6 ; % for CCM mode, it is bigger than 0.5

V\_Ro= (D\_max/(1-D\_max))\*V\_dc\_min;

V\_ds= V\_dc\_max+V\_Ro;

%% Lm Determination

f\_s= 45000; % Switching Frequecny Hertz

K\_f= 0.3; % for ccm 0.25-0.50

L\_m= (( V\_dc\_min\*D\_max)^2)/(2\*Input\_power\*f\_s\*K\_f)...

\*1e3; % mili Henry

fprintf('% f mH \n', L\_m);

L\_m=L\_m\*1e-3;

%% Calculation of peak current of FSP( mosfet, IGBT)

I\_edc= Input\_power/(V\_dc\_min\*D\_max); % average ...

... switching amplifier

Delta\_Ids= (V\_dc\_min\*D\_max)/(L\_m\*f\_s);

Ids\_Peak=I\_edc+(Delta\_Ids/2);

Ids\_rms=sqrt((3\*I\_edc^2) + ((Delta\_Ids/2)^2\*D\_max/2));

fprintf('%f %f \n',Ids\_Peak,Ids\_rms);

%% Primary Side Turns Determination

Ae=540\*1e-6; % m^2

B\_sat=1/2 ; %Tesla

N\_p= ((L\_m\*Ids\_Peak)/(B\_sat\*Ae));

fprintf('%f \n', N\_p);

%% Secondary Side Turn Ratio

N\_s= N\_p/((V\_Ro)/(15+0.7));

fprintf('%f \n', N\_s);