



# **Design and Simulation of Flyback Converter in MATLAB using PID Controller**

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**ABSTRACT:** This paper presents the simplest approach for the DC voltage control using the single phase single switch AC to DC flyback converter with isolation. This method has the combination of uncontrolled diode rectifier with capacitor filter and then DC to DC converter topology which here is flyback topology used. This converter can be used for step up voltage control can be achieved using this by choosing the value of duty cycle. The input 230 V AC supply is converted into 240 V DC voltage with 100 W power output. The open loop and closed loop simulation and designing of flyback converter in CCM are performed in MATLAB which matches well with the calculated value.

**KEYWORDS:** CCM, DCM, flyback converter, average state space model.

## **I.INTRODUCTION**

Due to more number of external components and complexity of circuit to provide isolation and regulation of output voltage in power supplies, the modern science continuously look for the best solution for the size and simplicity of power supplies. Simplicity in design, small design, isolation and perfectly regulated output cannot be obtained in a single design of converter. There are many converters available in market from which one which suits our requirements can be chosen from. The figure 1 gives the block diagram of AC-DC converter.

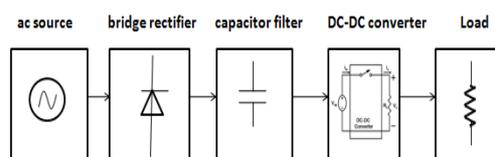


Figure 1 Block diagram of a AC-DC converter.

In this system three stage conversion i.e. AC-DC, DC-AC and AC-DC will take place. Main AC supply voltage is given to input which will be converted into unregulated DC using bridge rectifier which is uncontrolled rectifier and capacitor filter to remove the unwanted ripples in the voltage and current. The input for DC-DC converter is unregulated DC voltage which is in turn the output of capacitor filter. The final output will be regulated DC voltage. This regulated DC output will be given to load.

Flyback converter is the power supply which is generally used when power requirement is low and the isolation between input and output is required [1-3,6]. This power supply is mainly used for power less than 100W. This power supply has simpler design circuitry due to presence of less number of components and no inductor is there in output side. Only one switch is there so its operation is easy to understand and control. It has generally one primary and secondary winding so its transformer design is also simple to design as compared to other SMPS. The circuit can also be build up to have multiple outputs just by increasing the number of secondary windings of transformer.

This converter is mainly of the same kind as that of buck-boost only differing by adding transformer in parallel to the inductor in the buck-boost topology offering the advantage of same polarity output as that of input with either step up ,step down or both characteristics simultaneously. The output voltage of flyback converter can be given as:

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$$V_o = \left(\frac{N_2}{N_1}\right) \left(\frac{D}{1-D}\right) \cdot V_s$$

The solution to lower efficiency of flyback converter can be achieved by modifying the circuit and using two switches in place of single switch but after that it will lose its characteristic of simple circuit and low cost as two switch power supply will increase complexity in structure and also the cost. The simple flyback converter has a single controllable switch like MOSFET with switching frequency in the range of 100 kHz which is shown in figure 2.

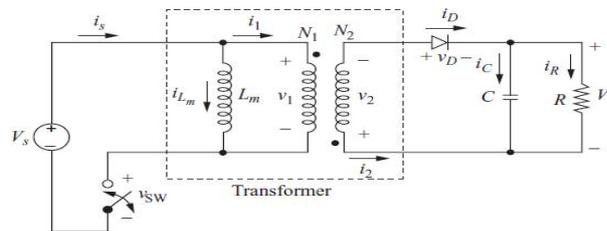


Figure 2 Basic topology of flyback converter

## II. OPERATION AND MODELLING OF FLYBACK CONVERTER

The flyback converter operates in two periods:

### 1) Switch on:

In this period the switch which is MOSFET in this case is switched on for time  $0 < t < DT$  where D is duty cycle and T is periodic time[1]. In this period the current builds up in primary and the transformer will act as energy storage device. as polarity on transformer is reverse, this stored energy will not be transferred to the secondary side as the diode on output side is reverse bias in this time.

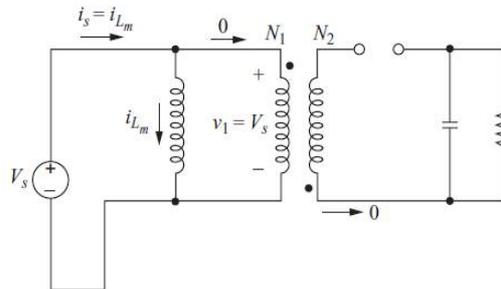


Figure 3 Switch on time circuit

The load voltage is supplied by the capacitor voltage whose value is kept very high so as to maintain the output constant even if secondary is not conducting. Figure 3 show the circuit during this period:

Applying KVL and KCL in loops we can get following equations:

Voltage across primary is

$$v_1 = V_s = L_m \frac{di_{Lm}}{dt} \quad (1)$$

Solving for magnetizing current during switch close will give,

$$(\Delta I_{Lm_{closed}}) = \frac{V_s \cdot D \cdot T}{L_m} \quad (2)$$

Voltage across output load is equal to voltage across capacitor. Voltage across secondary will be constant and that will be equal to

$$V_2 = V_1 \frac{N_2}{N_1} = V_s \frac{N_2}{N_1} \quad (3)$$

And from KVL law, the voltage across the diode is the sum of secondary voltage and the capacitor voltage.

$$V_D = -V_o - V_s \frac{N_2}{N_1} \quad (4)$$

**2) Switch off:**

During this cycle of operation the primary side path is broken as the switch is off for the remaining period of T, and the inductor polarity will change according to law of magnetic designs[7]. So now the diode will be forward bias. This diode conduction path will charge the capacitor and the load is also supplied from secondary voltage. In this case as the polarity are reversed the transformer primary will transfer the energy stored during on cycle to the load through secondary and the remaining energy due to air gap is dissipated in inductor parallel to primary side inductor. Figure 4 shows the circuit during off period.

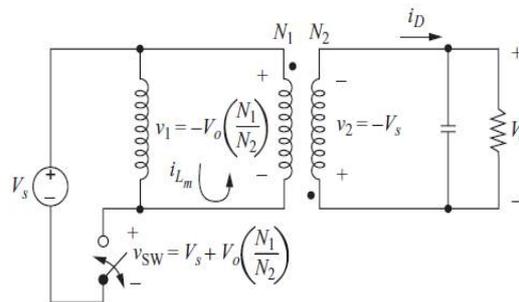


Figure 4 Switch off time circuit

Applying KVL and KCL in the circuit diagram loops, we can have the following equations:

The secondary voltage transforms back to the primary, establishing the voltage across Lm at

$$V_1 = V_2 \frac{N_1}{N_2} = -V_O \frac{N_1}{N_2} \quad (5)$$

$$\frac{dI_{Lm}}{dt} = \frac{\Delta I_{Lm}}{\Delta t} = \frac{\Delta I_{Lm}}{(1-D)T} = -\frac{V_O}{L_m} \frac{N_1}{N_2}$$

$$\left(\Delta I_{Lm_{open}}\right) = -\frac{V_O(1-D)T}{L_m} \frac{N_1}{N_2} \quad (6)$$

For ideal case the power absorbed in resistor will be equal to that of power supplied by source.  $P_O = P_S$  ,  
So power equation becomes:

$$I_{Lm} = \frac{V_O}{R(1-D)^2} \left(\frac{N_2}{N_1}\right)^2 \quad (7)$$

This flyback converter operates in two modes of conduction:

**Discontinuous Conduction Mode (DCM):** in this mode of operation the value of the inductor current at starting of switching cycle is zero. Afterwards it reaches to peak value of primary current and then it starts decreasing through secondary winding. The value of inductor current reaches to zero before starting of the next switching cycle i.e. the energy in the inductor becomes zero before next switching cycle. Here there will be more conduction loss in this mode. figure 5 shows the waveform of discontinuous conduction mode.

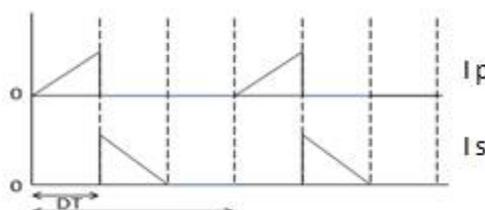


Figure 5 Waveforms of DCM

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Continuous Conduction Mode (CCM): In this mode the value of inductor current is not zero at the starting of the switching cycle but it will start from one non-zero initial value and reach to maximum value in ON time and will start decrease during OFF time. But it will not reach to zero value even at the end time of the switching period. So the energy in inductor doesn't become zero even at the end of switching period, Here the conduction losses are less as compared to discontinuous conduction mode. The figure 6 below shows the waveform of continuous conduction mode.

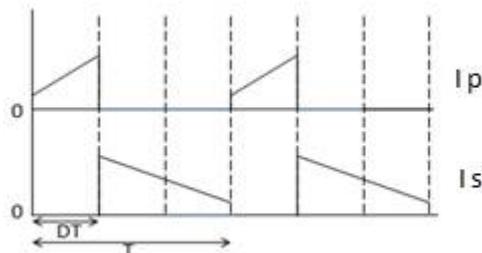


Figure 6 Waveforms of CCM

### III. CIRCUIT PARAMETER DESIGNING

The circuit here is designed for 230 V AC input voltage which i turn will give the regulated 240 V DC voltage with 100W power. The following table gives the parameter specification if the flyback converter. The switching frequency is high[9],[1] so the size of transformer in this converter will be small resulting in smaller size of converter with isolation.

Parameter	Value
Output voltage	240 V DC
Output power	100 W
Output current	0.416 A
Switching frequency	50000 Hz
Duty cycle	0.51
Input voltage	230 VAC
Inductor	13.75 mH
Resistor	576 $\Omega$
Capacitor	54 F

Table 1 Table of parameters

The values of the components of flyback converter can be obtained from the calculations according to equations of modelling.

### IV.STATE SPACE MODEL

There are many models for modelling of any system in state space analysis. But from that the average model is used[6] here due to the reason that the converter due to high switching characteristics acts as a nonlinear system. so its modelling is difficult as at every point of time the values of components will change due to continuous on and off of switch.ao in order to have transfer function of whole cycle time we have to average the states of the on time cycle and that during the off time as shown below:

$$\dot{X} = Ax + B V_g \quad (8)$$

Where x is the matrix of  $I_L$  and  $V_C$  state variables.

From state space averaging model,

$$A = (A1 * d) + A2 * (1 - d) = \begin{bmatrix} 0 & -35.6 \\ 90741 & -0.6 \end{bmatrix}$$

$$B = (B1 * d) + B2 * (1 - d) = \begin{bmatrix} 37.0909 \\ 0 \end{bmatrix}$$

$$C = (C1 * d) + C2 * (1 - d) = [0 \ 1]$$

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$$D = (D1 * d) + D2 * (1 - d) = 0$$

So small signal analysis will give linearity in modelling as all the signals are considered for small interval of time so the modelling will become easy which can be done by only considering the DC component as zero[6]. As a result the final transfer function can be of two types and can be given as under:

Transfer function of output voltage to input voltage:

$$\frac{\hat{V}_0}{\hat{V}_g} = C * (sI - A)^{-1} * B$$

$$\frac{\hat{V}_0}{\hat{V}_g} = \frac{-(5.105 * 10^{-15})s + (3.366 * 10^5)}{s^2 - 0.642s + (3.234 * 10^5)} \quad (9)$$

Transfer function of output voltage to duty cycle:

$$\frac{\hat{V}_0}{\hat{d}} = C * (sI - A)^{-1} * f$$

$$\frac{\hat{V}_0}{\hat{d}} = \frac{(1.571 * 10^4)s + (3.098 * 10^8)}{s^2 - 0.642s + (3.234 * 10^5)} \quad (10)$$

## V.SIMULATIONS AND RESULTS

The open loop simulation of the flyback converter in MATLAB is done and the result is observed. The simulation model in open loop and the output voltage and current waveform are shown in figure. It can be seen from the waveform that the value of the output voltage is in validation with the calculated value.

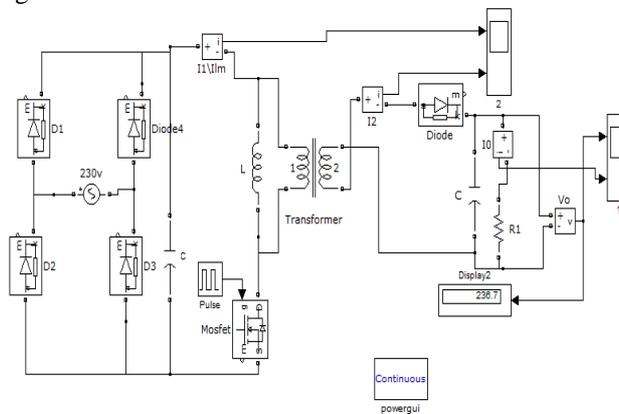


Figure 7 Open loop model with d=0.51

The waveform of the output voltage and current of open loop flyback converter at 230 V 50 Hz AC voltage at input at duty cycle 0.51.

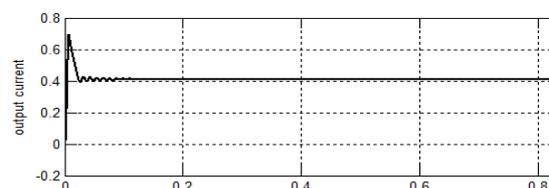


Figure 8 waveforms of open loop with d=0.51

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The response of the open loop converter output shows that in starting there is spike which can affect the system greatly. There is some difference in the output value as compared to the required value which is the error in output. This is required to be eliminated.

For this the feedback control is necessary which can be used in many controlled using many control strategy. Out of many control strategy, closed loop PID controller is the most effective control strategy which is mostly used in industry. The following figure shows the closed loop simulink model with PID controller which will remove the error of open loop converter.

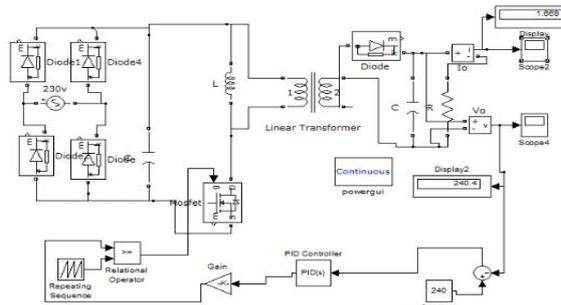


Figure 9 Close loop model with PI controller

From the graph of output waveform of voltage it is clearly seen that the curve is smooth and the oscillations in the voltage and error is removed using continuous control using PI controller.

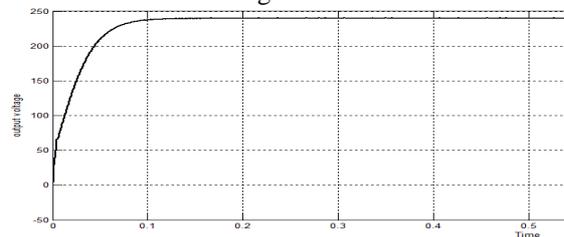


Figure 10 output waveform of close loop PI controller

## VI. CONCLUSION

From the MATLAB simulink models of open and close loop flyback converter, it is easily noticed that the response is much reliable when the converter is operated in close loop. The oscillations are removed from the system response and the system gives more accurate output voltage. Now a days there are so many fields and application in which SMPS are proved to be quite useful. So flyback in close loop is the more accurate choice when isolation is required and the circuit complexity is measure point of interest. Error in the open loop which was noticed to be around 3 V is removed using PI controller tuning. If in rural area where the requirement is of both AC and DC voltages then this converter can be used in multiple output design which can be obtained by just adding one more secondary winding.

## REFERENCES

- [1] Luocheng Wang, student member, IEEE; Ali M. Bazzi, member, IEEE, "A Dual ac and dc output flyback converter", @2014 IEEE
- [2] Deepa.K, Hridya Merin Saju, M. Vijaya Kumar "Soft Switched Flyback Converter For SMPS Applications", @2013 IEEE.
- [3] S. Howimanpom, C. Bunlaksananusom, "Performance Comparison of Continuous Conduction Mode (CCM) and Discontinuons Conduction Mode (DCM) Flyback Converters ", @2003 IEEE PEDS.
- [4] Bhim Singh, Senior Member, IEEE, and Ganesh Dutt Chaturvedi, "Comparative Performance of Isolated Forward and Flyback AC-DC Converters for Low Power Applications", @2008 IEEE..
- [5] E. E. El-Kholy, "AC/DC Flyback Converter with a Single Switch Controlled DC Motor Drives",@ 2005 IEEE PEDS.
- [6] Sanjeev Kumar Pandey, Dr. S.L.Patil, and Mrs. Vijaya S. Rajguru "Isolated Flyback Converter Designing, Modelling and Suitable Control Strategies", DOI: 02.PEIE.2014.5.15 © Association of Computer Electronics and Electrical Engineers, 2014, ACEEE.
- [7] Power Electronics: Converter, Applications And Designs, Ned Mohan
- [8] Switch Mode Power Supply Handbook, Keith H. Billings, M.I.E.E.
- [9] Power Electronics, Daniel W. Hart.