iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 10 Issue: V Month of publication: May 2022

DOI: https://doi.org/10.22214/ijraset.2022.42861

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue V May 2022- Available at www.ijraset.com

Constant and Green Mode Operation Technique in Flyback and Push-Pull DC-DC Converter

Sachin J M[1], Anitha G S[2]
[1, 2]Department of Electrical and Electronics Engineering, RV College of Engineering, Bengaluru, India

***Abstract:** The high frequency switching causes switching losses and reduces the efficiency of converters. Therefore, operating the DC-DC converters with lower frequencies at light loads reduces the switching losses significantly. Variable frequency switching is generally defined as Green mode operation. The green mode control method is obtained from high efficiency over the entire load range. This method is also called variable frequency control and it changes the switching frequency according to the load condition. At full load conditions, the controller increases the switching frequency to decrease switching ripple and ripple-related conduction loss. When the load decreases, the controller decrease switching frequency to diminish switching loss and increase switch life cycle. In this paper, the flyback and push-pull converter topologies are simulated using MATLAB/Simulink and the results obtained from the variable switching converter are compared with the results obtained from constant switching frequency.*

***Keywords:** Green Mode Operation, Flyback Converter, Push-Pull Converter, Variable Switching Frequency, Constant Switching Frequency.*

I. INTRODUCTION

A DC-DC converter is a power electronics device that accepts a DC input voltage and also provides a DC output voltage. The output voltage of DC-DC converter can be greater than the input voltage or vice versa. The converter output voltages are used to match the power supply required to the loads. The connection and disconnection of power supply to the load can be controlled using a switch in the simple DC-DC converter circuit. DC-DC converter circuits consists of a transistor or diode switch, energy storage devices like inductors or capacitors and these converters are generally used as linear voltage regulators or switched mode voltage regulators. DC-DC converters are used to provide DC regulated power supply, constant DC power supply to the electrical and electronics circuits.

A. Flyback Converter Topology

DC-DC converters are widely used in power electronics, and therefore more efficient use of converters has become an important field of research. Flyback converter is one of the most attractive because of its relative simplicity compared with other topologies used in low power applications. Flyback converters are generally used in cell phones, notebooks, personal computers and LCD TVs as a power supply circuit. Flyback converters are also generally used in Switched Mode Power Supply (SMPS) because of its design simplicity, low cost, multiple isolated outputs, high output voltages and high efficiency. A transformer is used in flyback converters for energy storage, input-output isolation and output power transformation. The polarities of the windings of flyback transformers are designed such that when the current passes through one winding, no current passes through the other winding. The circuit diagram of flyback converter is as shown in below fig. 1.

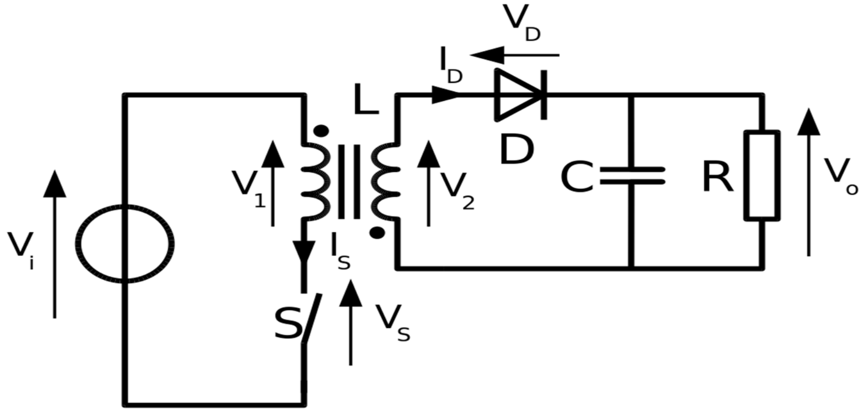


Fig. 1: Circuit diagram of flyback converter

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue V May 2022- Available at www.ijraset.com

This converter operates in two modes:

1) *Mode 1:* When the switch is closed (top of Fig. 2), the primary of the transformer is directly connected to the input voltage source. The primary current and magnetic flux in the transformer increases, storing energy in the transformer. The voltage induced in the secondary winding is negative, so the diode is reverse-biased (i.e., blocked). The output capacitor supplies energy to the output load.
2) *Mode 2:* When the switch is opened (bottom of Fig. 2), the primary current and magnetic flux drops. The secondary voltage is positive, forward-biasing the diode, allowing current to flow from the transformer. The energy from the transformer core recharges the capacitor and supplies the load.

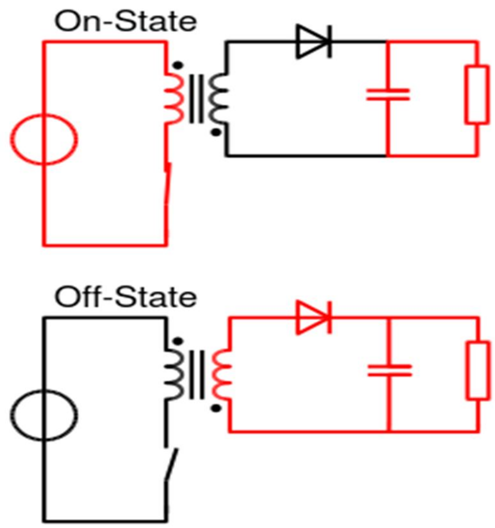


Fig. 2: The two modes of a flyback converter in operation

Generally, converters operated with constant switching frequency may have switching ripple and ripple related conduction losses which will reduce the efficiency of the converter. In order to overcome this problem we can use variable switching frequency method.

Variable frequency switching is generally defined as green-mode operation. The green mode control method is obtained from high efficiency over the entire load range. This method is also called variable frequency control and it changes the switching frequency according to the load condition. At full load conditions, the controller increases the switching frequency to decrease switching ripple and ripple-related conduction loss. When the load decreases, the controller decrease switching frequency to diminish switching loss and increase switch life cycle[1].

A flyback DC-DC converter operated with variable switching frequency for green-mode operation is presented in this study. The proposed topology is operated with lower frequencies at light load conditions compared to rated output power by using the output voltage which is processed in a sawtooth waveform technique to generate PWM signals. After analyzing the variable switching frequency flyback topology, the obtained results are compared with the results obtained from constant switching frequency flyback topology for the same input/output conditions.

II. FLYBACK CONVERTER TOPOLOGY AND OPERATIONS

The flyback converter is generally used in SMPS for low output power applications where the output voltage needs to be isolated from the input main supply. The circuit operation of this topology simpler than other SMPS circuits. This circuit can provide multiple isolated output voltages and can work with different input voltages. The flyback converter has lower energy efficiency than the other SMPS circuits, but its simple topology and low cost allow it to be preferred in low power applications. The flyback converter usually works at high frequencies to reduce transformer size and weight, but this increase switching losses. The switch control is performed by the PWM signal and when the controller signal is on, MOSFET transmits. Current does not flow on the secondary side because the transformer windings have reverse polarity. When the switch is in the cut, the energy stored in the core is transferred to the load[2-3].

The flyback converter have two different operating modes. If the secondary current drops to zero before the Toff time is complete, this operation is called discontinuous conduction mode (DCM). If the current is greater than zero when the Toff time is complete, this operation is defined as continuous conduction mode (CCM). Research has suggested CCM operation in high power applications, while focusing on DCM operation in lower power applications[7-9].

The transformer section is an important part in converters that determines the efficiency performance, output voltage regulation and electromagnetic interference. The transformer of the flyback converter is inherently an inductor that is used for energy storage and isolation contrary to the classical power transformer. In the general transformer, the current flows in both the primary and secondary winding at the same time. However, in the flyback transformer, the current flows only in the primary winding while the energy in the core is charged and in the secondary winding while the energy in the core is discharged. Usually, gap is introduced between the core to increase the energy storage capacity[6].

One of the most important calculations in transformer design is the primary inductance calculation as given in below equation for L(p) which is the primary side inductance.

$$L(p) = (Vdc*Dmax)/(2*Pin*Fs*K)$$

Where, Pin: Maximum input power, D(max): Maximum duty cycle, Vdc: Minimum DC voltage, Fs: Switching frequency, K: Ripple factor

The ripple factor is closely related with the transformer size and the RMS value of the MOSFET current. Though the conduction loss in the MOSFET can be reduced through reducing the ripple factor, too small a ripple factor forces an increase in transformer size. For DCM operation, KRF = 1 and for CCM operation KRF < 1.

When L(p) is determined, the maximum peak current, current ripple ΔI in normal operation are obtained as

$$\boldsymbol{\Delta}I = (Vdc*Dmax)/(Lp*Fs)$$

Duty ratio:

$$N2/N1=(Vo(1-D))/(Vs*D)$$

Output Capacitor:

$$C=(Vo*D)/(R*F*\boldsymbol{\Delta}Vo)$$

Duty Cycle:

$$D = T_{on}/T_s$$

Time period:

$$T_s = 1/F_s$$

A. Variable Frequency PWM Generator

A variable frequency PWM generator is designed in MATLAB simulation program as shown in fig. 3. The output of the controller is used to obtain duty cycle in constant frequency method. However, in this study, a variable frequency PWM generator is needed. Therefore, a variable frequency PWM generator which uses sawtooth waveform technique to generate the sawtooth signal is designed. This sawtooth signal is compared with the duty cycle which is calculated by using above equations. Finally, the output signal is scaled to a standard output range of 0-1.

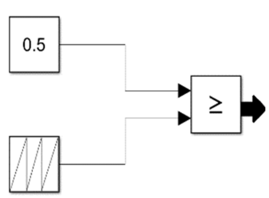


Fig. 3: Sawtooth waveform technique

Constant frequency and variable frequency switching patterns are given in Fig. 4 and Fig. 5 respectively. As shown in the related figure, only on-time is changed in the constant frequency method while the switching frequency is kept constant. Therefore, the flyback converter is always operated in constant switching frequency for all load conditions and this cause higher switching losses at light loads.

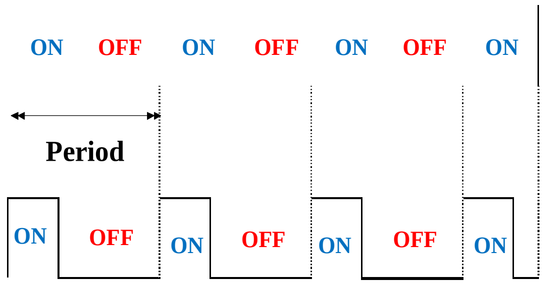


Fig. 4: Duty cycle operation principle

Fig. 5 shows the variable frequency switching pattern. In this switching method the on-time (Ton) is kept constant while the switching frequency is changed according to load conditions and this reduces the switching losses at light loads.

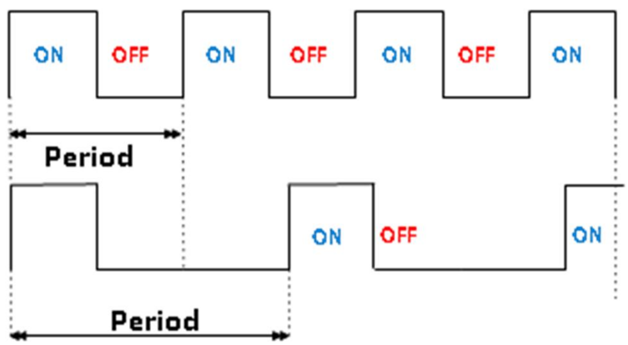


Fig. 5: Variable frequency operation principle

III.PUSH-PULL CONVERTER TOPOLOGY AND OPERATIONS

A push–pull converter is a type of DC-to-DC converter, a switching converter that uses a transformer to change the voltage of a DC power supply. The distinguishing feature of a push-pull converter is that the transformer primary is supplied with current from the input line by pairs of transistors in a symmetrical push-pull circuit. The transistors are alternately switched on and off, periodically reversing the current in the transformer. Therefore, current is drawn from the line during both halves of the switching cycle. This contrasts with buck-boost converters, in which the input current is supplied by a single transistor which is switched on and off, so current is only drawn from the line during half the switching cycle. During the other half the output power is supplied by energy stored in inductors or capacitors in the power supply. Push–pull converters have steadier input current, create less noise on the input line, and are more efficient in higher power applications[4-5].

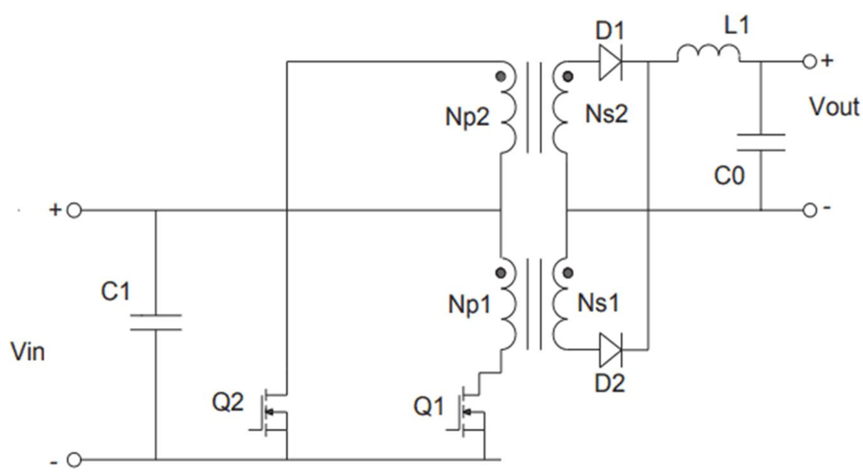


Fig. 6: Typical Push-pull converter Circuit Diagram

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue V May 2022- Available at www.ijraset.com

A. A Typical Push-Pull Converter Contains

1) 2 transistors as switches (Q1 and Q2)
2) 1 transformer with center tapped (Np1, Np2, Ns1 and Ns2)
3) 2 diodes as passive switches/rectifiers (D1 and D2)
4) 1 LC filter (CO and L1)
5) 1 input capacitor (C1)

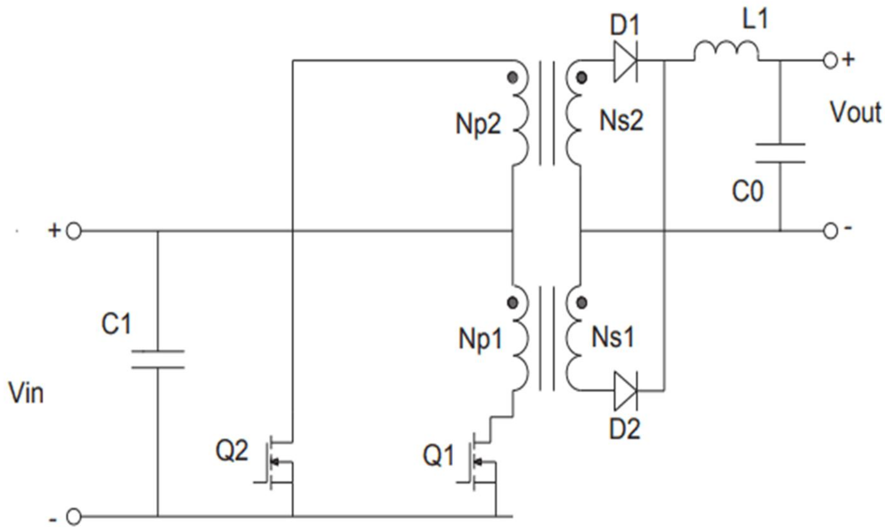


Fig. 7: Current Flow with Q2 Switch Closed

At first half cycle of switching frequency, Supply is given at Vin, Q1 is on and Q2 is off, direction of current is clockwise, Np1 gets charged, Ns1 and Ns2 also will get charged due to induction. D1 will get forward biased and D2 will be reverse biased. LC filter will smooth the output voltage and ripple to a pure DC form output voltage[10-12].

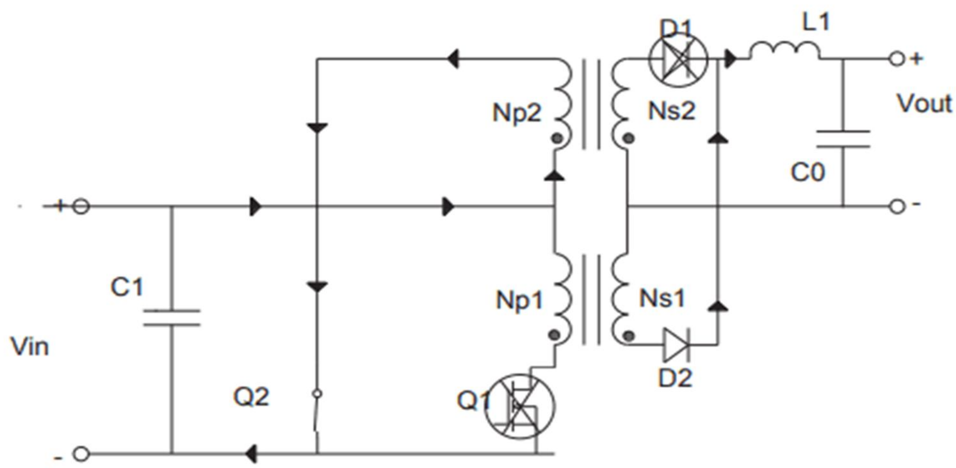


Fig 8: Current Flow with Q1 Switch Closed

At second half cycle of switching frequency, Q1 is off and Q2 is on, direction of current become counterclockwise, Np2 gets charged, Ns1 and Ns2 will keep inducing. But direction of current will be reversed, D1 will get reverse biased and D2 will get forward biased. LC filter will carry the filtering function as mentioned above.

Two transistors Q1 and Q2 keep on and off periodically and repeatedly in every period so we can get steady and regulated output voltage. However, the most important is that two transistors must never be closed simultaneously, they will damage if they get closed together.

B. Design Equations for Push-Pull Converter

Duty ratio:

$$D=(Np*Vo)/(2*Vs*Ns)$$

Auxiliary inductance:

$$Lx = (V0(1-D))/(\Delta Ilx*F)$$

Average inductor Current:

$$I_{(Lx)} = Vo/R$$

Capacitance Value:

$$\Delta Vo/Vo=(1-2D)/(32F^2*Lx*C)$$

C. Variable Frequency PWM Generator

A variable frequency PWM generator is designed in MATLAB simulation program as shown in fig. 9. The output of the controller is used to obtain duty cycle in constant frequency method. However, in this study, a variable frequency PWM generator is needed. Therefore, a variable frequency PWM generator which uses sawtooth waveform technique to generate the sawtooth signal is designed.

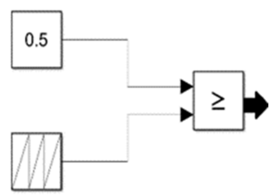


Fig. 9: Sawtooth waveform technique

IV. SIMULATION AND RESULTS

The flyback converter was designed and simulated according to nominal properties given in Table 1. First the flyback converter was designed by using above equations. Then this converter is operated with constant switching frequency (65kHz) by using MATLAB/Simulink software. Finally, the designed converter is operated with variable switching frequency (24kHz- 65kHz) for obtaining green mode converter.

Table 1: Nominal Properties OF Flyback Converter

Variables	Nominal Value
Nominal Power	100 W
Input Voltage	311 V
Output Voltage	12 V
Constant Frequency	65 kHz
Variable Frequency	24kHz - 65 kHz
Transformer Primary Inductance	0.87 mH
Transformer Secondary Inductance	2 µH
Transformer Primary Winding Turns	155
Transformer Secondary Winding Turns	6

A. MATLAB Simulink Model of Flyback Converter

The MATLAB Simulink model of flyback converter is shown in figure 10. In the below figure, simulation of flyback converter is done with constant switching frequency (65kHz) and variable switching frequency(24kHz-65kHz). The input voltage of 311 V is given as supply and transformer primary and secondary inductance values are 0.87mH and 2uH respectively. The maximum duty cycle of the converter is 0.67.

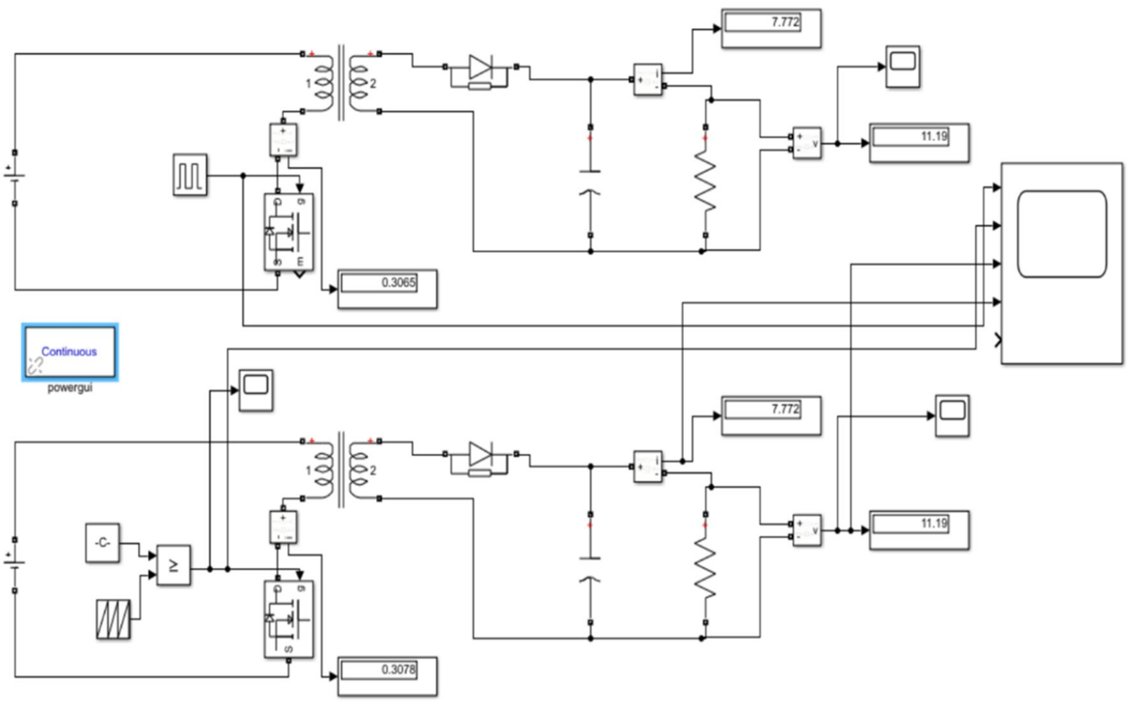


Fig. 10: Flyback converter circuit MATLAB/Simulink Simulation

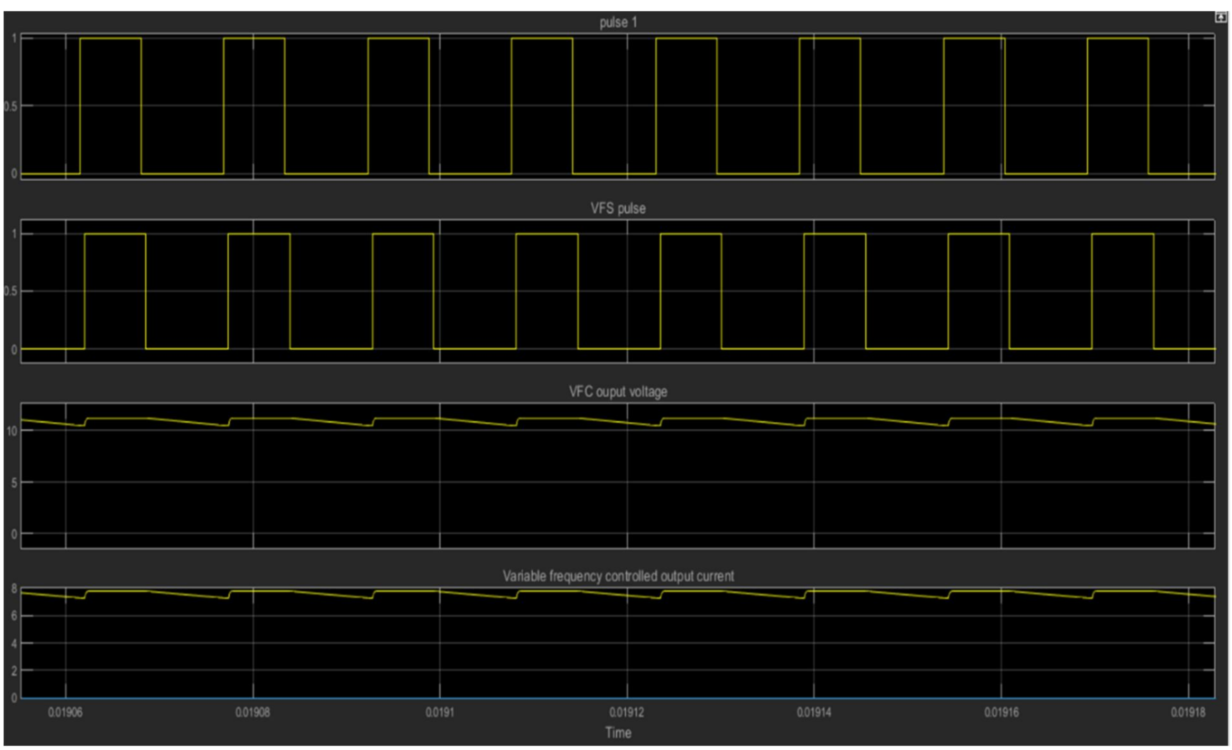


Fig. 11: (a) Simulation result of Flyback converter @ 100% Load (Frequency 65KHZ)

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue V May 2022- Available at www.ijraset.com

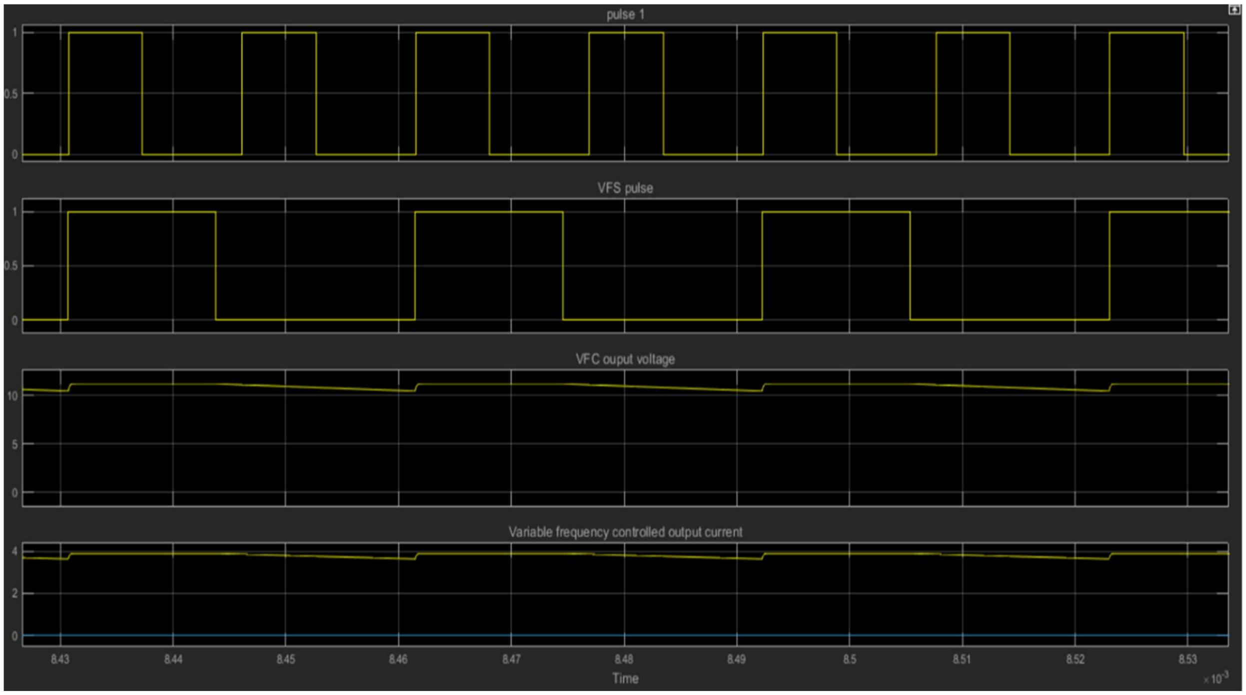


Fig. 11: (b) Simulation result of Flyback converter @ 50% Load

From the simulation results, it is seen that the converter is operated under variable output power from 100W to 50 W. Figure 11 shows that the designed variable frequency PWM generator changes the switching frequency according to output power. It is seen from the Fig. 11 that the output voltage is well regulated although there are changes in the output power and switching frequency.

B. Constant Frequency Control (65KHz)

Table 2: Output results of flyback converter

	Input Voltage (V)	Output voltage (V)	Input current (A)	Output current (A)	Efficiency
100% Load (65KHz)	311	11.99	0.006244	8.327	51.4%
50% Load (65KHz)	311	11.97	0.2806	4.158	57.03%

C. Variable Frequency Control

Table 3: Output results of flyback converter

	Input Voltage (V)	Output voltage (V)	Input current (A)	Output current (A)	Efficiency
100% Load (65KHz)	311	12	0.5966	8.33	53.893%
50% Load (33KHz)	311	12.01	0.2348	4.172	68.61%

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue V May 2022- Available at www.ijraset.com

D. MATLAB Simulink Model of Push-Pull Converter

The MATLAB Simulink model of Push-Pull converter is shown in fig. 12. In the figure, simulation of Push-Pull converter is done with constant switching frequency (150kHz) and variable switching frequency(75kHz-150kHz). The input voltage of 50 V is given as supply and nominal output power of the converter is 38.28W. The maximum duty cycle of the converter from design equation is 0.7.

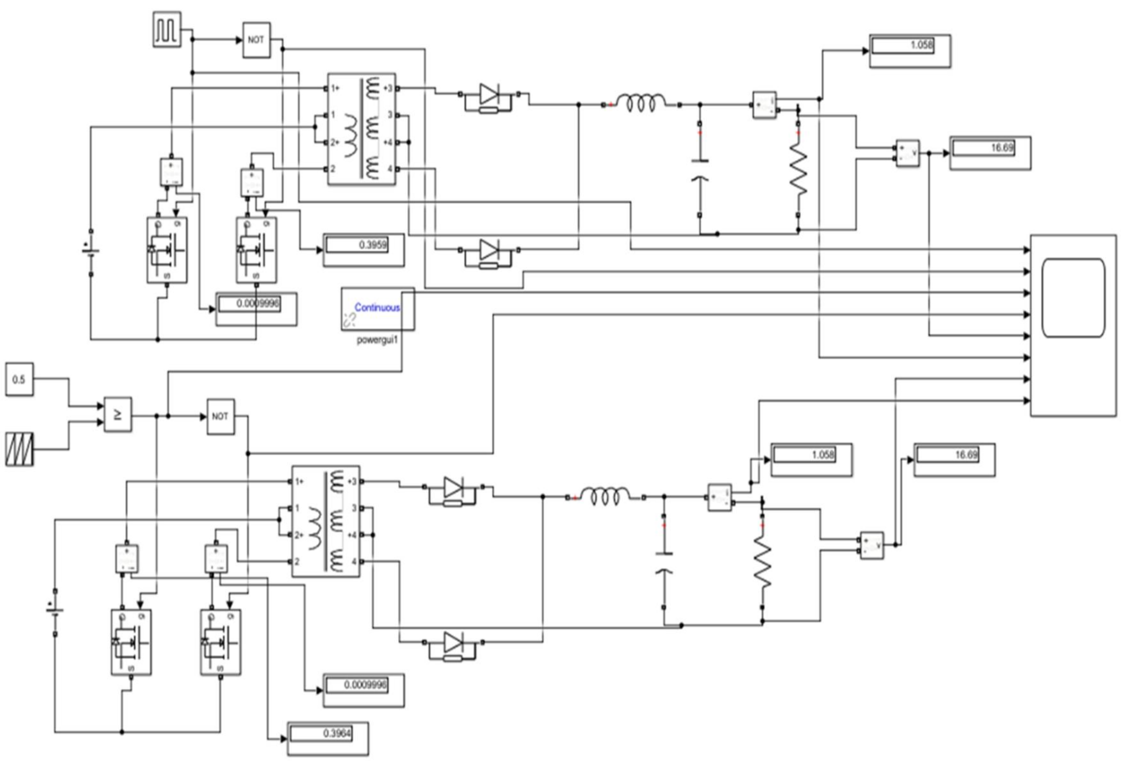


Fig. 12: Push-Pull converter circuit MATLAB/Simulink Simulation

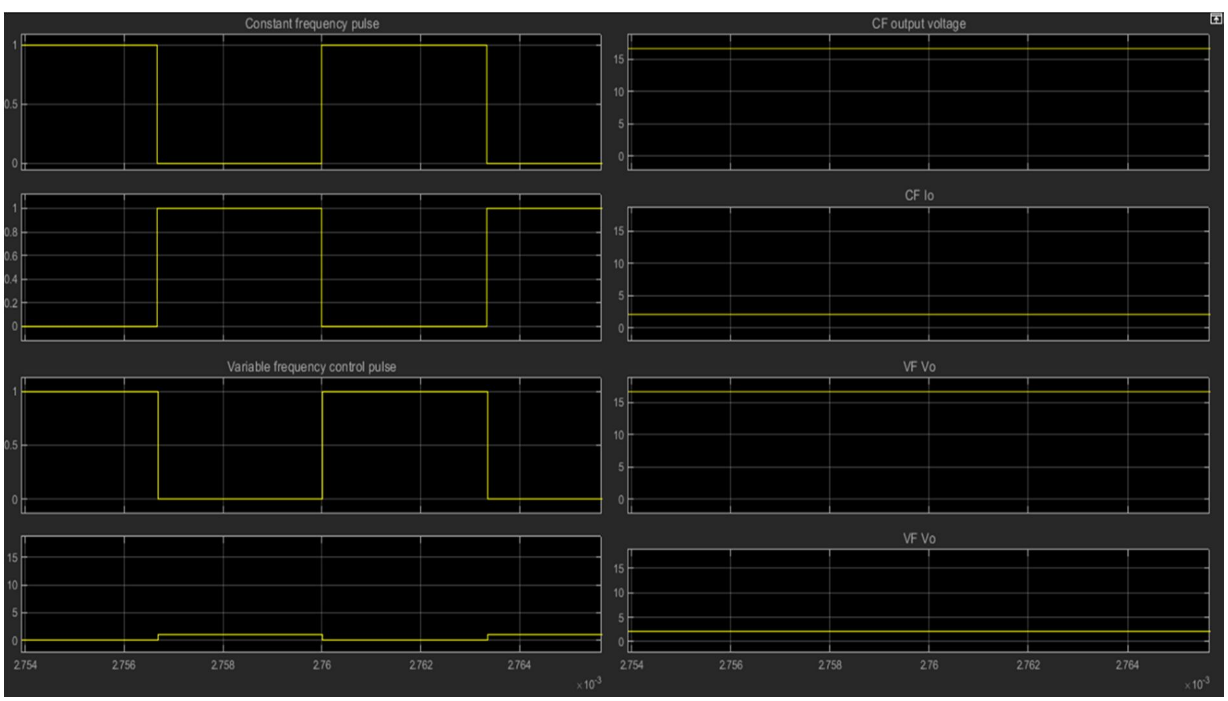


Fig. 13:(a) Simulation result of Push-Pull converter @ 100% Load

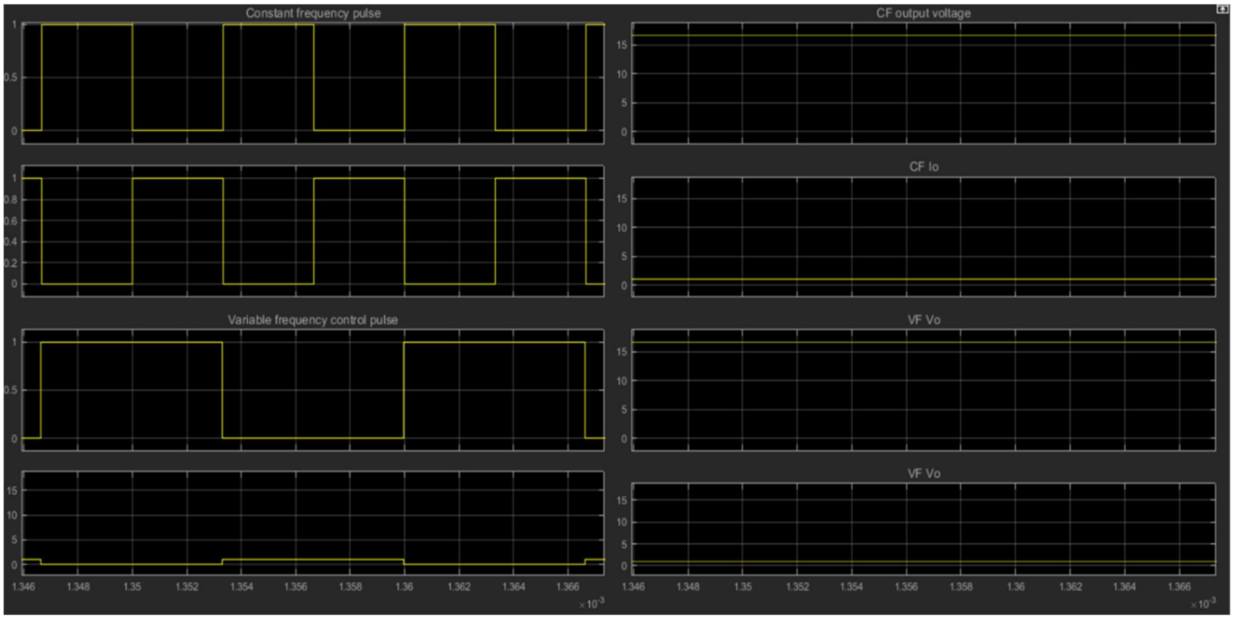


Fig. 13: (b) Simulation result of Push-Pull converter @ 50% Load

From the simulation results, it is seen that the converter is operated under variable output power. Fig. 13 shows that the designed variable frequency PWM generator changes the switching frequency according to output power. In addition, it is seen from the Fig. 13 that the output voltage is well regulated although there are changes in the output power and switching frequency.

E. Constant Frequency Control (150KHz)

Table 4 : Output results of Push-Pull converter

	Input Voltage (V)	Output voltage (V)	Input current (A)	Output Current (A)	Efficiency
100% Load (150KHz)	50	16.62	0.7679	2.01	86.5%
50% Load (150KHz)	50	16.69	0.3968	1.015	85.36%

F. Variable Frequency Control

Table 5 : Output results of Push-Pull converter

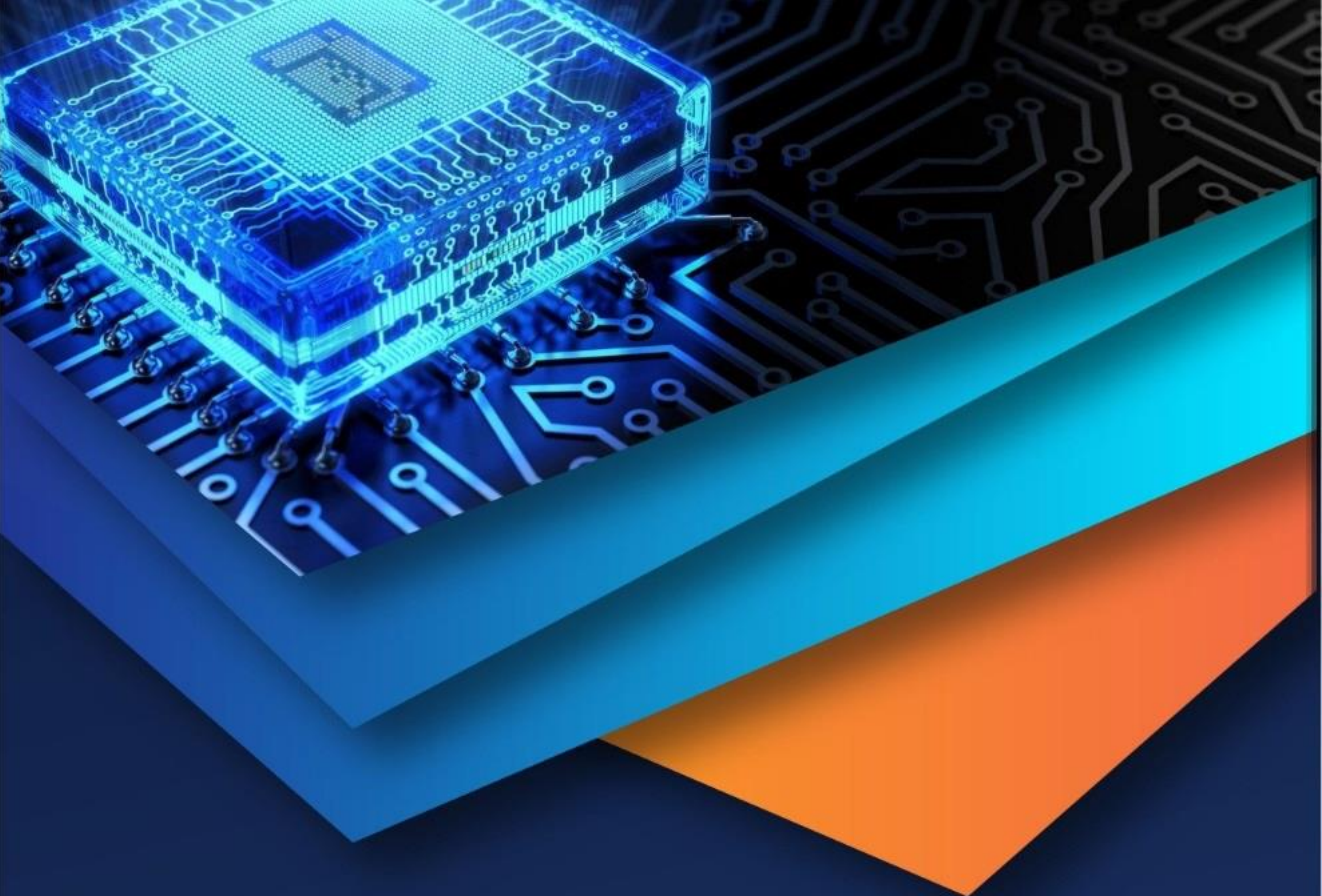
	Input Voltage (V)	Output voltage (V)	Input current (A)	Output current (A)	Efficiency
100% Load (150KHz)	50	16.67V	0.7550	2.098	92.6%
50% Load (75KHz)	50	16.69V	0.380	1.058	92.93%

V. CONCLUSION

This study present analyzing and comparing of a flyback and Push-Pull DC-DC converter which has a 100W and 38.28 nominal power operated under variable and constant switching frequency. The comparation has been done according to output power levels. The output power of the topology was changed from the rated value to half of nominal value. The efficiency of the converter was recorded for all stages. It was concluded that the flyback converter and Push-Pull converter operated with variable switching frequency is more efficient than that of the constant switching frequency.

REFERENCES

[1] Mehmet Can Taneri, Naci Genc, Ali Mamizadeh, "Analyzing and Comparing of Variable and Constant Switching Frequency Flyback DC-DC Converter," 2019 4th International Conference on Power Electronics and their Applications (ICPEA) , 25-27 Sept 2019, 25 Nov 2019, , Elazig, Turkey, pp. 1006-1010.
[2] Gourab Das , M.De, K.K.Mandal, "Design of Flyback Converter by using an Ideal Switch and a MOSFET Switch," 2018 IEEE Electron Devices Kolkata Conference (EDKCON), 24-25 Nov 2018, 25 July 2019, Kolkata, India, pp. 1026-1030.
[3] Garvit Anand, Ashok Kumar Pandey, "Comparison and Design of Flyback Converter using an Ideal Switch and a MOSFET Switch," 2018 International Conference on Power Energy, Environment and Intelligent Control (PEEIC), 13-14 April , 14 Mar 2019, Greater Noida, India, pp. 1120-1123.
[4] Kalariya Chandresh, M.V. Makwana, R.N.Rathod, Mounika.A, D.Medhini, "Design and Implementation of Soft Switching based Push Pull Converter for LED Application," 2019 IEEE International Conference on Innovations in Communication, Computing and Automation (ICCI-19) , 23-23 March 2019, 23 April 2021, Chennai, India, pp. 1030-1035.
[5] Hadi Tarzamni, Ebrahim Babaei, Farhad Panahandeh Esmaeelnia, Payman Dehghanian, Sajjad Tohidi, Mohammad Bagher Bannae Sharifian, "Analysis and Reliability Evaluation of a High Step-Up Soft Switching Push–Pull DC–DC Converter," IEEE Transactions on Reliability, Vol:69, Issue:4, Dec 2020, Espoo, Finland, pp. 1030-1035.
[6] I. Iskender, S. A. Hashjin,A. Mamizadeh, "Design And Implementation Of A Six Isolated Output Flyback Converter," International Journal of Engineering, Technology and Natural Sciences, vol. 1(2), pp. 12-19, September 2016.
[7] T. J. P. Liang, K. H. Chen, J. F. Chen, "Primary side control for flyback converter operating in DCM and CCM," IEEE Transactions on Power Electronics, vol. 33(4), pp. 3604-3612, April 2018.
[8] H. Onay, V. Sueel, A. Hava, "A Comprehensive Loss Analysis of Quasi Resonant Flyback Converter for Design Purpose," International Exhibition and Conference for Power Electronics, Intelligent Motion, Renewable Energy and Energy Management pp. 1-8, June 2018
[9] Fairchild semiconductor. Transformer Design Consideration for off-line Flyback Converters using Fairchild Power Switch, Application Note AN4140. Fairchild semiconductor document. (2002). [Online]. Available: http://www.fairchildsemi.com/
[10] Abraham I. Pressman, "Switching Power Supply Design," Second Edition McGraw- Hill.
[11] Muhammad H. Rashid, "Power Electronics Circuit, Devices, and Applications," Third Edition, New Delhi (Prentice-Hall of India Private limited), 2004.
[12] Daniel W. Hart, "Power Electronics," Published by McGraw- Hill,2011.



INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY