ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

An ISO 3297: 2007 Certified Organization
Vol. 5, Special Issue 2, March 2016

National Conference on Future Technologies in Power, Control and Communication Systems (NFTPCOS-16)

on 10, 11 and 12th March 2016

Organised by

Dept. of EEE, College of Engineering Perumon, Kollam, Kerala – 691601, India

An Efficient Interleaved Flyback DC-DC Converter

Viji Chandran[1], Kannan S.A[2], Renjith .G[3], Jeby Roy[4], Bilha Mathew[5], Greeshma.G[6], Mithila R.S[7], Veena P.M[8]

Assistant Professors, College of Engineering Perumon, Kerala, India[1,2,3]

B.Tech Scholars, Dept. of Electrical and Electronics, College of Engineering, Perumon, Kerala, India[4,5,6,7,8]

ABSTRACT: The growing importance of power consumption in today's appliances leads to new research works on the converter area .The dc-dc converters primarily strive for efficiency ,with new technologies playing a role to achieve that goal .This paper demonstrates analysis ,design and comparison of two converter systems to develop a high efficient dc-dc converter .Efficiency is an important dc-dc converter characteristics ,particularly for virtually every battery-based or embedded system.it affects the physical package sizes of both power supply and the entire system and has direct effect on the system's operating temperature and reliability .A desired converter should be small and light weight with low system cost .The first converter under study is a normal forward converter with single interleaving provided .It is compared against a 3 cell interleaved converter working as per flyback design .The flyback topology has a benefit to work under high power with reduced cost and size of working elements .The use of three interleaving cells in flyback topology enhance it's use under high frequency applications with reduced size of filtering the performance elements .It is demonstrated that the performance of a proposed flyback system is extremely good than the conventional forward system.

KEYWORDS: Forward converter, Flyback converter.

I.INTRODUCTION

Forward converter topology is commonly used in switch mode power supply design. However, each topology has certain limitations that are hard to resolve. The forward converter is really just like transformer isolated buck converter .Like flyback topology, this is best suited for lower power application. The forward converter does have the advantage over the flyback converter when high output current are required .since the output current is not pulsating, it is well suited for the application where the current is in excess of 15A.Its efficiency is similar to that of flyback. Compared with flyback converters, forward converters require one additional output inductor, although they have reduced requirements for the output capacitor. It does have the disadvantage of having an extra inductor on the output and it is not well suited for high voltage output .Toavoid transformer saturation, a resetting circuit in a forward converter is needed. All of these increase the component count and cost.The flyback topology is essentially the buck-boost topology that is isolated by using a transformer as the storage inductor. The transformer not only provides isolation, but by varying the turns ratio, the output voltage can be adjusted. Since a transformer is used, multiple outputs are possible. The flyback is the simplest and most common of the isolated topologies for low-power applications. While they are well suited for high-output voltages, the peak currents are very high, and the topology does not lend itself well to output current above 10A.

One advantage of the flyback topology over the other isolated topologies is that many of them require a separate storage inductor. Since the flyback transformer is in reality the storage inductor, no separate inductor is needed. This, coupled with the fact that the rest of the circuitry is simple, makes the flyback topology a cost effective and popular topology.

II.DC-DC CONVERTERS

A DC-to-DC converter is a power electronics device that accepts a DC input voltage and produces a DC output voltage at a different voltage level than the input. The output voltage of DC to DC converter can be greater than the input voltage or vice versa. DC to DC converter circuits consists of a transistor or diode switch, energy storage devices like

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

An ISO 3297: 2007 Certified Organization Vol. 5, Special Issue 2, March 2016

National Conference on Future Technologies in Power, Control and Communication Systems (NFTPCOS-16)

on 10, 11 and 12th March 2016

Organised by

Dept. of EEE, College of Engineering Perumon, Kollam, Kerala – 691601, India

inductors or capacitors and these converters are generally used as linear voltage regulators or switched mode voltage regulators. In addition, DC-to-DC converters are used to provide noise isolation, power bus regulation, etc.

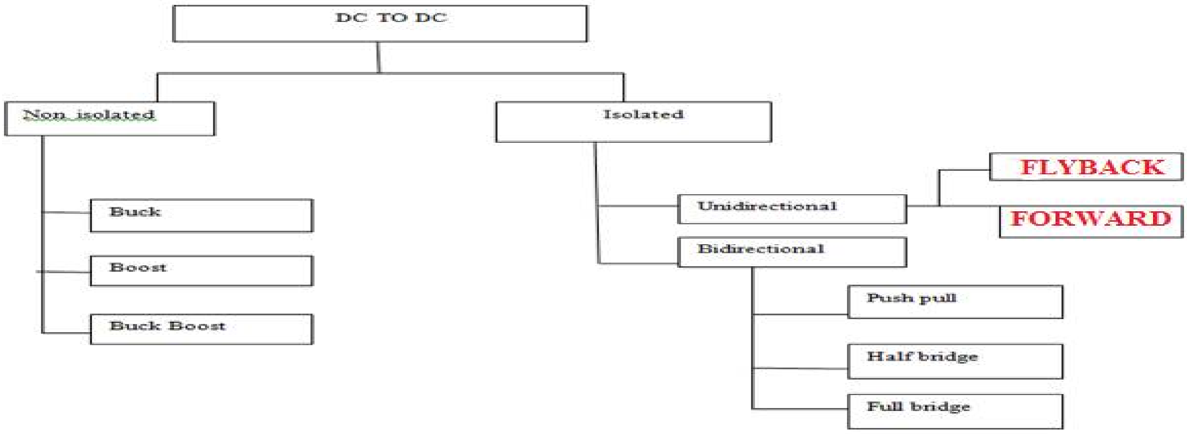


Fig 1.Classification of converters

DC-to-DC converters may be operated in two modes, according to the current in its main magnetic component (inductor or transformer):

1. **Continuous** mode- the current fluctuates but never goes down to zero
2. **Discontinuous** mode- the current fluctuates during the cycle, going down to zero at or before the end of each cycle

A converter may be designed to operate in continuous mode at high power, and in discontinuous mode at low power. Both the unidirectional and bi-directional DC-DC converters are preferred to be isolated to provide safety for the devices.

III.ISOLATED DC-DC CONVERTERS

The isolated DC-DC converter is electrically separated between the input and the output terminals. Sometimes an isolated DC-DC converter is also called isolated ground or galvanic isolated type. They have strong noise and interference blocking capability thus providing the load with a cleaner DC source.

A.FORWARD CONVERTER

The forward converter is an isolated version of the buck converter. The concept behind the forward converter is that the ideal transformer converting the input AC voltage to an isolated secondary output voltage. It uses a transformer to increase or decrease the output voltage (depending on the transformer ratio) and provide galvanic isolation for the load. The transformer used in the forward converter is desired to be an ideal transformer with no leakage fluxes, zero magnetizing current and no losses.

When the transistor is ON, Vin appears across the primary and then generates :

$$Vx = \frac{N_1}{N_2} Vin$$

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

An ISO 3297: 2007 Certified Organization Vol. 5, Special Issue 2, March 2016

National Conference on Future Technologies in Power, Control and Communication Systems (NFTPCOS-16)

on 10, 11 and 12th March 2016

Organised by

Dept. of EEE, College of Engineering Perumon, Kollam, Kerala – 691601, India

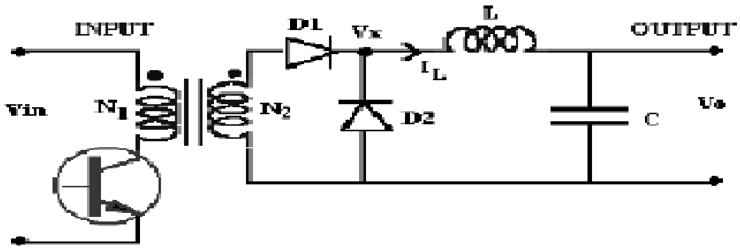


Fig2. Forward converter

The diode' D1' on the secondary ensures that only positive voltages are applied to the output circuit and the 'D2' provides a circulating path for inductor current if the transformer voltage is zero or negative.

i.Modes of operation

Mode 1: When switch 'S' is turned oninput dc gets applied to the primary winding and simultaneously a scaled voltage appears across the transformer secondary Since the dotted sides of both the windings are now having positive polarity, diode 'D1', connected in series with the secondary winding gets forward biased and the scaled input voltage is applied to the low pass filter circuit preceding the load.

Both primary and secondary windings start conducting simultaneously and the their winding currents and voltages are related to their turns-ratio (NP / NS), as in an ideal transformer. During mode 1, the load gets a voltage equal to $(N_s/N_p)E_{dc}$, which is the maximum achievable dc voltage across the load. Mode-1 can be called as powering mode.

Mode 2: When switch 'S' is turned off(fig), the primary as well as the secondary are suddenly brought down to zero. Diode 'D1' remains off during this mode and the current through the filter inductor and the load continues through the freewheeling diode 'D2'.

ii.Design of transformer and inductor

Turns ratio: $n=N_1/N_2$

Relation between turns ratio and duty cycle:

$$D=\frac{N_1}{N_2}\frac{V_0}{V_{in}}$$

The effective currents through the transformer is given by:

$$I_{eff.sec} = I_0\sqrt{D}$$

$$I_{eff.prim} = I_0\frac{N_2}{N_1}\sqrt{D}$$

Relationship exists between the ripple, frequency and inductance:

$$L = V_0\left(\frac{1-D_{min}}{I_{ppmax}\,f}\right)$$

Primary turns:

$$N_1 \geq \frac{V_{in\,min}t_{on\,max}}{\Delta B\,A_e}$$

Filter inductance L_{out}

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

An ISO 3297: 2007 Certified Organization Vol. 5, Special Issue 2, March 2016

National Conference on Future Technologies in Power, Control and Communication Systems (NFTPCOS-16)

on 10, 11 and 12th March 2016

Organised by

Dept. of EEE, College of Engineering Perumon, Kollam, Kerala – 691601, India

$$L_{out} = \frac{(V_o + V_{rect})\, t_{off\ max}}{\Delta I_{L\ out}}$$

The Forward converter looks similar to the Flyback at first glance, but is fundamentally different in its operation and features. The forward converter have some drawbacks compared to Flyback, which include:

1. High cost: Since extra output inductor and freewheeling diode is required
2. Minimum load requirements: particularly with multiple outputs, since gain dramatically changes if converter goes into DCM operation
3. Higher voltage requirement for the MOSFET

Flyback topology doesnot require a separate storage inductor whereas the forward converter does have the disadvantage of having an extra inductor on the output and is not well suited for high voltage outputs

B.INTERLEAVED FLYBACK CONVERTER

The flyback converter is the lowest cost converter among the isolated topologies since it uses the least number of components. This advantage arises from the ability of the flyback topology combining the energy storage inductor with the transformer. This eliminates the bulky and costly energy storage inductor and thus achieves a reduction in cost and size of the converter.

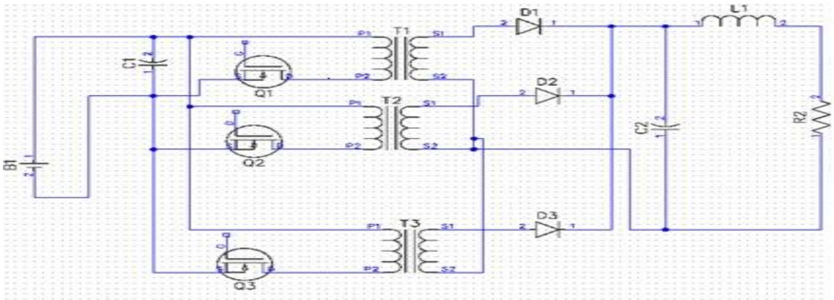


Fig 3.Three celled interleaved flyback topology

The implementation of high power flyback converter requires large air gap. As a result in the reduction of magnetizing inductance with low leakage inductance and also causes large leakage flux and poor coupling with poor energy transfer efficiency. The interleaving of flyback converter stages facilitates its use in high power applications with an added benefit of easy filtering of the ripple components or using smaller sized filtering elements. The switching frequency of each flyback cell is 40 kHz. The choice of operation mode for the converter is discontinuous current mode (DCM).

i.Flyback Transformer

A flyback transformer is multiwinding coupled inductor where energy is stored. Inductor design depends greatly on the inductor current operating mode.

- Discontinuous inductor current mode: when the instantaneous ampere-turns (totaled in all windings) dwell at zero for a portion of each switching period.
- Continuous inductor current mode: In this mode total ampere-turns do not dwell at zero (although the current may pass through zero).

The choice of operation mode for the converter is discontinuous current mode (DCM). The fundamental motivations for selecting DCM operation

- It provide very fast dynamic response
- No reverse recovery problem
- No turn on losses
- Small size of the transformer
- No need for a feed back loop to control the grid current,so it is easy to control

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

An ISO 3297: 2007 Certified Organization Vol. 5, Special Issue 2, March 2016

National Conference on Future Technologies in Power, Control and Communication Systems (NFTPCOS-16)

on 10, 11 and 12th March 2016

Organised by

Dept. of EEE, College of Engineering Perumon, Kollam, Kerala – 691601, India

ii.FlybackTransformer Design

The flyback transformers have to store large amount of energy and then transfer it to the output through magnetic coupling at every switching cycle.When inductors are designed for the discontinuous mode, with significant core loss,the total loss is at a broad minimum when core and winding losses are approximately equal. In order to store and return energy to the circuit efficiently and with minimal physical size, a small non-magnetic gap is required in series with a high permeability magnetic core material.

Table I

Design parameters	Specifications
Total maximum power from PV panel(W)	1000
PV voltage(V)	88
Duty ratio information(D_{peak})	0.3333
No. of interleaving cells(n)	3
Grid voltage(V)	230
Turns ratio(N)	1:10
Magnetic inductance(L_m,µH)	8

iii. Inductance Calculation

Several methods are in common use for calculating inductance:
Discrete gap length lg:

$$L=\frac{\mu_0 N^2 A_g}{L_g} * 10^{-2} \quad (2)$$

$$l_g=\frac{\mu_0 N^2 A_g}{2} * 10^{4} \quad (3)$$

Inductance factor A_L:

$$L=N^2 A_L \text{ nH} \quad (4)$$

From the duty cycle D, transformer turns ratio, n, is calculated according to the relationship:

$$n=\frac{V_{in}}{Vo} * \frac{D}{1-D} \quad (5)$$

$$D=\frac{nV_0}{V_{in+nV_0}} \quad (6)$$

Where
L: inductance in Henry
l_g: discrete gap length
A_g: corrected gap area
D: duty ratio
N: transformer turns ratio

The next major objective in the design of the flyback transformer is to obtain the lowest leakage inductance. It can be made possible by reducing the number of winding layers so that less space between the layers. The low-voltagewinding use 20 turns and the high-voltage winding uses 210 turns to get the turns ratio of 1:10.The switching frequency (f_s) is selected as 40KHzin order to achieve high efficiency along with smaller sized magnetics.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

An ISO 3297: 2007 Certified Organization *Vol. 5, Special Issue 2, March 2016*

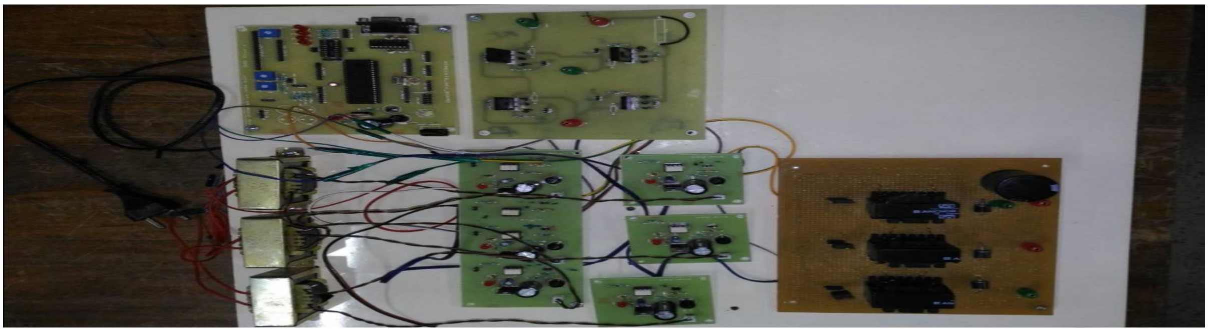
National Conference on Future Technologies in Power, Control and Communication Systems (NFTPCOS-16)

on 10, 11 and 12th March 2016

Organised by

Dept. of EEE, College of Engineering Perumon, Kollam, Kerala – 691601, India

IV.HARWARE OVERVIEW



V.OVERALL SIMULATION

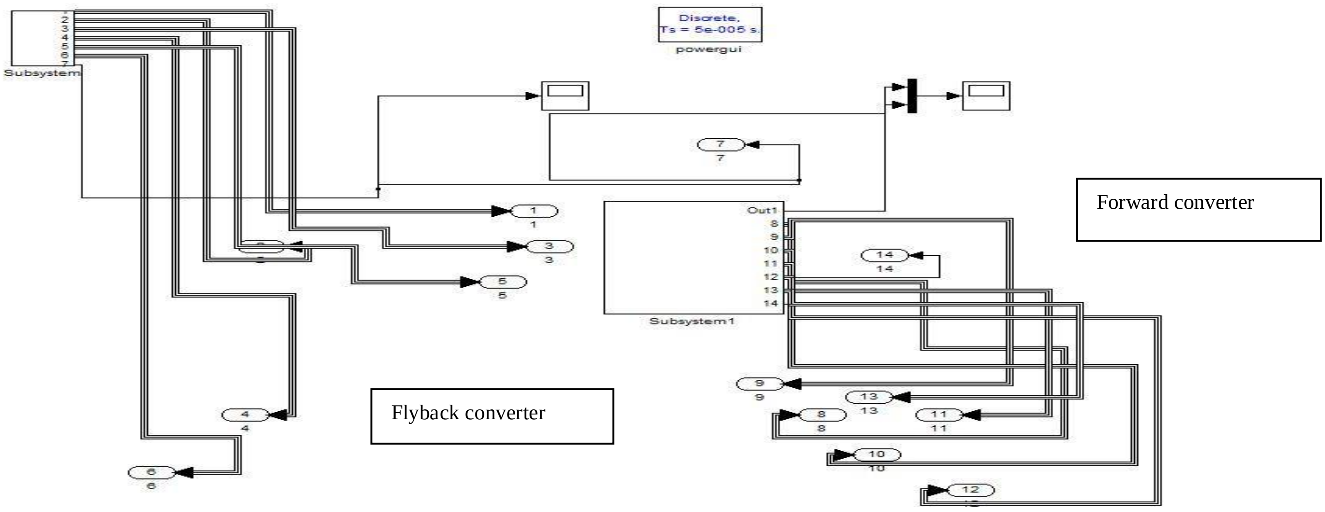


Fig 4 Simulation of flyback converter and forward converter

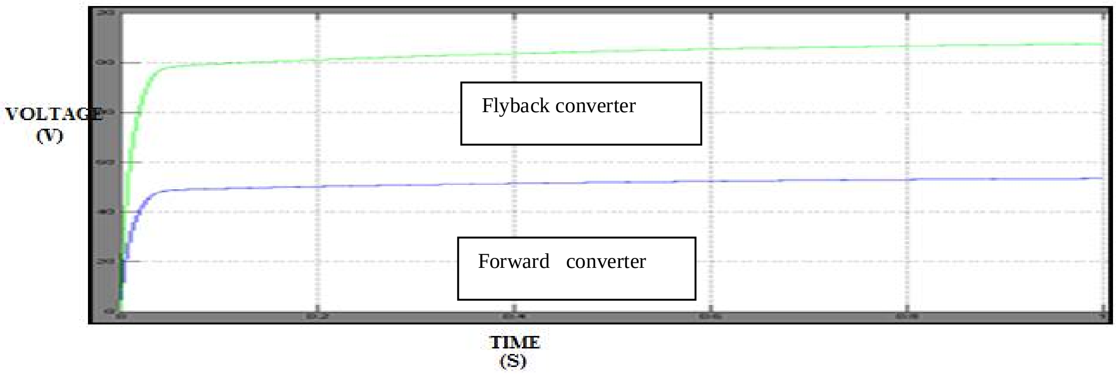
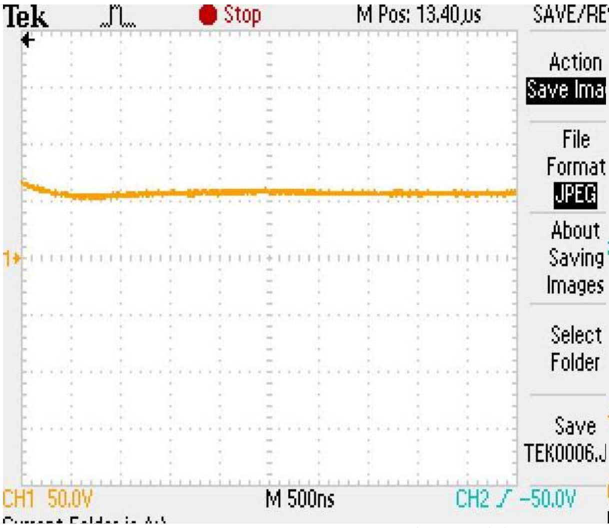


Fig 5 simulated waveform of flyback and forward converter

VI.EXPERIMENTAL RESULTS



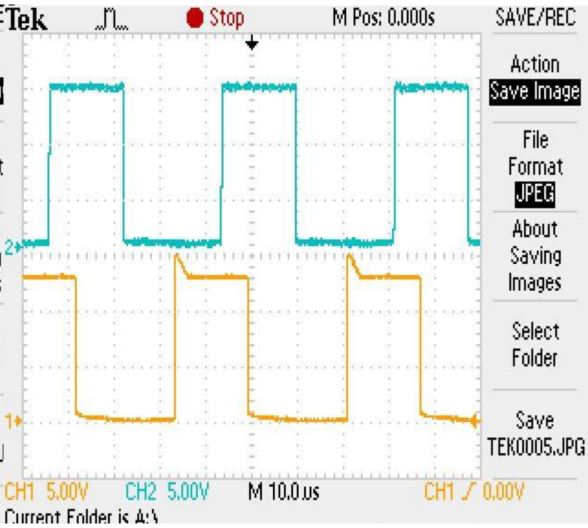


Fig 6 Experimental waveform of flyback transformer Fig7 Triggering waveforms to flyback

VII. CONCLUSION

The forward converter looks superficially like a flyback converter but it operates in a fundamentally different way. It does not store energy during the conduction time of the switching element transformers cannot store a significant amount of energy, unlike inductors.Instead, energy is passed directly to the output of the forward converter by transformer action during the switch conduction phase.In flyback converter ,the operation of storing energy in the transformer before transferring to the output of the converter allows the topology to easily generate multiple outputs with little additional circuitry. The inductor split to form a transformer, in the flyback converterso that the voltage ratios are multiplied with an additional advantage of isolation.A typical efficiency of around 80% may be assumed for the forward converter.In Conventional flyback converter efficiency approaching 90% for typical operation loads.

REFERENCES

1. BunyaminTamyurek, *Member, IEEE*, and BilgehanKirimer "*An Interleaved High-Power Flyback Inverter for Photovoltaic Applications*."; IEEE Trans June 2015.
2. E.Roman,R.Alonso,P.Ibanez,D.Goitia, S.Elorduizapataraietexe;"*Intelligent PV module for Grid connected PV Systems";* Industrial Electronics IEEE Trans, Issue 4,June 2006.
3. N.Kasa, T.lida and L.Chen,"*Flyback Inverter Controlled By Sensorless current MPPT for Photo Voltaic Power System*" IEEE Trans.Ind.Electron,Vol.52,Aug.2005.
4. WongsakornLimsiri, PairoteSirinamaratana and EkachaiLeelarasmee "*Development of PLC Circuit for Solar farm Monitoring "; IEEC* 2014.