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A Review on Single Stage Forward and Fly back Converter to Improve its Performance

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Abstract:

Universal demand for power increases due to continuous development to fulfil all these demand. Resources are used with optimization. A high efficiency and high power factor converters are the major parts of energy transfer system. This paper present a general review on single stage forward and flyback converter topologies to get better its performance. This is paper presents a kind general idea of increasing efficiency and power factor of single stage forward and fly back converter.

Keywords — **Forward-Fly back, MOSFET, PFC, THD**

I.   INTRODUCTION

Recently power converters either AC-AC or DC-DC are broadly used in a high and low Power application. Traditionally, these AC-DC converters are mostly consist of two stages. In the first stage, AC voltage is converted into an uncontrolled DC voltage using Diode and rectifiers, which gives its output second stage of isolated DC-DC converters as input using HF transformer for isolation. These two-stage AC-DC converters have the problems of power quality in terms of injected harmonic currents at AC mains, caused voltage distortion, degraded power factor, high crest factor, and large size of DC capacitor filter at first stage. Though all these concern are considered. Modern AC-DC converters are being developed in single-stage to improve power quality, reduced number of components and high efficiency. These problems can be avoided using newly developed single-stage enhanced power quality AC-DC converters using transformer isolation. They are also known as input current shapers, high power-factor single-stage converters, power factor correction (PFC) converters; universal input single-stage PFC isolated converters.

This paper deals with overview of enhanced topologies of AC-DC converter with isolation. All these enhanced single stage AC-DC converters with isolation are generally classified.
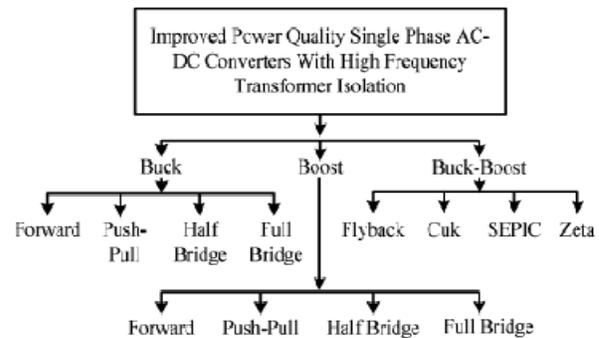

Fig.1 Classification of AC-DC Converter

Fig. 1 shows the classification isolated single-phase AC-DC converter. The enhanced power quality AC-DC converters feed from single-phase AC mains is classified into three major categories, namely, buck, boost, and buck-boost topologies. All these three types of converters are further classified into four types of configurations. Some of these converters are also known as single-phase, single-stage converter or single-stage single-switch converter).

Normally, fly back converter have good power factor but having issues with high offset current through the transformer magnetizing Inductor, large core losses and low power conversion efficiency. Whereas forward converter can achieve good power conversion efficiency with low core loss. They have low power factor. All

these limitations can be achieved by combining both topologies in same package.

II. LITRATURE REVIEW

In this paper, a high efficiency and high power factor single-stage balanced forward-flyback converter merging a forward and fly back converter topologies is studied. The conventional AC/DC fly back converter can achieve a good power factor but it has a high offset current through the transformer magnetizing inductor, which results in a large core loss and low power conversion efficiency. And, the conventional forward converter can achieve the good power conversion efficiency with the aid of the low core loss but the input current dead zone near zero cross AC input voltage deteriorates the power factor. On the other hand, since the proposed converter can operate as the forward and fly back converters during switch on and off periods, respectively, it cannot only perform the power transfer during an entire switching period but also achieve the high power factor due to the fly back operation. Moreover, since the current balanced capacitor can minimize the offset current through the transformer magnetizing inductor regardless of the AC input voltage, the core loss and volume of the transformer can be minimized. Therefore, the proposed converter features a high efficiency and high power factor. To confirm the validity of the proposed converter, theoretical analysis and experimental results from a prototype of 24W LED driver are presented. [1, 3]

Fly-back converters have been widely used because of the irrelative simplicity and their excellent performance for multi output applications. They can save cost and volume compared with the other converters, especially in moderate low power applications. In a fly-back converter, a transformer is adopted to achieve galvanic isolation and energy storage. [2]

Global energy consumption tends to grow continuously. To satisfy the demand for electric power against a background of the depletion of conventional, fossil resources the renewable energy sources are becoming more popular. According to the researches despite its fluctuating nature and weather dependency the capacity of renewable resources can satisfy overall universal demand for power. High gain DC/DC converters are the key part of renewable energy systems .The designing of high gain DC/DC converters is compulsory by severe demands. The power conditioning systems for the photovoltaic power sources needs high step-up voltage gain due to the low output of the generating sources. A high step-up topology employing a Series-connected Forward-Fly Back converter, which has a series-connected output for high boost voltage-transfer gain. Series-connected Forward-Fly Back converter is a hybrid type of forward and fly back converter. By stacking the outputs of them extremely high voltage gain can be obtained with small volume and high efficiency with a galvanic isolation. The separated secondary windings reduce the voltage stress of the secondary rectifiers and results in high efficiency.[4]

In order to reduce output voltage ripple, it is a common practice to place a large electrolytic capacitor at the output of the conventional, single phase capacitive rectifier. This results in power converter with poor power factor and high total harmonic distortion (THD). In recent years, many high   frequency power factor correction (PFC) circuits and current shaping control techniques were developed to meet certain standards. [5]

The Fly back converter can both step up and step-down the input voltage, while maintaining the same polarity and the same ground reference for the input and output. MOSFETs are used as a switching device in low power and high frequency switching applications. It may be noted that, as the turn-on and turn-off time of MOSFETs are lower as compared to other switching devices, which reduces the switching losses. High frequency operation of MOSFET reduced size of filters components. These converters are now being used for various applications, such as Switched Mode Power Supply (SMPS) etc. Due to designing and tuning of Fly back converters it can be used to designing of an optimized controller for isolated DC-DC Fly back converter for constant voltage applications. [6]

The Zero Voltage Switching (ZVS) technique is used to achieve soft switching. A bidirectional boost converter is connected with an output module as a Parallel Input Serial Output configuration. The flyback converter with Voltage Doubler Rectifier (VDR) acts as an output module.

This connection makes a bidirectional boost converter an active clamp circuit which is connected to the output side in order to extend the step up ratio. A converter with active clamp technique is used to recycle the leakage energy, to eliminate voltage spike due to coupled inductors and also to provide a mechanism to achieve ZVS. To overcome the efficiency degradation during light load due to load dependent soft switching of the ZVS, a control method using Pulse Width Modulation (PWM) proportional to the load current is used.[7]

A zero-voltage switching (ZVS) forward-flyback DC-DC converter, which is able to process and deliver power efficiently over a wide input voltage variation. The converter operates at boundary mode between current continuous and discontinuous mode to achieve ZVS. Variable frequency with fixed off time is used for reducing core losses of the transformer, achieving high efficiency.[10]

A new bridgeless buck PFC rectifier that substantially improves efficiency at low line of the universal line range is introduced. By eliminating input bridge diodes, the proposed rectifier's efficiency is further improved. Moreover, the rectifier doubles its output voltage, which extends useable energy of the bulk capacitor after a drop-out of the line voltage.[9]

III.   CONCEPT OF FLY BACK CONVERTER

Fly-back converter is the most commonly used SMPS circuit for low output power applications where the output voltage needs to be isolated from the input main supply. The output power of fly-back type SMPS circuits may vary from few watts to less than 100 watts. The overall circuit topology of this converter is considerably simpler than other SMPS circuits. Input to the circuit is generally unregulated dc voltage obtained by rectifying the utility ac voltage followed by a simple capacitor filter. The circuit can offer single or multiple isolated output voltages and can operate over wide range of input voltage variation. In respect of energy-efficiency, fly-back power supplies are inferior to many other SMPS circuits but its simple topology and low cost makes it popular in low

output power range. The commonly used fly-back converter requires a single controllable switch like, MOSFET and the usual switching frequency is in the range of 100 kHz. A two-switch topology exists that offers better energy efficiency and less voltage stress across the switches but costs more and the circuit complexity also increases slightly. The present lesson is limited to the study of fly-back circuit of single switch topology. Fig.2 shows the basic topology of a fly-back circuit. Input to the circuit may be unregulated dc voltage derived from the utility ac supply after rectification and some filtering. The ripple in dc voltage waveform is generally of low frequency and the overall ripple voltage waveform repeats at twice the ac mains frequency.
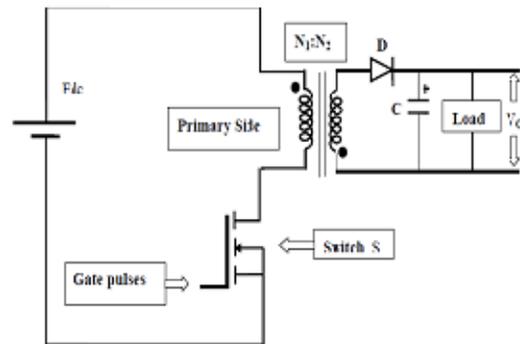

Fig.2. Basic Topology of Fly-Back Converter.

Since the SMPS circuit is operated at much higher frequency (in the range of 100 kHz) the input voltage, in spite of being unregulated, may be considered to have a constant magnitude during any high frequency cycle. A fast switching device („S"), like a MOSFET, is used with fast dynamic control over switch duty ratio (ratio of ON time to switching time-period) to maintain the desired output voltage. The transformer, in Fig.2, is used for voltage isolation as well as for better matching between input and output voltage and current requirements.

IV.   CONCEPT OF FORWARD CONVERTER

Forward converter is another popular switched mode power supply (SMPS) circuit that is used for producing isolated and controlled dc voltage from the unregulated dc input supply. The forward converter, when compared with the fly-back circuit,

is generally more energy efficient and is used for applications requiring little higher power output (in the range of 100 watts to 200 watts). However the circuit topology, especially the output filtering circuit is not as simple as in the fly-back converter Fig.3 shows the basic topology of the forward converter. It consists of a fast switching device 'S' along with its control circuitry, a transformer with its primary winding connected in series with switch 'S' to the input supply and a rectification and filtering circuit for the transformer secondary winding. The load is connected across the rectified output of the transformer-secondary.
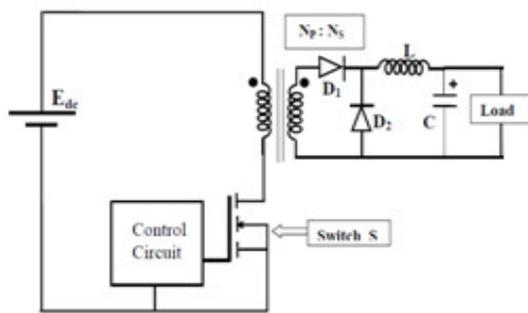
Fig.3. Basic forward converter topology

The transformer used in the forward converter is to be an ideal transformer with no leakage fluxes, zero magnetizing current and no losses. The basic operation of the circuit is explained with different mode operation here assuming ideal circuit elements. In fact, due to the presence of finite magnetizing current in a practical transformer, tertiary winding needs to be introduced in the transformer and the circuit topology changes slightly.

V. SINGLE SWITCH CONVERTER

PFC circuit can be available in two forms, i.e. single stage and two –stage scheme in two stage schemes. In two stage scheme, AC-DC converter is connected to the line to provide good input power factor and generate regulated dc voltage. Generally this voltage cannot directly supply the load since it contains intolerable second harmonic content. Therefore a ac/dc converter is cascade to tightly

regulate the output voltage. These two power stages are controlled separately. And thus it makes optimization of both converters possible. The main drawbacks of this scheme are its higher cost and larger size resulting from its increased component number and complicated control circuits. The one – stage PFC scheme combines the PFC circuit and the voltage regulation circuit in one stage. Due to the simplified power stage and control circuit of the single stage scheme, it is attractive to many applications with cost size.
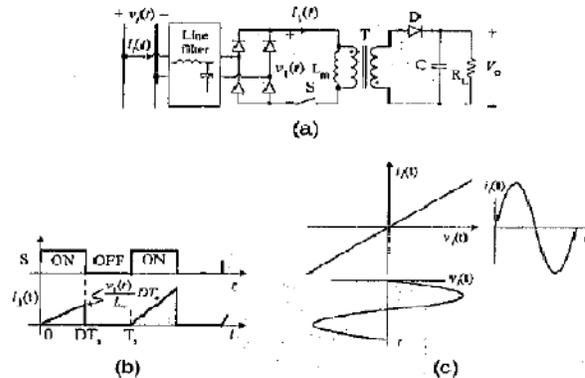

Fig. 4. InputV-I characteristics of basic flyback converter operating in DCM.
(a) Flyback converter in PFC application.
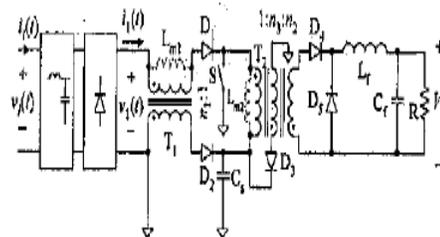(b) Input current. (c) Input V-I characteristics.

Fig.5. Basic circuit schematic of proposed converter.

The isolated flyback converter circuit and its input current waveform are shown in Fig. 4. (a) and (b), respectively.[5] Since switching frequency, it is reasonable to assume that the line voltage is constant in a switching cycle.

The basic circuit schematic of proposed new single stage single switch isolated converter is shown in Fig.5.[5] The input circuit employs a Flyback topology and the output circuit is a forward converter. The power switch and storage capacitor

are placed between the two circuits with diode D1 and D2 coordinating their two separate operations.

Table 1. Time intervals and staus of devices in mode operation

Mode	Time interval	Conducting device					
		S	D1	D2	D3	D4	D5
M1	to<t<t1	×	×			×	
M2	t1≤t≤t'2			×	×		×
	t'2≤t≤t2				×		×
M3	t2≤t≤to +Ts						×

It can be shown that in steady state the converter operates in three operation modes during one switching cycle. Table1. Shows three modes of operations. According to corresponding times and the status of the switching devices.
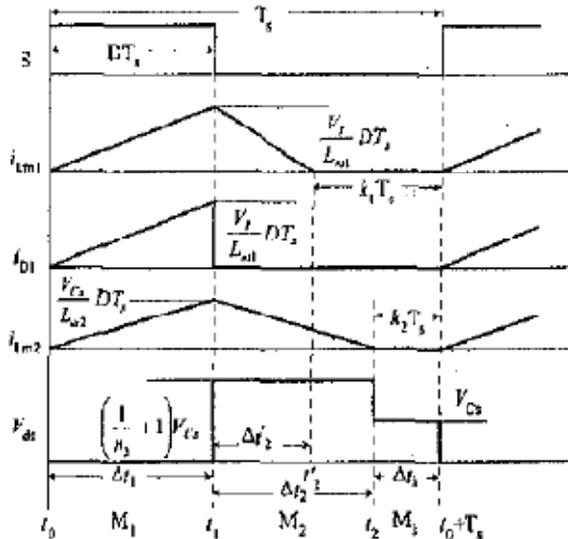

Fig.6. Theoretical key waveforms of proposed converter.

Typical steady state operation waveforms are shown in fig. 6. Which consist of three modes can be deeply studied with table1 having output filter maintains the output voltage until next switching cycle begins. Considering all design parameters i.e. maximum duty ratio, magnetizing inductance, transform ratio, selection of capacitor, filter inductance, power switch and diodes. The waveforms of filtered line current, switch voltage and current through diodes D1 were recorded at

peak line voltage. It is found that simulated and experimental waveforms are in a good agreement. The line current waveforms are almost sinusoidal and in phase with the line voltage, proving that good power factor was achieved by this converter topology. Fig.7. represents measured power factor and efficiency under different load condition.
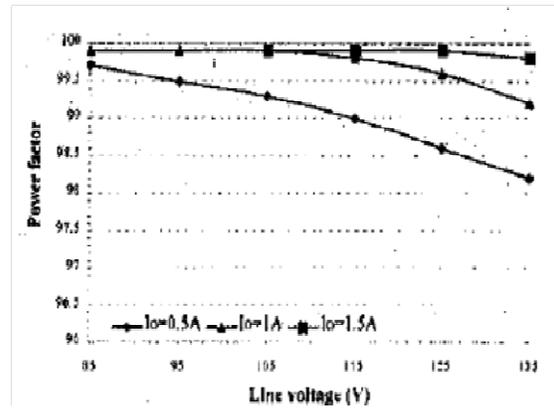
(a) Input power factor
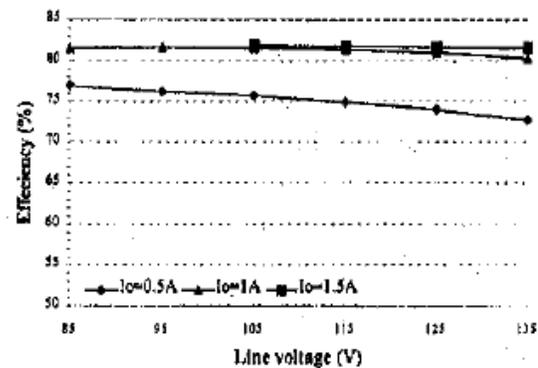
(b)Efficiency

Fig.7. Experimental efficiency and input power factor.

VI. Conventional single stage PFC converter

Recently, conventional single-stage PFC (power factor correction) LED drivers shown in fig. 8, which are well known as most cost effective solutions. Fig.9. shows their transformer magnetizing inductor currents. As shown in this figure, the magnetizing inductor offset current of fly back converter is larger than that of forward
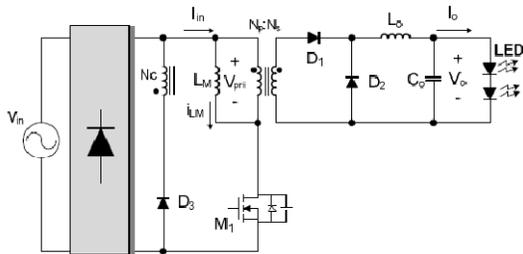
converter. The magnetizing inductor offset current of fly back and forward converter is

$$< i \, LM, flyback > = \frac{I_o}{n(1-D)} \qquad (1)$$

$$< i \, LM, farward > = \left(1 + \frac{Nc}{Np}\right) \frac{Vin}{2LM} D^2 Ts$$

(2)
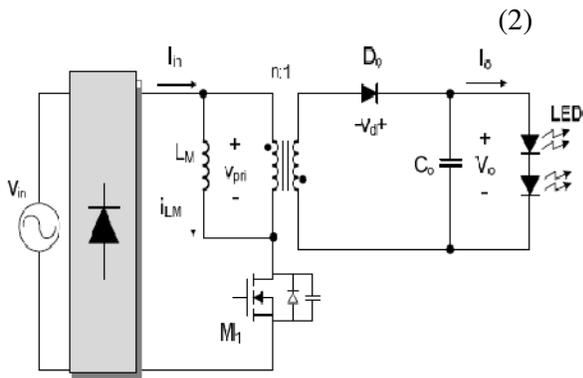
(a) Single-stage flyback converter

(a) Single stage forward converter

Fig 8 Conventional single stage PFC converter circuits

Fig.9. Transformer magnetizing inductor currents of conventional flyback and forward converters
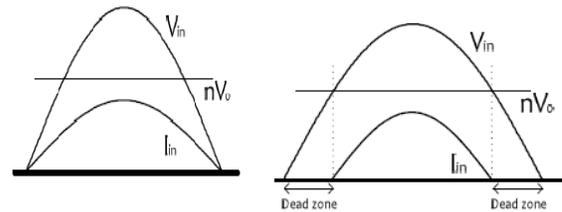
Fig 10.PFC performance of forward and flyback

Moreover, from equations (1) and (2), while the magnetizing inductor offset current of flyback converter is dependent on the load current Io, that of forward converter is not. Therefore, as the load current is more increased, the offset current of flyback converter becomes larger, which might result in the larger core loss and volume of transformer. For these reasons, the forward converter is superior to the flyback converter in terms of the transformer size and energy conversion efficiency.
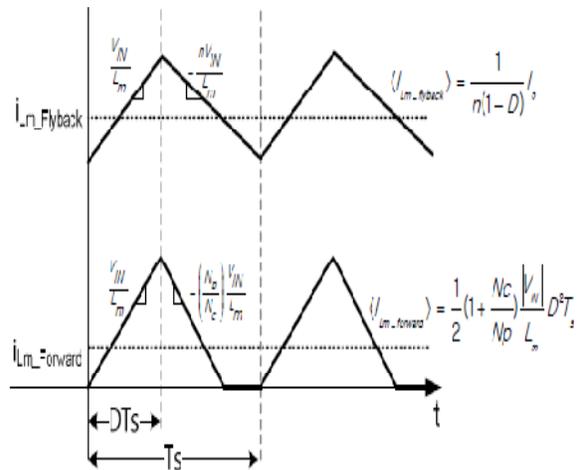
In the meanwhile, as shown in Fig. 10, while the flyback converter can transfer the input energy to the output side over an entire range of input voltage, the forward converter cannot at the lower input voltage than the reflected output voltage nVo to the transformer primary side. This is because the forward converter is originated from the step-down buck topology. Therefore, the input current dead zone near zero cross AC input voltage is always observed and deteriorates the power factor in the forward converter. Therefore, the flyback converter is superior to the forward converter in terms of the PFC performance.

VII. Proposed single stage PFC forward flyback converter

To solve all these problems, a high efficiency and high power factor single-stage balanced forward-flyback converter is proposed as shown in Fig.11. Since the proposed converter merges the forward and flyback topologies, it can operate as the forward and flyback converters during switch turn-on and off periods, respectively. Therefore, it cannot only perform the power transfer during an entire switching period but also achieve the high power factor. Especially, since the charge balanced capacitor Cb can make the proposed converter perform the forward operation regardless of the input voltage, the magnetizing inductor offset current, core loss and transformer size can be minimized.
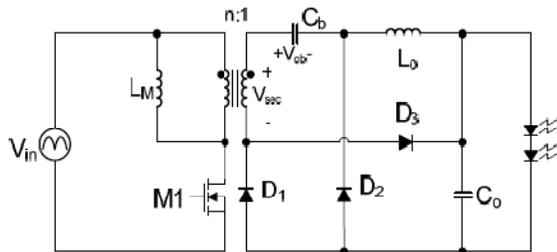

Fig.11. Proposed single stage PFC forward flyback converter circuit

Fig. 11 shows the circuit diagram of the proposed forward flyback converter.[1] As shown in this figure, its primary side is exactly same as that of the conventional flyback converter consisting of one power switch (M1) and one transformer. On the other hand, its secondary side consists of one output inductor (Lo) for forward operation, one DC blocking capacitor (Cb) for balancing operation and three output Diodes (D1, D2, D3). When M1 is conducting, the proposed converter operates as a forward converter. On the other hand, when M1 is blocked, the proposed converter operates as a flyback converter. However, if it is assumed that the proposed converter has no balancing capacitor Cb, abovementioned forward operation is possible only when the reflected primary voltage Vin/n to the transformer secondary side is higher than the output voltage Vo. This is because the forward converter is originated from the buck converter. Therefore, the forward-flyback converter operates

only as a flyback converter over the range of Vin/n < Vo. Especially, at the minimum input voltage near Vin=90Vrms, Vin/n is lower than Vo during most of periods and thus, the transformer has a large magnetizing offset current similar to the conventional flyback converter. In this case, the transformer core loss and volume are also as large as those of the conventional flyback converter. On the other hand, if the balancing capacitor Cb is serially inserted with the transformer secondary side, it can make the average current through Cb during forward operation become exactly same as that during flyback operation by the charge balance principle of Cb. In other words, since the voltage across Cb charged by flyback operation is added to the Vsec=Vin/n during forward operation, Vin/n+Vcb becomes higher than Vo and thus, the forward operation is possible even at Vin/n<Vo
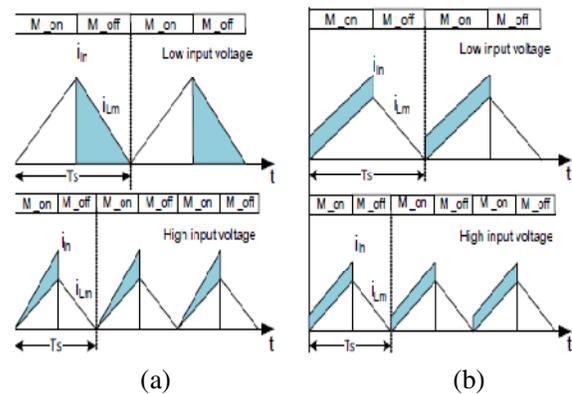

Fig.12. Primary and magnetizing currents of forward-flyback converter according to the input voltage. (a) Without balancing capacitor (b) with balancing capacitor

Therefore, the proposed forward-flyback converter with the balancing capacitor Cb can always operate as both forward and flyback converters regardless of the input voltage.

Fig.12. shows the primary and magnetizing current waveforms of the proposed converter operating in the boundary conduction mode (BCM). And, Fig.12 (a) and (b) show current waveforms without and with balancing capacitor Cb according to the input voltage, respectively. As mentioned earlier, the proposed converter with Cb can operate as both forward and flyback converters over an entire range of input voltage with the aid of Vcb. On the other

hand, while the proposed converter without Cb can transfer the input energy to the output side at Vin/n>Vo, it cannot at Vin/n<Vo. As a result, the proposed converter with balancing capacitor Cb features a smaller magnetizing offset current, resultant smaller core loss and more reduced transformer volume.
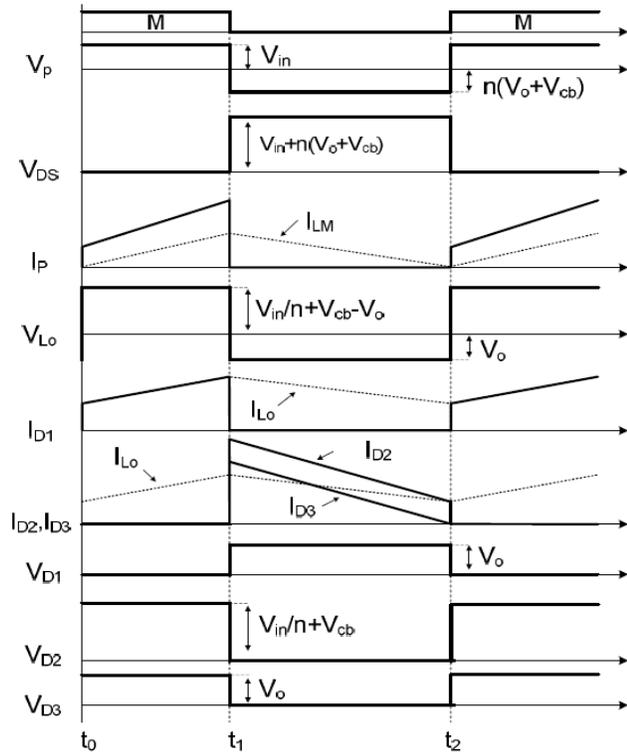

Fig.13. Key waveforms of the proposed forward – flyback converter

The circuit operation of the proposed converter is basically divided into two modes according to the conduction state of each switch as shown in fig.13. first mode operation from time interval t0-t1 and second from t1-t2. By considering all design parameters regarding proposed converter its performance is observed. Which also compared with conventional proposed individual converters and analysis conclude that it is suitable for low power application. For experimental performance of converter it's operated with different root mean

square values of voltage and efficiency and power factor is observed.
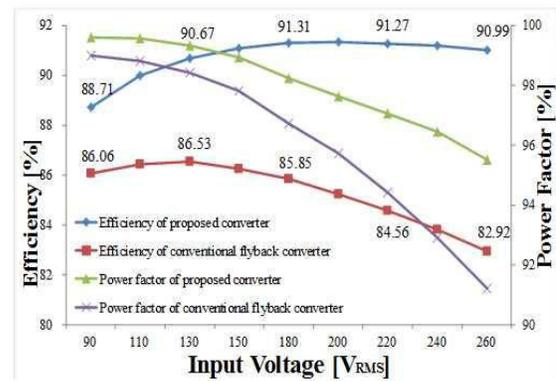

Fig.14. Comparisons of efficiency and power factor between flyback and proposed forward-flyback converter

Fig. 14 shows the measured efficiency and power factor of the proposed forward-flyback and conventional flyback converters. As shown in this figure, the proposed converter has the high power factor above 95% over a wide range of input voltage. Especially, its efficiency along wide input voltage range is above 88.71% and higher than the conventional converter by maximum 8.07% at $264V_{rms}$. This high efficiency is due primarily to the small transformer offset current and resultant reduced core loss.

VIII. CONCLUSION

This paper discusses various topologies employed for improvement of performance AC-DC converter. Initially conventional forward flyback converter uses two Transformers. This is having problems regarding size and cost due to large number circuit component. In order to overcome these drawbacks of two stage scheme. One stage PFC scheme adopted which combines fly back and forward circuit in single stage it makes optimization of converter in single package. Another issues of magnetizing offset current , core loss are overcome with single stage balanced forward –flyback type proposed converter .which have current balanced capacitor can minimize the offset current all the way through the transformer magnetizing inductor apart from input AC voltage and reduce core loss. After this review we realized that single stage

scheme is outstanding solution for low power application. It also provides good power factor and efficiency.

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