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Analysis of Cell Balancing Techniques for Li-Ion Batteries

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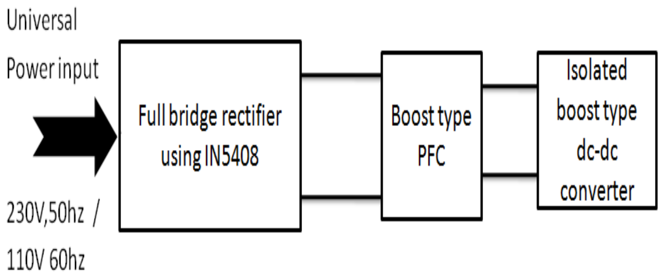
ABSTRACT: A new ac-dc single stage converter topology for reduced dc bus voltage variation to proposed in this paper. we planned to design single stage converter typically a fly back converter. It contains 3 stages namely a full bridge dc-dc converter. This new hybrid switching method introduces a possible ac-dc power conversion, in single power processing stage, providing both power factor correction and isolation at high switching frequency. This single stage converter operates in two different modes such as single fly back transformer mode, dual fly back transformer. In this work we consider the input voltage for single stage converter .the experimental results obtained from a converter are also presented.

KEYWORDS: Cell balancing, Lithium-ion batteries, Active balancing, Passive balancing, Battery management system (BMS), State of charge equalization, Energy storage optimization

I. INTRODUCTION

Single-stage ac–dc converters simultaneously perform both input power factor correction and dc–dc power conversion with just a single converter. An ac to dc converter is an integral part of any power supply unit used in the all electronic equipments. Also, it is used as an interface between utility and most of the power electronic equipments. These electronic equipments form a major part of load on the utility. Generally, to convert line frequency ac to dc, a line frequency diode bridge rectifier is used. To reduce the ripple in the dc output voltage, a large filter capacitor is used at the rectifier output. But due to this large capacitor, the current drawn by this converter is peaky in nature. This input current is rich in low order harmonics.



1.1 block diagram

Single stage ac–dc converters simultaneously perform both input power factor correction and dc–dc power conversion with just a single converter. They can be synthesized by combining an ac–dc front-end converter (typically a boost converter) with a dc–dc converter (typically a fly back or a forward converter), then removing all redundant elements.
Single-stage ac–dc converters simultaneously perform both input power factor correction and dc–dc power conversion with just a single converter. They can be synthesized by combining an ac–dc front-end converter (typically a boost converter) with a dc–dc converter (typically a fly back or a forward converter), then removing all redundant elements. A single-stage converter usually has only one controller, which is used to regulate the output voltage.

This means that the intermediate dc bus voltage the dc voltage at the transformer primary side that needs to be stepped down is therefore dependent on the input line and output load conditions and can thus vary considerably.

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When a single-stage converter is synthesized from an ac–dc boost converter, as is the case with most single-stage converters, the intermediate dc bus voltage has the potential to become very high as it does not have a separate and independent front-end converter to regulate it.

Power electronics researchers have proposed many techniques to try to keep the bus voltage to a maximum level of less than 450V to avoid large switch voltage stresses and capacitor size. These techniques can be classified as follows.
1) Variable switching frequency techniques; That limit the amount of input power that is transferred to the dc bus capacitor by increasing the switching frequency at decreasing load and vice versa
2) Bulk capacitor voltage feedback techniques; That use one or more auxiliary windings from the main power transformer to produce a counter voltage that limits the amount of voltage that is placed across the input inductor. Doing so reduces the charging current in the input inductor when the load is decreasing.
3) Load current feedback techniques; That adjust the input current by using information that is sensed at the load. 4) Direct power transfer techniques; That allow some of the power from the converter's input section to be transferred directly to the output instead of the dc bus Capacitor to reduce the amount of charge placed in this capacitor.
None of these techniques, however, significantly limits the variation in the dc bus voltage that can occur when the converter needs to operate under universal input line conditions. This can affect the design of the main power transformer as it must be designed to operate for all potential operating conditions. It can also affect the design of the converter with respect to hold-up time if this needs to be considered.

A widely varying dc bus voltage means that the converter must have appropriate hold-up time when the dc bus voltage is low or high, which, in turn, means that the dc bus capacitors must be selected for several bus voltages instead of just one. A new ac–dc single-stage converter is proposed in the paper. The outstanding feature of this converter is that its dc bus voltage is far less dependent on its operating conditions than is the case for most previously proposed single-stage converters.

Also, as power electronics equipments are increasingly being used in power conversion, they inject low order harmonics into the utility. Due to the presence of these harmonics, the total harmonic distortion is high and the input power factor is poor. Due to these problems we need a remedy. So here we proposed AC DC single stage converter. In order to reduce the THD and to improve the input power factor many approaches being used.

The significant reduction in dc bus voltage variation allows for a reduction in dc bus capacitor size as the need to satisfy hold-up time requirements for both low and high dc bus voltage is done away with. In the paper, the operation of the converter is discussed and its modes of operation are explained.

The analysis is used to develop a design procedure for the converter that is demonstrated with an example. The feasibility of the converter is confirmed with results obtained from an experimental prototype.

II. CONVERTER OPERATION

The proposed single-stage converter. It consists of a diode bridge rectifier transformers T_1 and T_2 , switch S, dc bus capacitor C, output capacitor C_1 , and diodes D_1 to D_4 . T_1 and T_2 have turns ratio of n_1 and n_1 , respectively, and each contain a magnetizing inductance $_{Lm1}$ and $_{Lm2}$. Each magnetizing inductance can be considered to be parallel to ideal transformer; the leakage inductances of T_1 and T_2 are negligible.

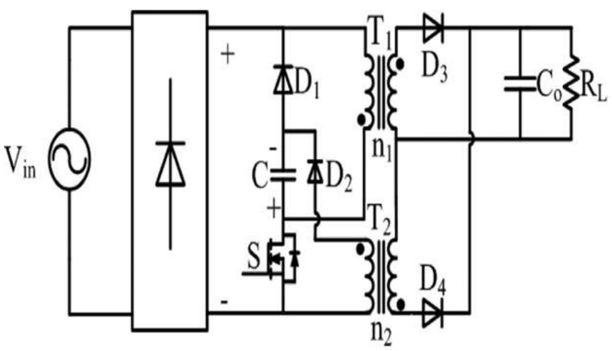

Fig 2.1 Proposed converter

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The input current is discontinuous and is bounded by a sinusoidal envelope so that it is essentially a sinusoidal waveform with HF harmonic components. The magnetizing current of each transformer can be either discontinuous or continuous. For the purpose of simplicity, it will be assumed that these currents are discontinuous so that both transformers are fully demagnetized after the switch is turned OFF. Moreover, making the magnetizing current of T_2 discontinuous will make Vc less susceptible to load variation.

The proposed converter has two distinct modes of operation, depending on the dc bus voltage Vc. In one mode, transformer T_1 acts like an inductor while T_2 acts like a fly back transformer; in the other mode, both transformers act like fly back transformers. Both modes are described in this section.

SINGLE FLYBACK TRANSFORMER MODE OF OPERATION

The converter is in this mode of operation when the dc bus capacitor voltage is less than $n_1 V_0$. This means that diode D_3 never conducts and T_1 becomes like an input inductor as no energy is transferred to the output. T_2 is the only transformer in the converter that actually operates as a flyback transformer. The converter goes through the following intervals when operating in the single flyback transformer mode of operation.

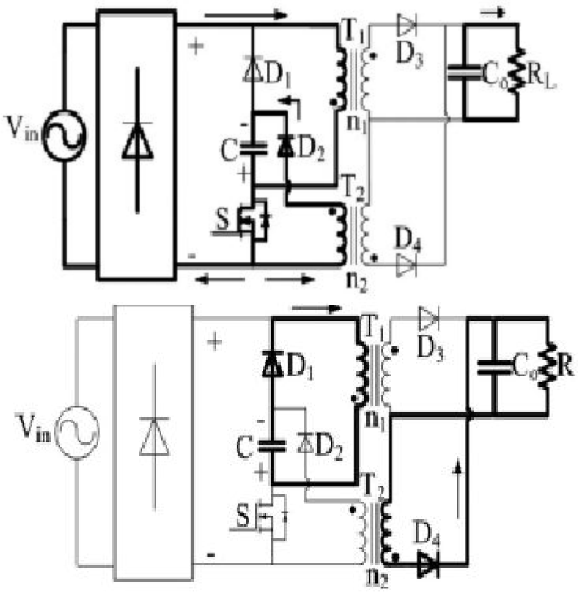

Fig 2.2 single flyback transformer

Interval 1 [t_0 –t_1]: Switch S is turned ON at t_0. The rectified input line voltage $|V_{in}|$ is applied to the magnetizing inductance of T_1, L_{m1}. Current in L_{m1} , begins to flow and increases linearly. Also during this interval, dc bus voltage V_c is applied across the magnetizing inductance of T_2 ,L_{M2} , causing its current iL_{m2} to increase linearly through D_2 .During this interval, there is no power transfer to the load, which is being supplied by C_0 .

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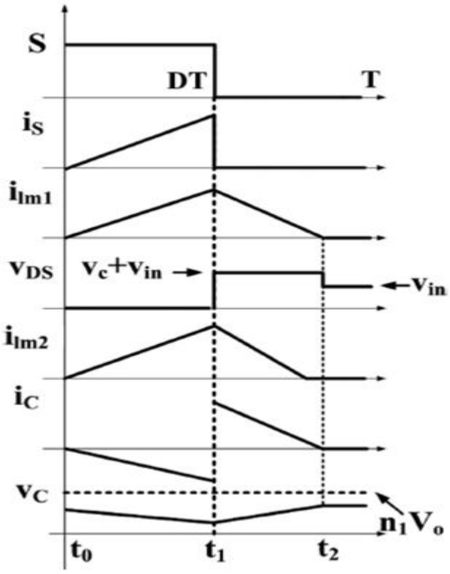

Fig. 2.3 Typical waveforms for single flyback transformer mode $V_c > n_1v$

Interval 2 [t_1 –t_2]: Switch S is turned OFF at t_1. All the energy that was placed in T_1 during interval 1 is transferred to bus capacitor C during this interval. Also during this time, all the energy that was placed in T_1 during interval 1 is transferred to the output through D_1. At some instant t = t_2, both T_1 and T_2 have been fully demagnetized and remain so until the start of the next switching cycle.

DUAL FLYBACK TRANSFORMER MODE OF OPERATION

The converter is in this mode of operation when the dc bus capacitor voltage is V_1=n_1v_0 Ideally, V_c can never exceed v_o because diode D_3 conducts if it tries to do so, allowing energy that would otherwise charge C to be transferred to the output During this mode, both T_1 and T_2 act like flyback transformers that demagnetize through their secondary's when switch S is OFF. It should be mentioned that a part of stored energy in the magnetizing inductance of T_1 goes to the dc bus capacitor after S has been turned OFF to make up for the drop in V_c that would otherwise occur due to the transfer of energy from C to T_2.

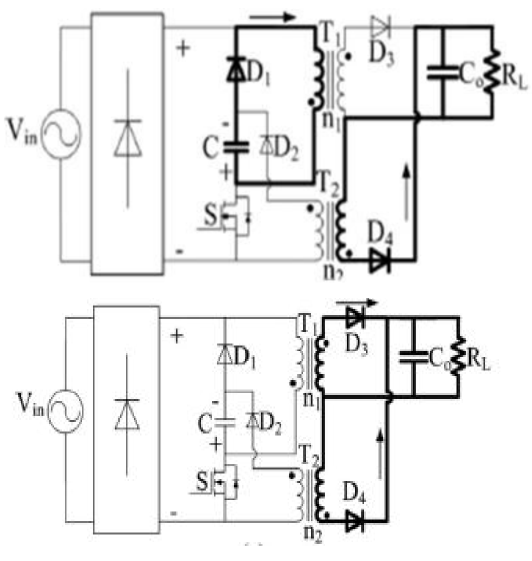

Fig 2.4 Dual flyback transformer

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Interval 1 [t_0– t_1]: The converter operates in the same way as it does for Mode 1, Interval 1.

Interval 2 [t_1 –t_2]: Switch S turns OFF at t_1. The converter operates in the same way as it does for mode 1 interval 2 as energy stored in T_1 is transferred to C to make up for the drop in V_c after the previous interval. The dc bus voltage reaches n_1V_0 at t = t_2. T_2 has not been fully demagnetized at this time.

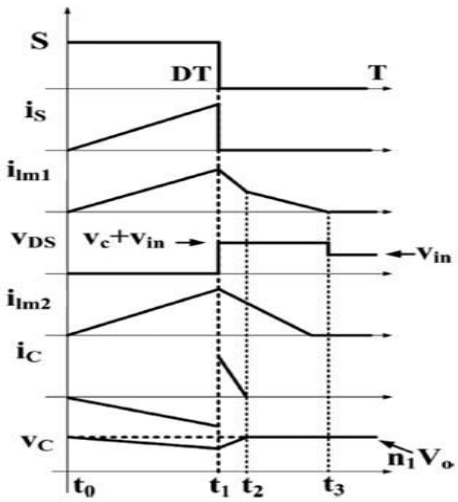
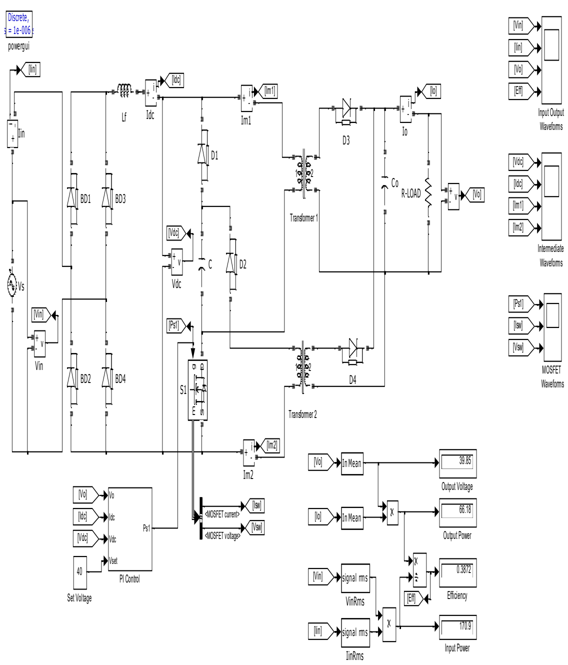


Fig.2.5 typical waveforms dual flyback transformer when n_1 v_0 = v_c

Interval 3 [t_2 –t_3]: At t = t_2, V_c is equal to n_1v_o and D_3 begins to conduct as it becomes forward biased. This releases the remaining energy stored in T_1 to the output. Also during this time interval, all the energy that was placed in T_2 during interval 1 is transferred to the output through D_4. At some instant t=t_3, both T_1 and T_2 have been fully demagnetized and remain so until the start of the next switching cycle. In addition to the modes of operation, the following should also be mentioned about the operation of the proposed converter.

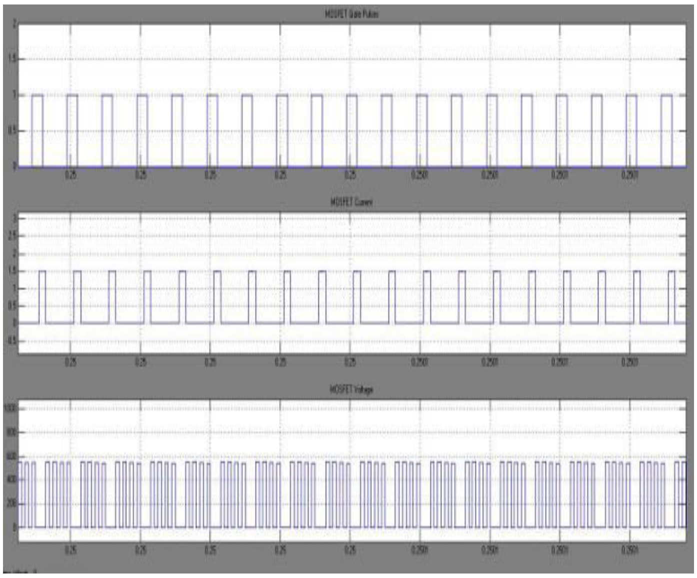
III. SIMULATION DIAGRAM AND RESULTS

SIMULATION DIAGRAM WITH CLOSED LOOP



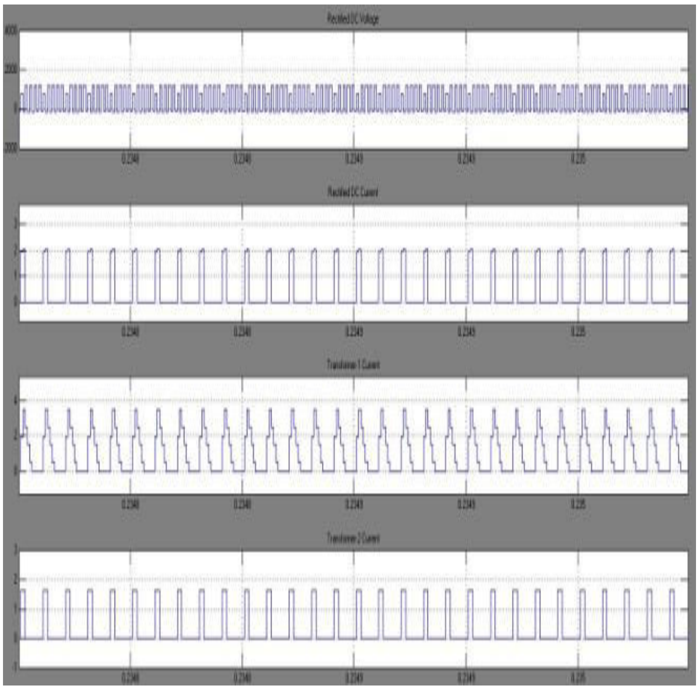
The voltage waveforms and typical primary and secondary current waveforms of T1 and T2 for different input voltages. shows that T1 and T2 are working in DCM when the input voltage is at its minimum and that both transformers are fully demagnetized after the switch is turned OFF. shows the same currents and voltage for the maximum input voltage.

MOSFET INPUT AND OUTUT WAVEFORM



shows the output current of T2 and the drain–source voltage of the switch when input voltage is at the minimum and the load is at its maximum value. It shows that T2 is completely discharged within the switching cycle

INTERMIEATE WAVEFORM



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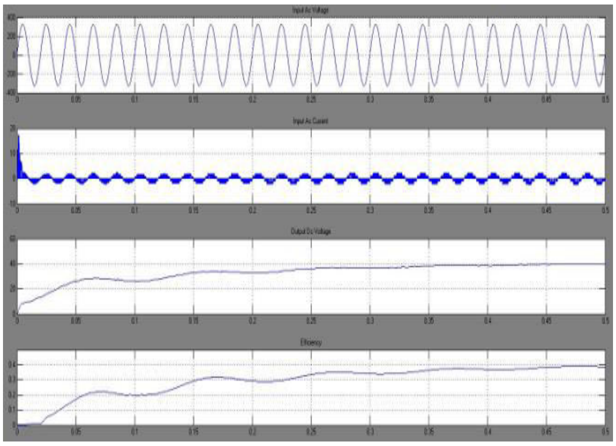
INPUT AND OUTPUT WAVEFORM



The dc bus voltage versus input voltage for different load power conditions. These results confirm that the dc bus voltage is almost fixed for different load and input voltage conditions. This makes it easier to satisfy hold-up time requirements for all different load and input voltage conditions if such a feature is needed. It should be noted that the bus voltage is not clamped to exactly n1Vo = 120V because of nonidealities in the converter components and transformers such as leakage inductance.

The increase in VC that occurs when the input voltage is increased is due to the fact that primary and secondary leakage inductances have voltage drops that become larger as more current flows in T1.

IV. CONCLUSION

In this project, a new single-stage high-power factor converter is proposed. The outstanding feature of this converter is that its dc bus voltage variation is significantly less than that of other single-stage converters, which allows smaller sized components to be used. This is the result of the buck–boost type input section and clamping of V_C by the secondary winding of T_1 to n_1V_o .The key characteristic equations were derived and used to design the converter. its ability to operate with a nearly fixed dc bus voltage regardless of line and load conditions and its ability to operate with an excellent input power factor. This project is done by using MATLAB Simulator.

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