International Journal of Trend in Scientific Research and Development (IJTSRD)
Volume 5 Issue 6, September-October 2021 Available Online: www.ijtsrd.com e-ISSN: 2456 – 6470

DCM-Based Bridgeless PFC Converter for EV Charging Application

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ABSTRACT

An Embedded system is a controller programmed and controlled by a Real-Time Operating System (RTOS) with a dedicated function within a larger mechanical or electrical system, often with Real-Time computing constraints. Embedded systems control many devices in common use today. The project aims to design an air, water, and noise pollution monitoring and controlling using internet of things. The level of pollution has increased with times by lot of factors like the increase in population, increased vehicle use, industrialization and urbanization which results in harmful effects on human wellbeing by directly affecting health of population exposed to it. In order to monitor quality of air, water quality and sound level of the environment over IoT based new framework is proposed which is based on data acquisition, transmission and controlling. The proposed bridgeless converter precedes a flyback converter to manage the charging of 48V/100Ah battery throughout the constant current (CC)/ constant voltage (CV) profile as well as built-in PFC capability at the mains side is inherited. An 850W prototype is designed and developed tosupport the enhanced performance of the battery charger by reconstructing the line current waveform and significantly reducing the input harmonics distortion to the recommended IEC 61000-3-2 standard.

KEYWORDS: *microcontroller (Atmega328P), Buck Converter, Electric Vehicles*

How to cite this paper: P. Selvan | P. Selvan | V. Navanitha Krishnan | B. Pavunraj | K. Sureshkumar "DCM-Based Bridgeless PFC Converter for EV Charging Application" Published in International Journal of Trend in Scientific Research and Development (ijtsrd), ISSN: 2456-6470, Volume-5 | Issue-6, October 2021, pp.183-187, URL: www.ijtsrd.com/papers/ijtsrd39922.pdf

IJTSRD39922

I. INTRODUCTION:

The automotive industry globally is witnessing a major transformation. Growing concerns for the environment and energy security clubbed with rapid advancements in technologies for power train electrification are revolutionizing the automotive sector. One of the key facets of such a change is the accelerated development in the field of electric mobility which might transform the automotive industry like ever before. As per Germany's Centre for Solar Energy and Hydrogen Research (ZSW), there were 5.6 million EVs on the world's roads at the beginning of 2019 with China and the United States catering to the majority market shares of about 2.6 million and 1.1 million respectively. Recent market research predicts that between 2040 and 2050 there would be more than 1.0 billion EVs on road, yet in the present situation EVs are not holding off in the market due to the high cost of batteries, overcomplicated charger design and underdeveloped charging infrastructure. Hence, a need for more smart and intelligent charging process would be required. EVs comprises of vehicles that are run by lithium-ion battery packs with voltage levels of 400 to 450 V and the vehicles such as golf-cart and E-Rickshaws that run at low voltage battery packs of 48 V . This low voltage battery pack require the chargers ranging between 1.0 kW to 3.3 kW. These on-board chargers (OBC) are powered by plugging in household single phase supply mains line. The charger converts variable AC input voltage to the desired level of DC voltage and current. The OBC is induced in the EV and takes single-phase AC input (50 Hz or 60 Hz) to charge the battery. Thus, OBC desires a power factor correction (PFC) converter at the AC supply frontend to meet the harmonic limits set by the IEC standard. In addition, these chargers should have isolation to reduce the common mode noise and provide short circuit protection. These PFC converters along with isolation can be implemented easily using two-stage converters. In two-stage converter, the front-end active PFC converter is employed at first stage followed by an isolated DC-DC converter at second stage. This paper mainly focusses on active front-end PFC converter. Since OBC are mounted on the EV's, they must have higher power density, higher efficiency and lower cost which are distinctively crucial aim for the EV manufacturers. The conventional front-end converter employs diode-bridge rectifier along with a boost converter for PFC .This front-end converter is the most complex and loss part because of its high semiconductor count. As these converters are operated in continuous current conduction mode (CCM), the control of such converters requires phase-locked loop (PLL) in order to synchronize with grid. For implementation of PLL and unity power factor (UPF) operation, in total of three sensors, i.e. input current, input voltage and output voltage sensors are required. Higher sensors count not only increases the cost, but also complicates the control and reduces the converter reliability. Reference identifies that the bridge rectifiers are accountable for a sizable part of conduction losses in any frontend PFC converters. Therefore, to eliminate the diode bridge rectifiers for improved efficiency and reduced losses, bridgeless topologies are implemented. Thus, a viable option that can work as front-end AC-DC converter is the one which has the following features:

1. Accomplish PFC over scope of information voltage.
2. Keeps up low THD (under 5%).
3. Keeps up solid directed DC voltage.
4. Straightforward control and diminished number of semiconductor gadgets and sensors.

Contemplating the above features, this paper proposes a bridgeless buck-help decided PFC converter for EV charging application. The proffered converter is planned to work in\ irregular conduction mode (DCM) to achieve standard PFC for variable AC input. This action eliminates the distinguishing of data current, making converter more strong and monetarily shrewd. The converter control is especially essential with the essential of only one control circle, and a single sensor. A compact discussion on top tier available bridgeless geologies is presented.

II. BUCK CONVERTER

A buck converter (venture down converter) is a DC-to-DC power converter which steps down voltage (while venturing up current) from its information (supply) to its yield (load). It is a class of exchanged mode power supply (SMPS) ordinarily containing in any event two semiconductors (a diode and a semiconductor, albeit current buck converters habitually supplant the diode with a subsequent semiconductor utilized for coordinated correction) and at any rate one energy stockpiling component, a capacitor, inductor, or the two in mix. To lessen voltage swell, channels made of capacitors (now and then in mix with inductors) are regularly added to a particularly converter's yield (load-side channel) and information (supply-side channel).

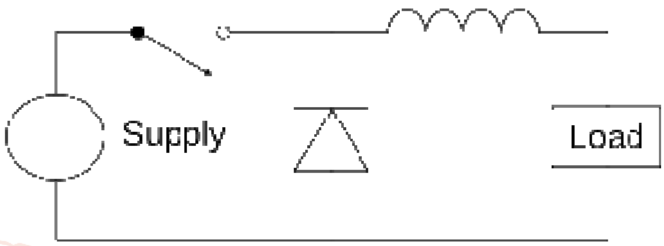

Fig.3.1: Buck converter circuit diagram.

Switching converters (such as buck converters) provide much greater power efficiency as DC-to-DC converters than linear regulators, which are simpler circuits that lower voltages by dissipating power as heat, but do not step up output current.Buck converters can be remarkably efficient (often higher than 90%), making them useful for tasks such as converting a computer's main (bulk) supply voltage (often 12V) down to lower voltages needed by USB, DRAM, the CPU (1.8V or less), etc.

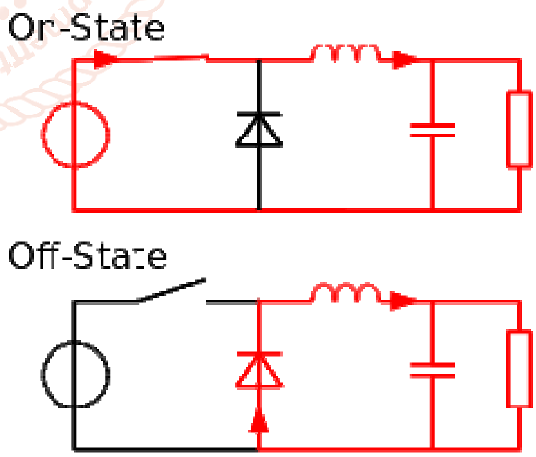

Fig.3.2 On and Off State of Buck Converter

The essential activity of the buck converter has the current in an inductor constrained by two switches (typically a semiconductor and a diode). In the romanticized converter, every one of the segments are viewed as great. In particular, the switch and the diode have zero voltage drop when on and zero current stream when off and the inductor has zero arrangement opposition. Further, it is accepted that the information and yield voltages don't change throughout a cycle (this would infer the yield capacitance as being endless).

Consistent MODE

A buck converter works in consistent mode if the current through the inductor (IL) never tumbles to zero during the substitution cycle. In this mode, the working guideline is depicted by the plots.

- When the switch presented above is shut (top of figure 2), the voltage across the inductor is VL =Vi-Vo. The current through the inductor rises straightly. As the diode is converse one-sided by the voltage source V, no current moves through it;
- When the switch is opened (lower part of figure 2), the diode is forward one-sided. The voltage across the inductor is VL = - Vo(neglecting diode drop). Current ILdecreases.

The energy put away in inductor L is

In this way, it tends to be seen that the energy put away in L increments during on schedule as ILincreases and afterward diminishes during the off-state. L is utilized to move energy from the contribution to the yield of the converter.

The pace of progress of ILcan be determined from: With VLequal to Vi-Voduring the on-state and to –Voduring the off-state. Thusly, the increment in current during the on-state is given by:

Where D is a scalar called the Duty Cycle with a worth

Conversely, the decrease in current during the off-state is given by:

$$\Delta I_{L_{off}} = \int_{t_{on}}^{T=t_{on}+t_{off}} \frac{V_L}{L}\,dt = -\frac{V_o}{L}t_{off},\ t_{off} = (1-D)T$$

If we assume that the converter operates in the steady state, the energy stored in each component at the end of a commutation cycle T is equal to that at the beginning of the cycle. That means that the current *IL*is the same at t=0 And at t=T (figure 4).

So we can write from the above equations:

$$\Delta I_{L_{on}} + \Delta I_{L_{off}} = 0$$

$$\frac{V_i - V_o}{L}t_{on} - \frac{V_o}{L}t_{off} = 0$$

The above integrations can be done graphically. In figure 4, $\Delta I_{L_{on}}$ is proportional to the area of the yellow surface, and $\Delta I_{L_{off}}$ to the area of the orange surface, as these surfaces are defined by the inductor voltage (red lines). As these surfaces are simple rectangles, their areas can be found easily: (Vi-Vo) for the yellow rectangle and $-V_o t_{off}$ for the orange one. For steady state operation, these areas must be equal.

As can be seen in figure 4, $t_{on} = DT$ and *toff* = (1 - *D*)*T*

This yields:

$$(V_i - V_o)DT - V_o(1-D)T = 0$$

$$V_o - DV_i = 0$$

$$\Rightarrow D = \frac{V_o}{V_i}$$

From this equation, it can be seen that the output voltage of the converter varies linearly with the duty cycle for a given input voltage. As the duty cycle D is equal to the ratio between *ton*and the period T, it cannot be more than 1. Therefore, Vo<=Vi. This is why this converter is referred to as step-down converter. So, for example, stepping 12 V down to 3 V (output voltage equal to one quarter of the input voltage) would require a duty cycle of 25%, in our theoretically ideal circuit.

DISCONTINUOUS MODE

We still consider that the converter operates in steady state. Therefore, the energy in the inductor is the same at the beginning and at the end of the cycle (in the case of discontinuous mode, it is zero). This means that the average value of the inductor voltage (V_L) is zero; i.e., that the area of the yellow and orange rectangles in figure 5 are the same.

$$(V_i - V_o)\,DT - V_o\delta T = 0$$

So the value of δ is:

$$\delta = \frac{V_i - V_o}{V_o}D$$

The output current delivered to the load (*Io*) is constant, as we consider that the output capacitor is large enough to maintain a constant voltage across its terminals during a commutation cycle. This implies that the Scurrent flowing through the capacitor has a zero average value. Therefore, we have :

$$\bar{I_L} = I_o$$

Where is the average value of the inductor current. As can be seen in figure 5, the inductor current waveform has a rectangular shape. Therefore, the average value of I_L can be sorted out geometrically as follow:

$$\bar{I_L} = \left(\frac{1}{2}I_{L_{max}}DT + \frac{1}{2}I_{L_{max}}\delta T\right)\frac{1}{T}$$

$$= \frac{I_{L_{max}}(D+\delta)}{2}$$

$$= I_o$$

The inductor current is zero toward the start and ascends during ton up to ILmax. That implies that ILmax is equivalent to:

Subbing the estimation of ILmax in the past condition prompts:

Also, subbing δ by the articulation given above yields:

This articulation can be reworked as:

It tends to be seen that the yield voltage of a buck converter working in irregular mode is significantly more convoluted than its partner of the consistent mode. Besides, the yield voltage is presently a capacity not just of the info voltage (Vi) and the obligation cycle D, yet in addition of the inductor esteem (L), the compensation time frame (T) and the yield current (Io).

SYNCHRONOUS RECTIFIER

A simultaneous buck converter is a changed adaptation of the fundamental buck converter circuit geography in which the diode, D, is supplanted by a subsequent switch, S2. This change is a tradeoff between expanded expense and improved productivity.

In a standard buck converter, the flyback diode turns on, all alone, soon after the switch kills, because of the rising voltage across the diode. This voltage drop across the diode brings about a force misfortune which is equivalent to

where:

- VD is the voltage drop across the diode at the heap current Io,
- D is the obligation cycle, and
- Io is the heap current.

By supplanting diode D with switch S2, which is beneficially chosen for low misfortunes, the converter productivity can be improved. For instance, a MOSFET with extremely low RDSON may be chosen for S2, giving force misfortune on switch 2 which is in the two cases, power misfortune is unequivocally reliant on the obligation cycle, D. Force misfortune on the freewheeling diode or lower switch will be corresponding to its on schedule. In this way, frameworks intended for low obligation cycle activity will experience the ill effects of higher misfortunes in the freewheeling diode or lower switch, and for such frameworks it is profitable to consider a coordinated buck converter plan.

Without genuine numbers the peruser will discover the convenience of this replacement to be hazy. Consider a PC power supply, where the info is 5 V, the yield is 3.3 V, and the heap current is 10A. For this situation, the obligation cycle will be 66% and the diode would be on for 34% of the time. An ordinary diode with forward voltage of 0.7 V would endure a force deficiency of 2.38 W. An all around chose MOSFET with RDSON of 0.015 Ω, be that as it may, would squander just 0.51 W in conduction misfortune. This means improved effectiveness and diminished warmth misfortune.

OUTPUT VOLTAGE RIPPLE

Yield voltage swell is the name given to the wonder where the yield voltage ascends during the On-state and falls during the Off-state. A few elements add to this including, however not restricted to, exchanging recurrence, yield capacitance, inductor, load and any current restricting highlights of the control hardware. At the most essential level the yield voltage will rise and fall because of the yield capacitor charging and releasing:

During the Off-express, the current in this condition is the heap current. In the On-express the current is the contrast between the switch current (or source current) and the heap current. The span of time (dT) is characterized by the obligation cycle and by the exchanging recurrence.

III. CONCULSION

A solitary stage exchanged mode bridgeless AC-DC buck boost determined converter is proposed in this paper which fill in as a possible front-end converter for on-board chargers. The proposed converter profits by diminished number of parts and number of sensors which further aides in limiting the charger cost. The converter is worked in DCM all together. A front-end Buck help PFC converter is planned and approved on a model to give the improved PQ based charger for EV battery. Because of killed line diodes and normal inductor during singular half cycle activity of BL Luo PFC converter, the misfortunes in the converter comes out to be not exactly the current DBR and Buck support PFC arrangements. Also, end of info channel just as plan of converter in DCM, further limits the size and cost of the charger with diminished number of sensors utilized in circuit. This BL converter followed by a fly back DC-DC converter, helps to charge the battery in CC and CV period of charging. The acquired test outcomes, adjust the improved PQ qualities of this EV charger, which is proficient to alleviate PQ issues existing in the regular charger.

A solitary stage exchanged mode bridgeless AC-DC buck boost derived converter is proposed in this paper which serve as a doable front-end converter for on-board chargers. The proposed converter profits by decreased number of components and number of sensors which further aides in minimizing the charger cost. The converter is worked in DC Min request

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