Nat. Volatiles & Essent. Oils, 2021; 8(2): 54-66

NVEO
Natural Volatiles & Essential Oils

Improvement Of Power Quality In ElectricVehicle Charging With Bridgeless Cuk Converter

R.PRAVEEN KUMAR[1] , Ms.B.Thamizhkani[2] , Ms.S.Kamatchi[3]

[1,2,3]DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING DHANALAKSHMI SRINIVASAN COLLEGE OF ENGINEERING AND TECHNOLOGY.

ABSTRACT

A bridgeless Cuk converter based EV (Electric Vehicle) battery charger is designed in the project. The charger designed is better than the conventional charger because it usesless number of devices due to which the conduction losses is reduced and hence, charger efficiency is increased. The flyback converter is used at the battery side which is helpful in isolating the battery as well as synchronising the battery commands during constant current and voltage mode. The proposed charger is helps in reducing the total harmonic distortion (THD) in supply current to the limits as per the IEC 61000-3-2 standard by drawing sinusoidal current from the supply. The power density of the battery is very high and the cost of the battery is low. The working of the charger is simulated in MATLAB/SIMULINK.

KEYWORD: Cuk converter, EV, Power Quality

1.INTRODUCTION

Power supplies with active power factor correction (PFC) techniques are getting necessary for several sorts of equipment to satisfy harmonic regulations and standards, like the IEC 61000-3-2. Most of the PFC rectifiers utilize a bridge converter at their front. However, a standard PFC scheme has lower efficiency due to significant losses within the diode bridge. In an attempt to maximise the facility supply efficiencyconsiderable research efforts are directed toward designing bridgeless PFC circuits, where the amount of semiconductors generating losses is reduced by essentially eliminating the complete bridge input diode rectifier bridgeless PFC rectifier allows the present to flow through a minimum number of switching devices compared to the traditional PFC rectifier. Accordingly the converter conduction losses are often significantly reduced and better efficiency are often obtained also as cost savings. Recently several bridgeless PFC rectifiers are introduced to enhance the rectifierpower density and to reduce noise emissions via soft-switching techniques or coupled magnetic topologies. On the other hand, the bridgeless boost rectifier has an equivalent major practical drawbacks because the conventional boost converter use dc supply whereas bridgeless uses ac input where arises the problem of galvanic isolation and high start-up

inrush currents. And for low-output voltage applications like telecommunication industry a converter or an isolation transformer is required to step- down the voltage. To overcome these drawbacks several bridgeless topologies which are suitable for step-up/step-down applications are recently introduced. However, the topology in still suffers from having three semiconductors within the current conduction path during each switching cycle. In a bridgeless PFC rectifier based on the single ended primary-inductance converter (SEPIC)topology is presented. Similar to the boostconverter, the SEPIC converter has the disadvantage of discontinuous output current leading to a comparatively high output ripple. A bridgeless buck PFC rectifier was recently in for step-down applications. However, the input line current cannotfollow the input voltage round the zero crossings of the input line voltage besides the output to input voltage ratio is restricted to half. Also, buck PFC converter leads to an increased total harmonic distortion (THD) and a reduced power factor. The Cuk converter offers several advantages in PFC applications like easy implementation of transformer isolation, natural protection against inrush current occurring at start-up or overload current, lower input current ripple and fewerelectromagnetic interference (EMI) related to the discontinuous conduction mode (DCM) topology. Unlike the SEPIC converter, the Cuk converter has both continuous input and output currents with a less current ripple. Thus, for applications which require a reduced current ripple at the input and output ports of the cuk converter seems to be a possible candidate within the basic convertertopologies. To obtain a price effective charging solution, the converter is chosen to work in DCM mode and voltage feedback based PWM control is employed due to the utilization of single sensor at output. To avoid the bursting phenomenon in DCM operation, the constant on-time control based PWM switching is seldom used.However, the variable duty cycle control based PWM switching is employed in converter due to the current shaping feature and retaining the advantages of DCM operation such as zero current switching.

2.BRIDGELESS CONVERTER

The topologies are formed by connecting two dc–dc Cuk converters, one forevery half-line period (T/2) of the input voltage and it is evident that there are two semiconductor(s) in the current flowing pathhence, the current stresses in the active and passive switches are further reduced and the circuit efficiency is improved compared to the traditional Cuk rectifier. In addition,that one of the output voltage bus is always connected to the input ac line through the slow-recovery diodes D_p and D_n or directly. Thus, the topologies don't suffer from thehigh common-mode EMI noise emission problem and have common-mode EMI performance almost like the traditional PFC topologies. Consequently, the topologies appear to be promising candidates for commercial PFC products. The bridgeless rectifier utilize two power switches (Q1 and Q2). However, thetwo power switches are often driven by an equivalent control signal which significantly simplifies the control circuitry. Compared to the traditional Cuk topology,the structure of the topologies utilizes one additional inductor which is usually described as an obstacle in terms of size and price. However, a far better thermal performance are often achieved with the two inductors compared to one inductor. It should be mentioned here that the three inductors within the topologies are often coupled on an equivalent core allowing considerable size and price reduction. Additionally, the “near zero-ripple-current” condition at the input or output port of the rectifier are often achieved without compromising performance. STAGE 1: This stage starts when the switch Q1 is turned ON. Diode D_p is forward

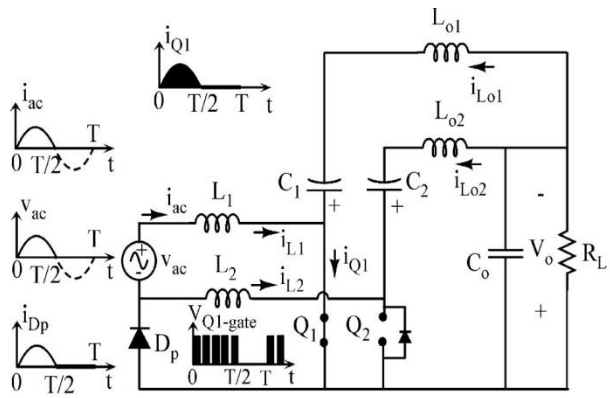
biased by the inductor current i_{L1}. As a result, the diode D_n is reverse biased by the input voltage. The output diode D_{01} is reverse biased by the reverse voltage (vac + Vo),while D_{o2} is reverse biased by the output voltage V_o. In this stage, the currents through inductors L_1 and L_{o1} increase linearly with the input voltage while the current through$L_{o\,2}$ is zero due to the constant voltage across C_2 . The inductor currents of L_1 and L_{o1} during this stage are given by

$$\frac{\mathrm{diLn}}{\mathrm{dt}} = \frac{\mathrm{Vac}}{\mathrm{Ln}} \qquad (1)$$

Accordingly, the peak current through the active switch Q_1 is given

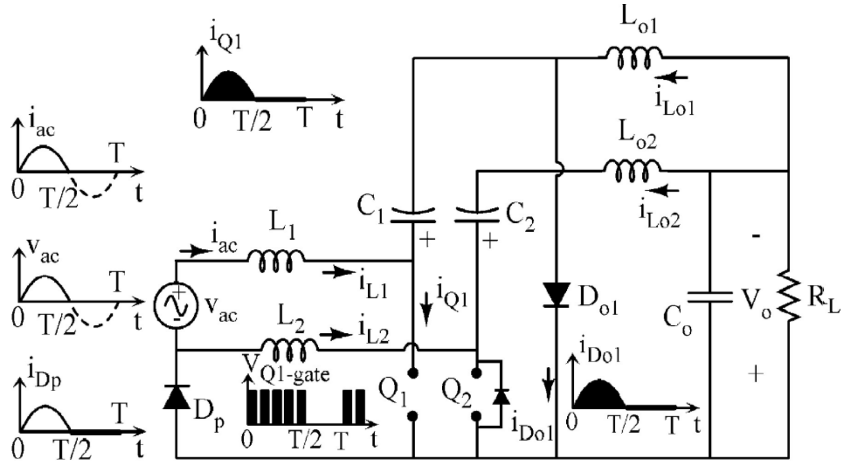
$$\mathrm{iq1} = \frac{\mathrm{Vm}}{\mathrm{Le}}\,\mathrm{D1Ts} \qquad (2)$$

where $V_m$is the peak amplitude of the input voltage V_{ac} , D_1 is the switch duty cycle,and $L_e$is the parallel combination of inductors L_1 and L_o.

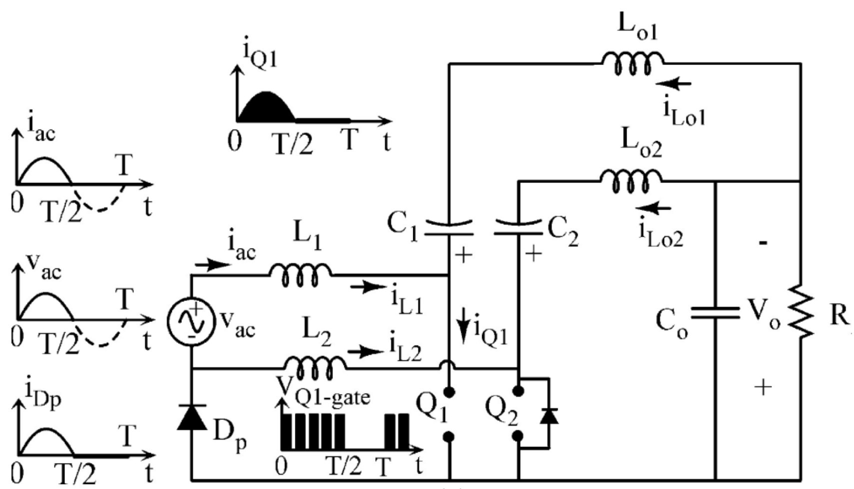


STAGE 2: This stage starts when the switch Q_1 is turned OFF and the diode D_{01} is turned ON simultaneously providing a path for the inductor currents i_{L1} and i_{L01}. The diode D_p remains conducting to provide a path for i_{L0} . Diode D_{02} remains reverse biased during this interval. This interval ends when i_{L01} reaches zero and D_{o1} becomes reverse biased. Note that the diode D_{o1} is switched OFF at zero current. Similarly, the inductor currents of L_1 and L_{o1} during this stage can be represented as follows:

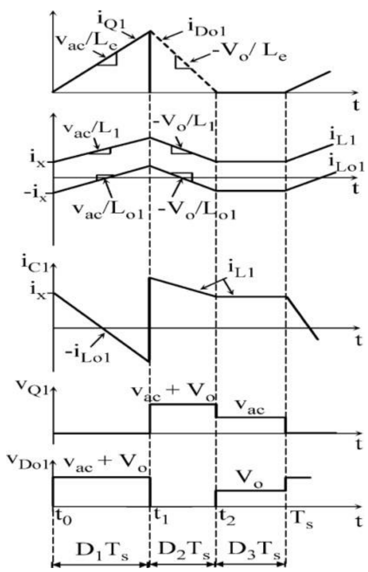
$$\frac{\mathrm{diL}}{\mathrm{dt}} = -\frac{\mathrm{Vo}}{\mathrm{Ln}} \qquad (3)$$



STAGE 3: During this interval, only the diode D_p conducts to provide a path for i_{L1}. Accordingly, the inductors in this interval behave as constant current sources. Hence, the voltage across the three inductors is zero. The capacitor C_1 is being charged by the inductor current i_{L1}. This period ends when Q_1 is turned ON.

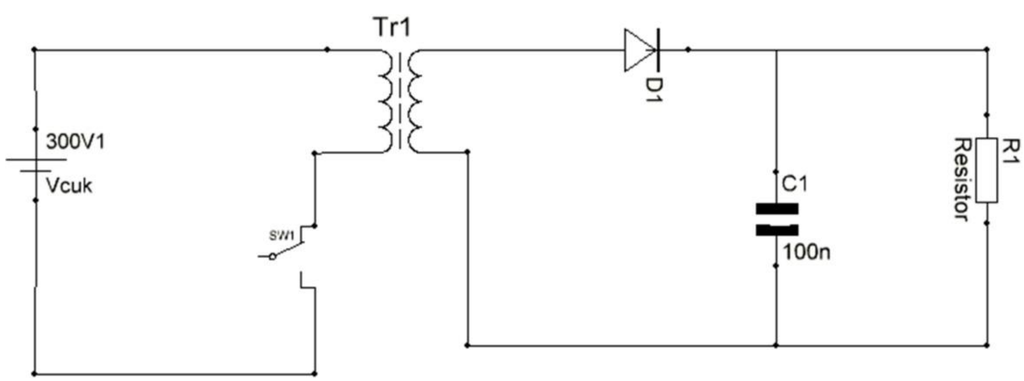


THEORETICAL WAVEFORM



3. FLYBACK CONVERTER

The operation of flyback converter is analysed on the basis of DCM of magnetizing inductance of the high frequency transformer (HFT). The current through the magnetizing inductance L_{mf} rises linearly and it stores the energy when the flyback switch S_f is made ON. The output diode D_f is reverse biased because of the dot convention of HFT, during this instant. The output power is delivered to the battery when the polarity of the HFT is reversed during turn off instant because the output diode D_f becomes forward biased. However, when the magnetizing inductance isdischarged fully during each switching cycle, then the output capacitor C_{batt} provides the specified battery charging current in CC mode.

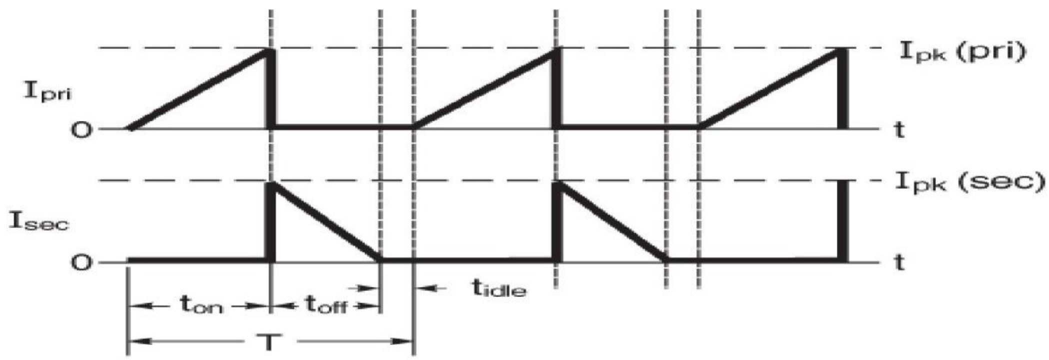


STAGE 1:

When the output from the bridgeless cuk converter which is regulated is given to the input of the flyback converter. The flyback converter has transformer core connected in series with the switch. When the switch is turned on the input supply is applied to the primary of the transformer. The magnetising inductance charges and it stores the energy. The current through the magnetizing inductance rises linearly shownin Fig.3.1. At this instant the diode is reverse biased providing the isolation from the load.

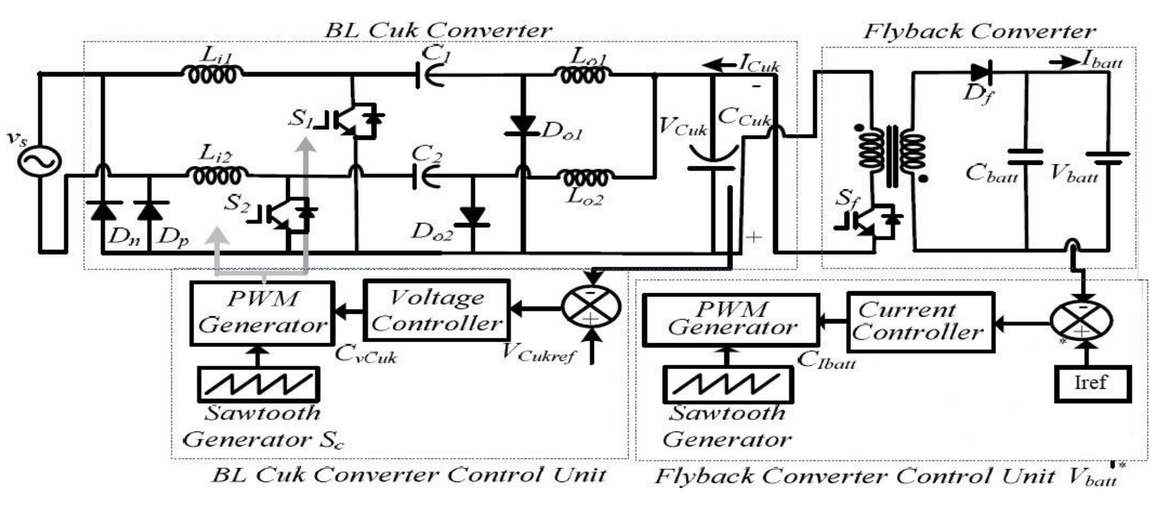
STAGE 2:

When the switch in the flyback circuit is turned off, then the polarity of the inductor changes, the energy that is stored in it is discharged to the load through diode and capacitor arrangements. The diode at the moment is forward biased and supports transfer of energy and the capacitor is used to remove away the ripples present. Here, the flyback converter mainly operates on discontinuous conduction mode so the energy which is stored is completely discharged to the load circuit and then the processof charging takes place.



4. CUK CONVERTER BASED EV CHARGER

The configuration of power quality improved EV charger is shown in Fig. 4.1 which consists of a bridgeless cuk power factor correction converter and a flyback converter. The PFC cuk converter operates for positive half cycle with switch S_1, input inductor L_{i1}, output diode D_{01} and output inductor L_{01}. Similar switching pattern is followedfor next half cycle with the switch S_2, input inductor L_{i2}, output diode D_{01} and inductor L_{02}. The DC link voltage of PFC cuk converter is maintained constant using single loop voltage feedback control, which reduces the charger cost because of the use of single voltage sensor. The flyback converter controls the current for charging in constant current mode using proportional integral (PI) controller.



4.1 CONTROL OF EV CHARGER

The DC link voltage of cuk converter is maintained constant by using voltagefeedback control, which reduces the charger cost by using single voltage sensor. The governing equations for error and control signal at nth sampling instant voltage which is the difference of reference and actual voltage expressed as,

$$V_{cuk}(n+1) = V_{cukref}(n) - V_{cuk}(n) \quad (1)$$

The gate pulse to cuk converter switches $S_{1,2}$ are obtained, after comparing the control signal Cvcuk to a sawtooth carrier waveform $S_c$with high frequency, such as for $V_S>0$;or $V_S<0$; if $S_C < C_{vcuk}$ then $S_{1,2} = 1$

$$S_C < C_{vcuk} \text{ then } S_{1,2} = 0$$

where, S_c represents the switching pulses of the bridgeless cuk converter. The requiredinherent PFC and regulated DC-link voltage are achieved by controlling the duty cyclesuch that the controller operates satisfactorily over wide mains voltage range.

The flyback converter is controlled to attain constant current which helps in charging the battery. The governing equations of the control and error signals for current is obtained by taking the difference of reference and actual current are givenby,

$$V_{batte}(n+1) = V^{*}_{batt}(n) - V_{batt}(n) \quad (2)$$

These control signals are passed through PWM comparator to generate the required duty cycle to maintain UPF in ac mains during battery charging in CC mode for steadystate as well as sudden variations. In bridgeless converter the output voltage has to be regulated at a particular voltage irrespective of the load and duty cycle. The voltage which is to be regulated is based on the application which we decide to work. We needa voltage sensor to detect the output voltage along with the reference voltage given to the controller. PI controller is specifically used to control the transients in the output voltage and also it reduces the steady state error that occurs.

The controller in these project for voltage regulation uses the value of k_p=1, k_I=10 and V_{ref}= 300V. In flyback operation, the battery is charged in constant current mode in which the current is maintained constant irrespective of load and input voltage.

Current sensor is used to detect the output current from the flyback converter and it is given to the controller along with reference current. The PI value of the controller in these loop is k_P=1, k_I=60.

Both the regulated output voltage and constant output current for battery operationis obtained.

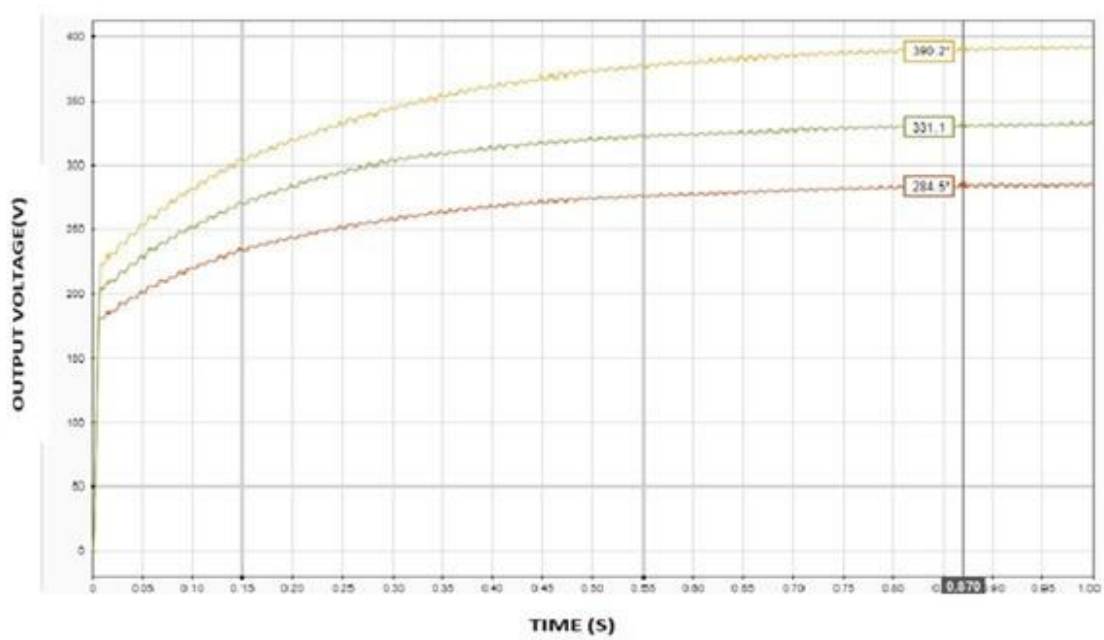
5.DESIGN SPECIFICATIONS

Using the output voltage V_{cuk} and peak input voltage, V_{peak} of PFC cuk converter,The voltage conversion ratio, is given as,

5.1 **SIMULATION RESULTS**

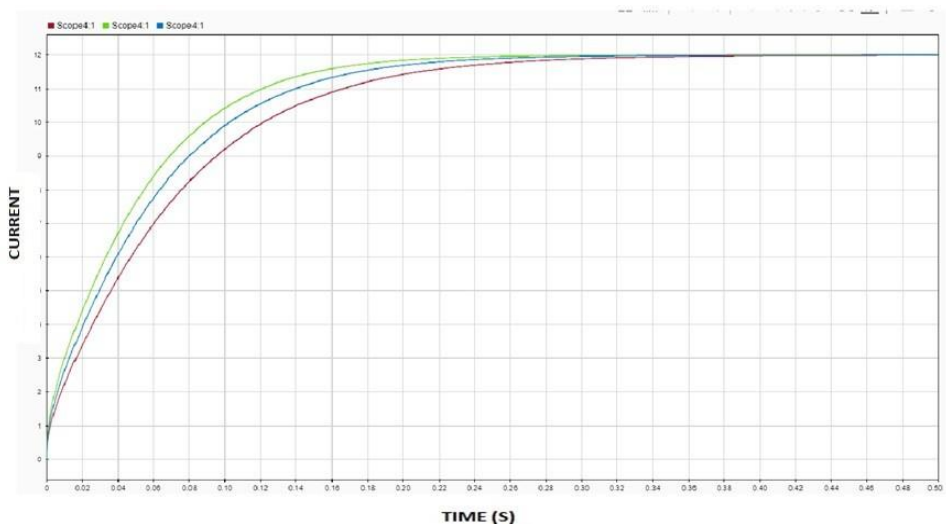
The Output voltage of the cuk converter is varied by varying the duty cycle.

INPUT VOLTAGE (V)	DUTY CYCLE	SIMULATION VOLTGE(V)
220	0.3	284.6
220	0.35	332.3
220	0.4	391.3

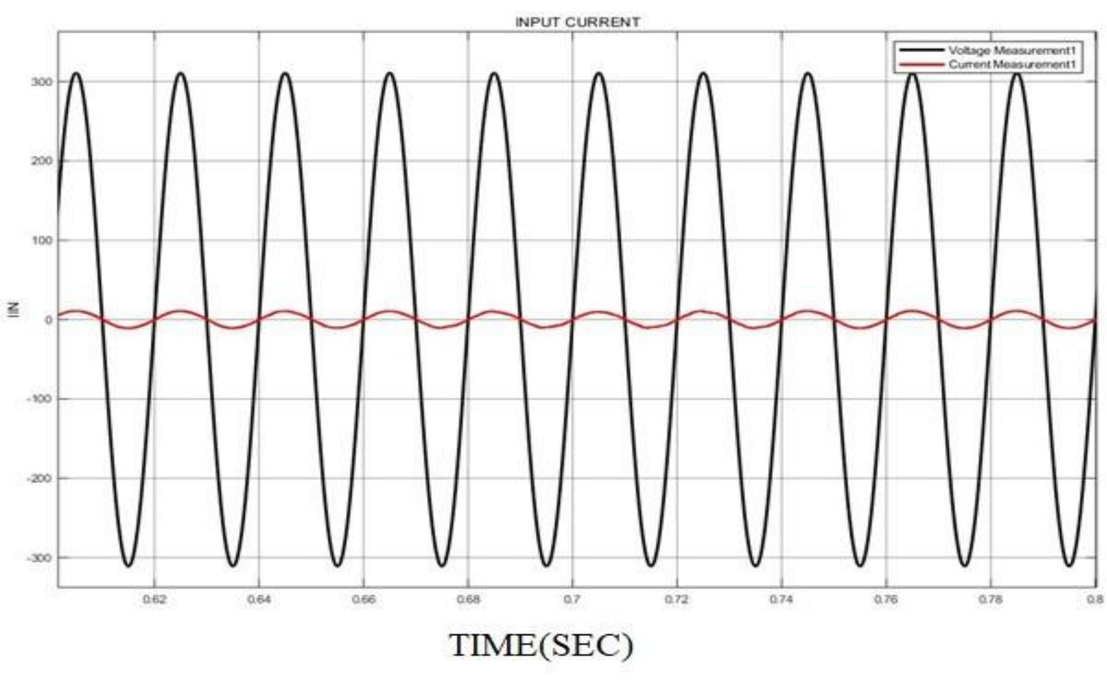


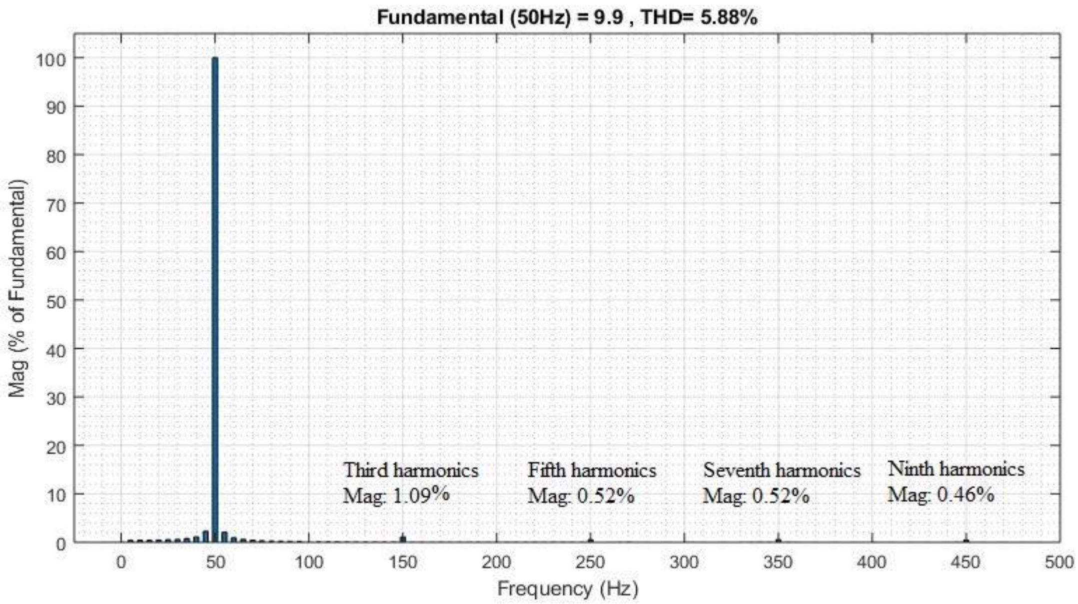
Simulation of EV charger in constant current control with disturbance.

INPUT VOLTAGE(Vrms)	OUTPUT VOLTAGE(V)	OUTPUT CURRENT(A)
250	59.8	12
300	59.9	12
350	60	12



5.2 THD ANALYSIS OF SUPPLY CURRENT





6.**HARDWARE IMLEMENTATION**

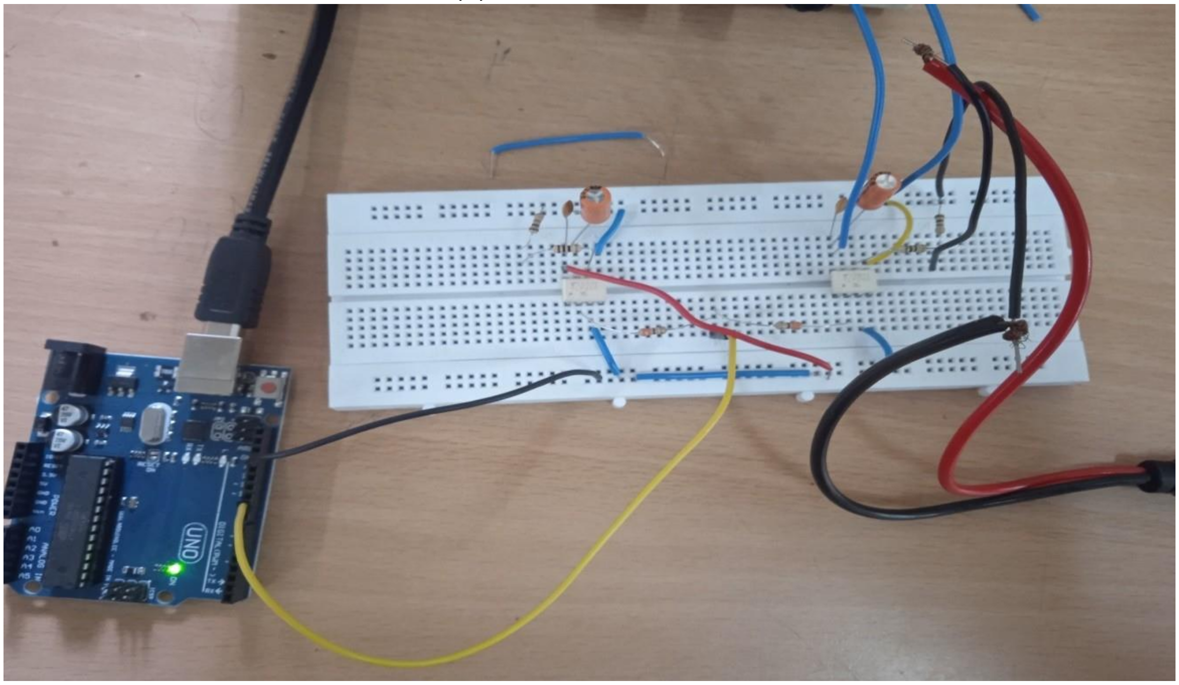
Hardware outputs

The followings are the outputs that has been observed on the course. The Arduino UNO output pins are given as a input to the gate driver circuit. Specifically the 9th pin and the 10th pin the Arduino is designated as output pins through Arduino code and these pins are given to the 2nd pin of TLP250.

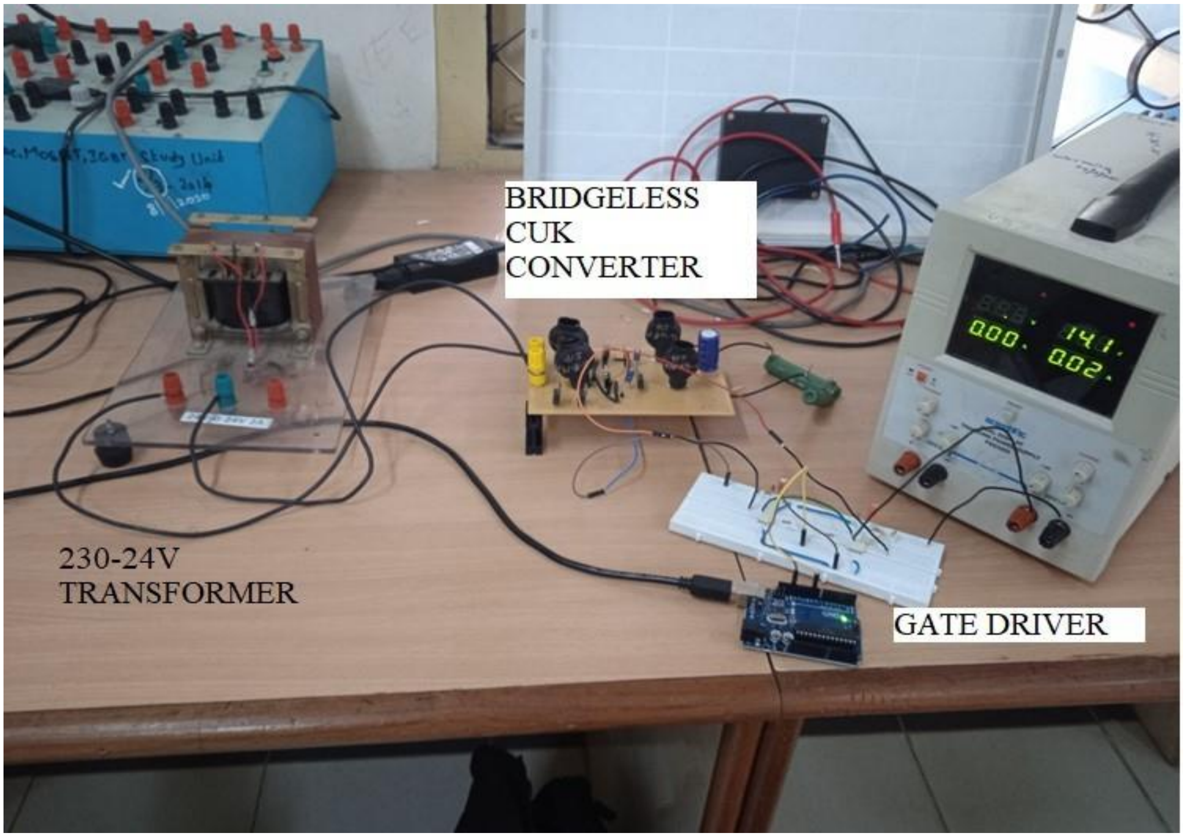
The output from the TLP250 is taken at the 8th pin and given to the gateterminal of the Mosfet.

The pwm pulses at the end of the IC is viewed through CRO to ensure Mosfet is triggered properly. The pulses given to the Mosfet is of 50% duty cycle and the switching frequency is 20KHZ. The 20KHZ switching frequency is generatedin Arduino with the inbuild Timer available in it.

PROJECT SETUP


UNO


15.0
0.00
0.01
DUAL DISPLAY
TRACKING POWER SUPPLY
PSD3205
A : 30V/3A
B : 30V/3A



INFERENCE

This project is mainly focused on improving the quality and increasing theefficiency of electric vehicle charging. The main inference from the project is that replacing the Bridge rectifier into Bridgeless configuration helps in improving all the aspects of charging and also the use of flyback converter helps in gaining a wide rangeof control so we can use it in wide applications.

The analysis of the THD of the supply current is done and the parameters of the bridgeless cuk and the flyback converter is studied for various condition and also the Inductor and capacitor values are calculated.

7. **CONFERENCE**

1. Fardoun, E. H. Ismail, A. J. Sabzali and M. A. Al-Saffar, "New EfficientBridgeless Cuk Rectifiers for PFC Applications," IEEE Transaction on Power Electronics, vol. 27, no. 7, pp. 3292- 3301, July 2012.
2. K. Yao, X. Ruan, X. Mao and Z. Ye, "Variable-Duty-Cycle Control to Achieve High Input Power Factor for DCM Boost PFC Converter," IEEE Transaction onIndustrial Electronic, vol. 58, no. 5, pp. 1856-1865, May 2011.
3. Bhim singh, Radha "A Power Quality Improved EV Charger With Bridgeless Converter." IEEE Transaction on Power electronics, May 2018.
4. Limits for Harmonics Current Emissions (Equipment current ≤ 16Aper Phase),

International standards IEC 61000-3-2, 2000.