A Study of Power Factor Improvement in Electrical Vehicle Applications

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Abstract

The main aim of this study the A front-end AC-DC PFC converter is used to convert grid AC voltage into DC voltage to charge the EV battery. A unidirectional AC-DC converter consists of a diode rectifier with PFC circuit. This kind of AC-DC converter enables the power flow only from the grid to EV charger. However, the bidirectional type ACDC converter or inverter will be used if the EV battery is meant to release power into the grid for vehicle to grid operation. Higher switching frequencies aren't utilized in power converters since they're proportional to the switching losses. By applying ZVS and ZCS soft switching strategies this particular effort helps to utilize higher switching frequency for the AC DC PFC power converter of EVs with little switching losses. The soft switching of AC DC converters reduces the switching losses, reduces switching stresses and hence improves the vii efficiency of the battery charged vehicle system. In order to enhance the performance as well as reliability of AC DC PFC converters, soft switching methods are actually applied by means of the unique snubber circuits.The enhancement of total charger effectiveness is a lot essential for the growth as well as recognition of the vehicular technologies, since as the charging efficiency goes up, the charge time as well as electric price decline. Because of insufficient area of cars as well as the increasing power usage, chargers have to supply much more power keeping the size of theirs as little it can be. As a major component of a charging system, the front end AC DC converter must recognize less input current harmonics, PFC, output voltage regulation, higher efficiency and higher power density.With this work, many snubber circuits for the front end AC DC PFC converter of EV charging is actually examined as well as proposed. A comprehensive systematic item for these converter topologies is actually produced, facilitating the estimation of power losses as well as efficiency. Experimental outcomes and the simulation of the front end AC DC boost converter with a regulated DC voltage of 400 V from common AC input voltage of 230 V at 1.5 KW are actually reported in this specific thesis to evaluate the effectiveness of theirs in phrases of Total Harmonic Distortion (THD), PF, switching efficiency and losses.

Keywords: *Power Factor Improvement, Electrical Vehical Applications, AC-DC PFC converter, AC-DC converter*

1. INTRODUCTION

A DC-DC converter with common voltage input comprises of a boost converter for PFC during the two-step converters for battery charging of electric vehicle. This two-step conversions conduct to increased component count and poor efficiency, A Bridgeless (BL) Cuk converter based Electric Vehicle (EV) battery charging with great power quality, maximum efficiency is developed and implemented. By eliminating DBR, to reduce the additional conduction losses and this charger absorb a minimum number of devices running over period of one switch. Hence, it is increasing the charger's efficiency. To keep the desired charger current throughout the battery followed by the CC & CV charger regions, the instructions are synchronized by a flyback converter.

To improve efficiency, high stage down gain, less current stress, and power electronics component count is minimized in PFC converter based a single-step switched inductor Cuk converter is applied in this scheme. The design equation, operational analysis for different items of cuk converter are follow up in Continuous Current Mode (CCM) using a multiplier approach of current that has been presented concerning power quality sign like voltage THD and current THD. The DCM of action in BL cuk PFC converter is designed, control of voltage follower mode is used, it is developed using PI controller no circulating current succeeding through the inductor inputs. Due to cascaded dual PI controller, converter of fly back is controlled and output of controller to supply CC charging to the each operating condition of battery. Completely charged the battery in CV mode at the end area of all period and the drawn source of current is cut down to completely charged condition of battery depicting value is less.

The battery charging/discharging conduct to attain power and load leveling together with increase in system reliability. To encourage a uninterrupted power to the grid, hence increasing the possibility of the Battery Energy Storage (BES) hold up to the system, converter of voltage source perform as an active power filter and carry out the mitigation of harmonics with compensation of reactive power, a special control is expanded due to mitigation of failure, grid to be reconnected. To keep an uninterrupted power supply to the load with help of Phase-Locked Loop (PLL), maintaining the power balance, and increases the battery lifespan through the attainment of the operation of the system. The switches are controlled in zero crossing voltage and current. Solar Photovoltaic Standalone Voltage Control (SPV-SVC) is obtained to maintain an endless power to the loads. Instantaneous quantities of proportional – Integral and load current is taken out appling adaptive filtering along with the LMS algorithms.

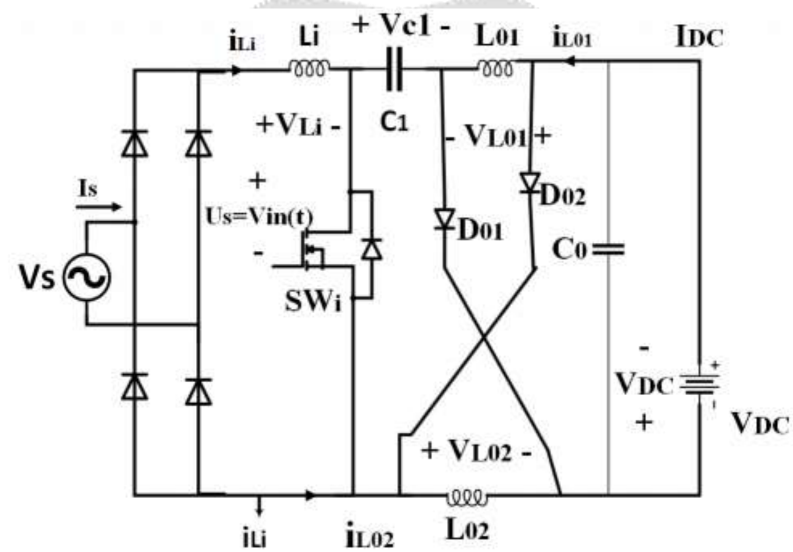

Figure 1: Circuit diagram of Switched inductor Cuk converter.

The DCM, due to voltage follower approach, the scheme of control is minimized by need of sensor and converter of output voltage is sensed by quantity. BL cuk converter based charger extract a sinusoidal current from the ac main and THD in the current of supply is minimized. Undesired conduction by the diode body of the idle switch in the earlier on advanced converter of BL cuk is ignored, also unpopular coupling of capacitive loop is erased and minimize the number of components count over one switching period. This significantly increases the efficiency of charger's. To reduce voltage stress and low output voltage on devices, a transformer may be need, which is more prices, mainly if galvanic isolation is not needed. Cuk converter by dividing inductor into two equal inductors and rectifier diode into two diodes here frequency of supply line is lower than the frequency of switch. The total power factor is follow out with different methods of battery load and resistive load in one and the other CC and CV mode.

PFC converter is successfully developed; the following assumptions are creating. Circuit diagram of switched inductor Cuk converter show in fig.5 As a result, large voltage ripples in the intermediate capacitor, current stress in switch, and voltages of the battery are notice to develop during this cycle. And also to reduced conduction losses, switching losses, diode conduction losses, and input inductor losses and increased efficiency can be noted. This topology consists of two converters, first-step cuk converter for PFC by working in the converter of LLC resonant, while the CCM of the primary inductor and the second stage the CVM and CCM control algorithms are operated for essential charging of EV battery. To minimize the turn off losses in LLC converter, the converter employ a control algorithm of frequency to actively change the dclink voltage based on the state of the battery. The benefit of cuk converter of the control algorithm based LLC resonant and phase-shifted zero voltage switching converters are presented used for high power fast charger. As result, the input current of harmonic free is realized by pulse width modulation (PWM) control of the cuk converter utilizing a two-loop design, neglecting any battery charging risk by use of LLC controller, to minimise turn off losses & switching losses, less LLC transformer flux density and then to increase efficiency.

Boost DC-DC Converter

Generally, the stress of voltage is minimized in the half of the voltage input, the absolute value of voltage gain is 1/(1-d),power inductor and switches are less than those of the more voltage gain in two-step cascaded and three-level boost DC-DC converter, but it's the result of the efficiency of all step ,more voltage stress in output step. A maximum voltage gain but stress of voltage beyond the power electronic switch is similar to the voltage output in an inductor of switched DC-DC boost converter. The single switch with diode capacitor units boost DC-DC converter is a easy structure, the principles of operation, the enlarge step, converter steady state characteristics and operation of fault tolerant are analyzed and given and also small-signal sample is derived. The converter is operated at the state-space average mode; the capacitor is charged in parallel and discharged in series. Due to voltage loop control PWM and Proportional –Integral (PI) voltage controllers are adopted in this converter, which provides less voltage stress, less switching losses and voltage gain is more.

2. METHODS OF CHARGING/DISCHARGING SYSTEMS

For Electric Vehicle (EV) applications charging/discharging are generally classified into 4 headings. All of the above mentioned methods have been discussed in the following sub-segments. An inductive charging/discharging system is one of a non- integrated design system, where one scrap of the system is assigned over on-board of the electric vehicle and further scrap over the off-board of the EVs.

1. On-board and off-board charging/discharging

Accommodation to charging/discharging the vehicle in on-board systems, wherever an electric power is available at outlet, as well the EV battery voltages match from an onboard system. The voltage from grid is normally constant, whereas the voltage of battery is not and it differs from V2V. The onboard systems are specifically fabricated by EV construct for all vehicles in order to meet the particular voltage need of the grid and battery. The same doesn't suits with off-board systems that are developed in order to keep a large collection of battery voltages. However, design parameters and schematic diagram of the on- board charger/discharger system. Fast charging/discharging is achieved by a current focus, which request maximum power heavy converter system and battery profile shown. It can be concluded that the EV operation should incur the cost of both charging / discharging but its reduced switching and conduction losses increase the efficiency of the system due to low diode conduction losses.

2. Integrated and Non-Integrated charging / discharging

In a non-integrated method of charging/discharging, the system drive is free of the charger/discharger, this demands a committed converter system to look after the charging/discharging of the EV battery. A Non-integrated type is preferred for charging/discharging of the system. However, if grid to vehicle and verse visa operation and tracking are shown.

Such an integrated charger/discharger is called an on-board system. An integrated system minimizes the voltage and current stress, conduction losses of an inductor, neglect the sub-harmonic oscillation in voltage output unexpected load changes, and the effect of thermal ageing is been eliminated. Some other integrated charging/discharging systems has been discussed that use an on-board three-phase full-bridge BADC for propulsion as well as to the regenerative braking and the three-phase permanent magnet synchronous motor windings to promote the power flow in both directions. To better power quality an isolated LLC resonant of cuk converters for an Electric Vehicle Battery Charger (EVBC) is planned definitely to charging a small Electric Vehicle (EV). The technique contain a two converters comprising of the first step cuk converter for PFC by operating in the LLC resonant converter, while the CCM of the primary inductor and the second stage the CVM and CCM control algorithms. To minimize the turn off losses in LLC converter switching devices, the converter make use of a frequency control algorithm to sincerely vary the in-between dc-link voltage based upon the state of the battery. The lead- acid batteries are charged by the C/10 ratio due to the battery thermal characteristics the keep up charging time limits their time of EV driving and but lithium batteries solve these issues under fast charging time (C/5,1C) minimum charging duration with travel long distance.

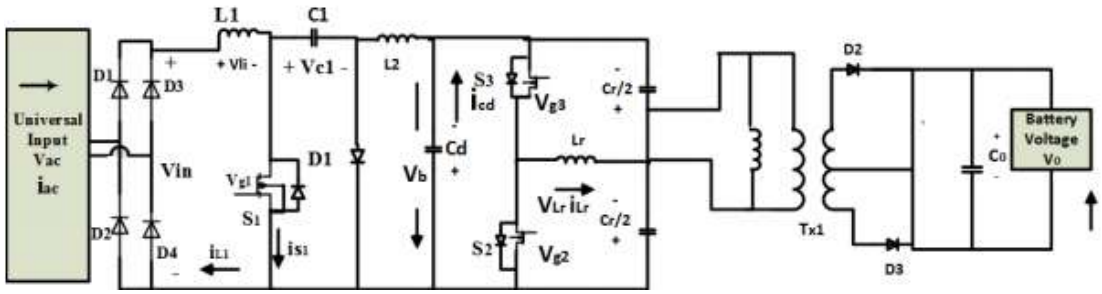

Figure 2: Configuration of PFC-Cuk converter fed isolated HB-LLC converter.

The benefit control algorithm of the cuk converter based LLC resonant and phase- shifted zero voltage switching converters are presented in used for high power fast charger. As result, the input current harmonic less is achieved by Pulse Width Modulation (PWM) a two loop structure of cuk converter is controlled, neglecting any battery charging risk by use of LLC controller to reduce turn off & switching losses, with less flux density of the LLC transformer and then to increase efficiency. Configuration of the PFC-Cuk converter fed isolated HB-LLC converter is shown.The On-Board Charger (OBC) supplies ZVS of each switches and minimize the reverse recovery problems by ZCS of the diode outputs. Two interleaved cells sharing a full-bridge diode rectifier for OBC, all cells are composed of a series resonant and active clamp circuits. The interleaved technique helps to keep the actual power quantity with maximum efficiency and the control algorithm permit power quality by the OBC without need of auxiliary circuit and the current input is balanced in between the two cells and also converter make sure compact size, a long lifetime and need no electrolytic dc-link capacitor. For low power application (less than 1kW) single stage topologies are applied. Single-stage, single cell OBC is shown, the control algorithms and development of a soft-switching single-stage converter, and then OBC transformer transforms the ac voltage input into the desired dc-voltage output in a single stage is presented, to achieve desired power factor and maximum efficiency. This converter is comprises of full bridge diode rectifier, along with a maximum-frequency DC-DC converter combined with a full-bridge series resonant circuit and an active clamp circuit. The main advantages of this converter is absorbed, the simple structure and maximum efficiency was conferred by soft switching of all elements. Moreover, to enable sharing power distribution between the interleaved cells, there needs an auxiliary PFC circuit. To achieve unity power factor at ac mains, a PFC step up converter based half-bridge LLC resonant converter which utilizes as a front end converter is operated in CICM for Electric Vehicle Battery Charging (EVBC) application.

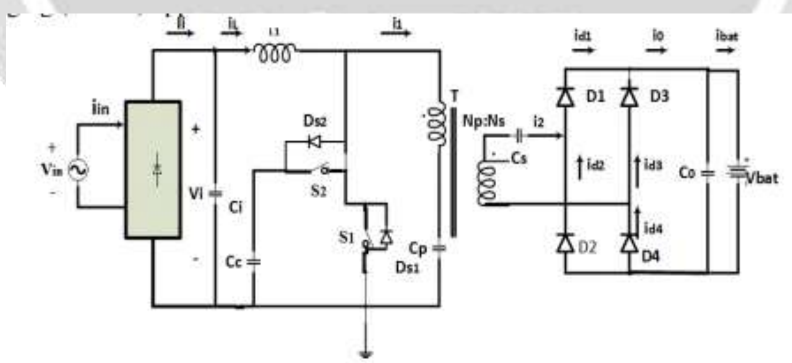

Figure 3: Single-stage, single cell OBC

LLC converter uses a Pulse Frequency Modulation (PFM), whereas a step up converter is works in PWM technique at a constant frequency to keep the power delivered to the battery. To measure the low value of inductor current, boost inductor that works in CCM and Average Current Mode (ACM) control is operated for less power loss.PFC boost converter is developed below CICM mode using ACM control at a desired switching frequency is described. A smooth rectified sine template even below the poor voltage quality control for the current generation is obtained in the phase-locked loop technique. DC link voltage is sensed by a less-cost possible divider that forms supply a reference current for inner current loop and outer voltage control loop. As a result, less ripple current throughout the inductor less the stress of current in semiconductor, high efficiency, and reduced charging time with less-cost developed power quality EVBC. An Asymmetrical Pulse Width Modulation (APWM) technique is used for controlling the output voltage and foremost switches, resulting in maximum efficiency. The design and implementation of the controller and control technique are introduced, which minimize the switching current stress , as well as the conduction losses and the circulating losses during the freewheeling session compared with the auxiliary inductor current is controlled by use of conventional phase shift modulation method, so that can increase the system efficiency.

In full-bridge DC-DC converter topology, maximum power density, high reliability of the system, and isolation ability A bidirectional DC-DC converter of switched-capacitor is shown, reduces the number of component count, and gets a large range of voltage gain along with less stress of voltage and a common ground. Additionally the synchronous rectifier permits to achieve ZVS turn on and turns off without need anyone additional hardware and converter efficiency is better. As a Hybrid Energy Source System (HESS) is a combination of a super capacitor and battery, an electric vehicle is considered as the best way to increase the battery life and overall efficiency of the vehicle. For maximum power density, greater cycle life and high efficiency, the super capacitor with the high voltage dc bus which keep away from any change in step in current from the battery is used. Regenerative braking and acceleration of supply power with the battery meets the requirements for long-range operation of energy storage density.

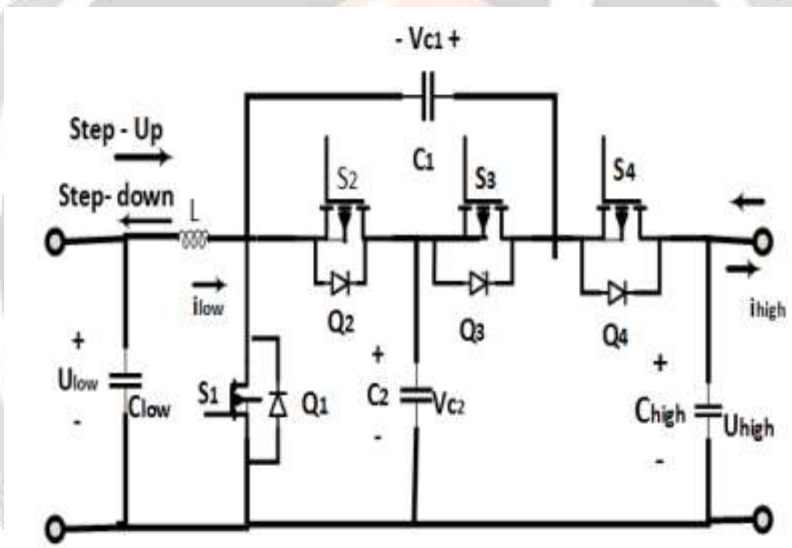

Figure 4: A bidirectional DC-DC converter of switched-capacitor

As a result, a very easy circuit of minimized number of components count of greater voltage gain, a less stress of voltage, and a common ground, but conduction and switching losses are high. A switched inductor-capacitor, coupled inductor, Walton multiplier, boosts converters with greater voltage gain ability as the non-isolated DC-DC power conversion step for Photovoltaic to applications of grid. Successfully, DC-DC boost converter helps the Photovoltaic (PV) voltage to reach the maximum-performance level, but they are not suggested for EV applications since they need a mandatory galvanic isolation in the middle of the PV panel and the greater voltage battery store. These proposed converters prosperous handle the PV voltage variations and MPPT demands to respond to the different battery charging state, but it doesn't address the pair of input and output variations simultaneously. From complete discharged condition to the charged floating voltage phase, the charger must operate in CVM and CCM or constant power modes based on the battery charge state. A schematic structure of full-bridge L3C resonant converter with capacitive output filter is shown, applicable for PV to more-voltage battery applications. The challenge of the converter is to combine both variables PV input voltage and an energy system utmost voltage gain variations from input to output at different current and voltage quantities. A high-efficiency fourth-order L3C resonant converter has been presented. Resonant converter all the time operates in ZVS for different load control and has less noise output voltage. L3C converters not only come up with protect the full-bridge inverter form over current and short circuit control but also charging the battery pack at constant current.

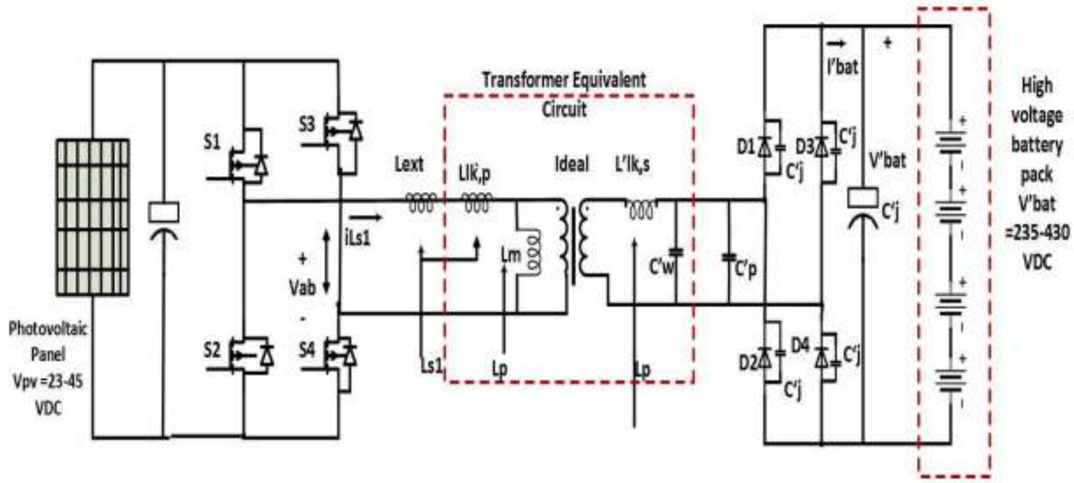

Figure 5: A schematic diagram of L3C resonant converter of full bridge function with capacitive output filter

To neglect the maximum voltage constructed by the reverse recovery current of diodes and to drop the noise level in the receiving end voltage, a function of rectifier diode output in a Zero Current Switching (ZCS). In order to charge the Li iron battery at a lesser price with an extended time of charge without lesser the life and allowed maximum current charger with the help of constant voltage and constant current mode. As a result, show the high-quality voltage output, the output current is limited, during the CCM a battery current is controlled, over current protection, maximize the converter efficiency, and during light loading conditions a converter efficiency is reduced and it's having more conduction losses. Fig.6 shows the Single-step, two-way AC/DC converters topology for OBC, the output voltage always great or less than the input voltage, and smooth transitions between the modes are operated in CCM and performance of the converter is expressed.

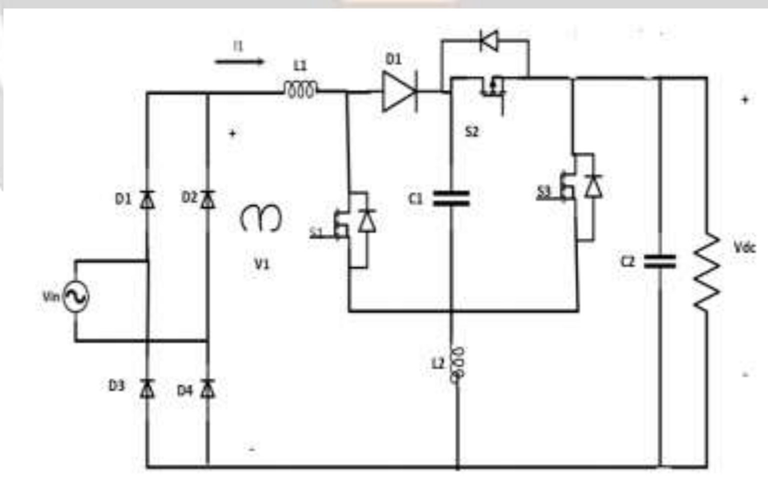

Figure 6: Single-step, two- way AC/DC converters topology for OBC

3. Inductive / conductive charger / discharger

Conductive charging/discharging systems are any one integrated or non-integrated systems and apply a direct conductive approach, normally a cable with Z connector to permit power flow in the middle of the grid and the EV. Such systems can supply a fast charging station to the EV. However flexibility and convenience is compromised since the EV has to plug in the wire all time. Inductive charging/discharging systems are all the time non- integrated method, where the pick-up side is placed on-board the EV and the primary side off-board the EV.

Uneven in between the primary and pick-up side inductive plan of action is the major of the problem of the inductive charging/discharging. Which small change the magnetic coupling between each sides leads to power transfer level and variable resonant frequency. When power is transferred inductively, perceptive configuration is important. As a result of bidirectional power flow, when the pick-up side LCL network of every one Electric Vehicle is tuned to the frequency of the track current and the load side converters are employed either in rectification or inverting method depending on the regulation of the power flow. A fallback phase angle solution in power flow from the source to load side, while leading phase angle outcomes in power flow load to the source side. The direction of power flow depends on the corresponding phase angle and magnitude between the voltages at primary to load side. A phase modulated square wave voltage is generated from a PI controller and a triangular wave is generated at source or load side control system. The output voltage and current harmonics are reduced with the help of the LCL network.

3. FRONT-END CONVERTER DESIGN FOR THE ON-BOARD CHARGER IN ELECTRIC VEHICLES

Two significant difficulties human progress is confronting these days are energy and climate. These days, energy costs have additionally been rising and general assessment on ecological insurance is expanding. Rules and guidelines have likewise gotten thorough, "discharge decrease" and "energy is saving” has become significant veritable issue. Henceforth, utilization of new innovation to lessen energy utilization and decrease has become a significant bearing in the improvement of the car business, and electric vehicle has become an appealing answer for energy saving and decrease in discharge. EV is ascribed in two straightforward focuses as: EV takes care of the issue of ecological contamination. Also, EV assists with disposing of dependence on oil assets. Electric vehicles contain footing batteries, whose voltages are regularly around 300-400V. The engineering of EV is appeared in Fig. 7. The way toward charging the EV alludes to the electronic correspondence between the EV battery and the matrix power supply. The reason for existing is to abstain from over-burdening and to affirm security. There are different sorts of energy stockpiling frameworks (batteries). Li-particle batteries have most noteworthy energy thickness and low self-releasing rate, contrasted with different batteries, and henceforth, has a possible world market.

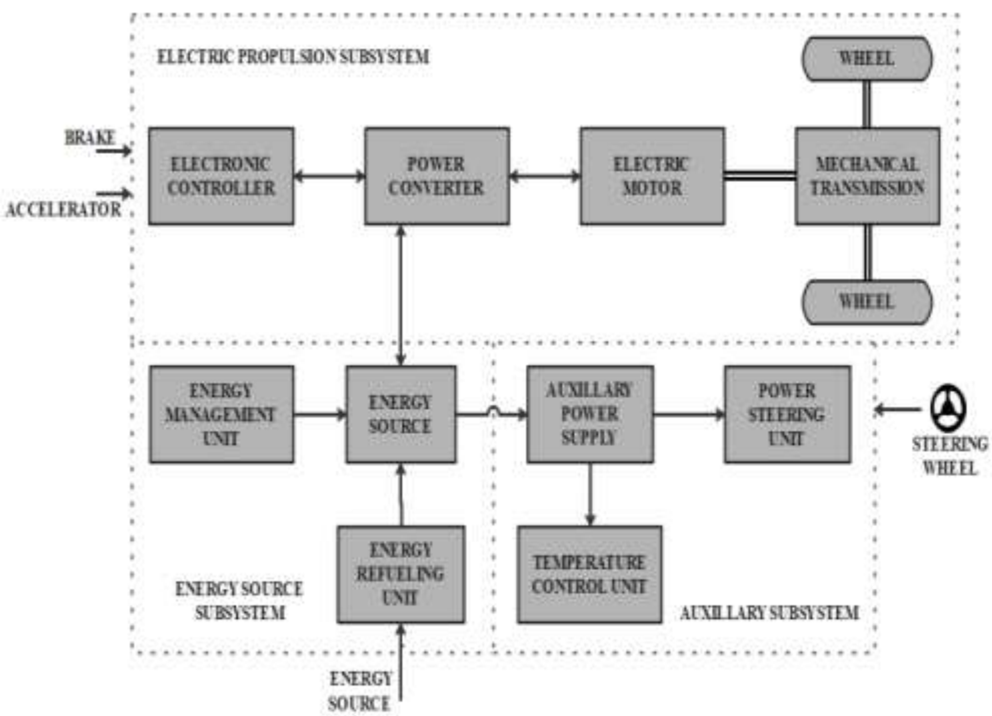

Figure 7: General Architecture of EV

Lion stockpiling cell is by and large useful in EVs due to their light weight. EVs use framework supply to charge the batteries. OBC's permit clients to charge their EV batteries any place there is an accessibility of electric power channel. The EV battery is charged just when the vehicle is at halt, aside from recovery at decelerating, in this way, utilizing the on-board foothold framework segments to shape a bound together charging gadget is made conceivable.

4. POWER FACTOR CORRECTION CONVERTER CONTROL OF AN EV ON-BOARD CHARGER FOR V2G APPLICATION

As the danger of a worldwide temperature alteration and the compulsory decrease of ozone harming substances, Electric Vehicle (EV) that can accomplish zero discharges assumes a significant job to the eventual fate of the human existence. The EV powered by battery-powered battery pulls in more consideration comparative with the EVs with the distinctive power sources since the overall development of the innovation. The lithiumion batteries that have the most noteworthy energy thickness among the battery-powered batteries have been broadly applied in existing marketed EVs. Be that as it may, one completely energized lithium-particle battery pack on every EV can scarcely give a reach under 160 km, for example Nissan Leaf. That implies it must be revived oftentimes in excess of an inner burning motor vehicle refuels. Hence, the charging wellbeing and foundation are essential to the acknowledgment of the EVs.

There are two techniques to charge the locally available battery, for example conductive or inductive charging. The previous one has higher ampacity and higher productivity of power transmission. Despite what might be expected, the last one could give more secure and adaptable power association. Despite the fact that everyone has its own dominants on the charging rate, foundation arrangement, and activity accommodation, the conductive charging has been generally applied on the EV market because of the straightforwardness of association interface and ease of unification. For example, the worldwide principles SAE J1772 and CHAdeMO characterize the correspondence convention and couplers for the AC and DC conductive charging, individually. To apply the AC charging, there will be a locally available charger to make AC/DC correction and charging current guideline. Its plan will think about the nature of power factor, solidness of energy conveyance, and security of charging measure. To accomplish this, few competitor geographies for the locally available charger are proposed. Besides, the determination rules of power stage geographies with the contemplations of charger proficiency and Power Factor Correction (PFC) is given. It is noticed that the PFC support converter as a functioning front power stage followed by a disengaged DC/DC converter is well known and pertinent joining for the EV battery charging application. In such a framework, the lift PFC converter manages AC input current to be relative to and in stage with the info voltage waveform. Likewise the yield is controlled to follow the voltage reference. There are a few geographies can be picked for the plan of the lift PFC converters. To accomplish the PFC viability, the regulator plan and systems are proposed in existing literary works.

Lately, the Vehicle-to-Grid (V2G) that portrays an idea to shrewdly control the electricity stream among EV and its associated framework has been acquainted with the plan and of EV charging framework and the administration of savvy brace. Such thought can give the value of burden balance in order to alleviate the interest on pinnacle power and office extension. To this end, the charging framework for the EVs will bidirectionally charge or release the battery electricity through shrewd administration. In like manner, a few issues identified with the impact of responsive power move and the savvy charging techniques are talked about. Indeed, even the current lift PFC converters perform well for EV battery charging, they can't be applied to the V2G lattice clear for the unidirectional impediment. This paper proposes a bidirectional lift PFC converter dependent on bridgeless interleaved help geography. The proposed converter has similar highlights of the bridgeless interleaved support PFC converter while dealing with the charging cycle and takes the battery DC power back to the brace by utilizing extra phase shift control on the changed geography.

5. CONCLUSION

It proposes four inactive snubber circuits for AC-DC PFC help converters. The proposed 2L-C-D (ZCS) inactive snubber has a high input current THD. The L-2C-3D (ZC-ZVS) inactive snubber reduced the input current THD. Anyway it has expanded the peak voltage stress on the main switch and peak current stress on the main diode. The 2L-C-D (ZC-ZVS) latent snubber has expanded the peak current stress on the main diode however it reduced the other peak stresses on different semiconductor components with an efficiency of 97 %. It likewise proposes the L-

2C-2D inactive snubber to reduce the input current THD and to maintain the efficiency of 97 %. In light of the outcomes got, the most possible uninvolved snubber for application in the front end AC-DC converter to upgrade the general vehicle efficiency is distinguished as the L-2C-2D (ZC-ZVS) latent snubber and the presentation is additionally approved experimentally utilizing the model created. The experimental outcomes affirm the accomplishment of soft switching states of the main switch and the close to solidarity PF with in stage input voltage and input current waveforms. The input current THD and losses are a lot of reduced to 3.07 % and 44.79 W separately. The proposed L-2C-2D (ZC-ZVS) inactive snubber limits the voltage and current stress across the main switch and the diode. This, thusly, reduces the switching losses of the proposed converter centering 97 % effective activity of EVs battery accusing frameworks of solidarity PF and THD < 5% according to the IEEE principles. It became beguiling that if the current devoured by these vehicles have sinusoidal waveform with solidarity PF, the current and voltage THD will be reduced and the working of such EVs battery charging frameworks won't influence the extent significantly.

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