A Study on Power Factor Enhancement in Modified Bridgeless Landsman Converter with Fuzzy Logic Controller Fed EV Battery Charger

Abhishek Kumar Pandey[1], Santosh Singh Negi[2]
[1]M.Tech Scholar, [2]Assistant Professor
[1]Electrical Engineering Department, [2]Electrical & Electronics Engineering Department
SRK University, Bhopal, Madhya Pradesh, India
[1]pandeyabhi486871@gmail.com, [2]santoshsnegi@gmail.com

ABSTRACT: *This research work deals with the study of a new charger for battery operated electric vehicle (BEV) with power factor improvement at the frontend. In the proposed configuration, the conventional diode converter at the source end of existing electric vehicle (EV) battery charger is eliminated with modified Landsman power factor correction (PFC) converter. The PFC converter is cascaded to a fly back isolated converter, which yields the EV battery control to charge it, first in constant current mode then switching to constant voltage mode.*

Keywords: *Landsman converter, Battery, PI Controller, Fuzzy controller, Pulse Generator.*

1. Introduction

The charging protocol (how much voltage or current for how long, and what to do when charging is complete, for instance) depends on the size and type of the battery being charged. Some battery types have high tolerance for overcharging (i.e., continued charging after the battery has been fully charged) and can be recharged by connection to a constant voltage source or a constant current source, depending on battery type. Simple chargers of this type must be manually disconnected at the end of the charge cycle, and some battery types absolutely require, or may use a timer, to cut off charging current at some fixed time, approximately when charging is complete. Other batter types cannot withstand over-charging, being damaged (reduced capacity, reduced lifetime), over heating or even exploding. The charger may have temperature or voltage sensing circuits and a microprocessor controller to safely adjust the charging current and voltage, determine the cut off at the end of charge. A trickle charger provides a relatively small amount of current, only enough to counteract self-discharge of a battery that is idle for a long time. Some battery types cannot tolerate trickle charging of any kind; attempts to do so may result in damage. Lithium ion battery cells use a chemistry system which does not permit indefinite trickle charging. Slow battery chargers may take several hours to complete a charge. High-rate chargers may restore most capacity much faster, but high rate chargers can be more than some battery types can tolerate. Such batteries require active monitoring of the battery to protect it from overcharging. Electric vehicles ideally need high-rate chargers. For public access, installation of such chargers and the distribution support for them is an issue in the proposed adoption of electric cars. A good battery charger provides the base for batteries that are durable and perform well. In a price-sensitive market, chargers often receive low priority and get the “after-thought” status. Battery and charger must go together like a horse and carriage. 5 Prudent planning gives the power source top priority by placing it at the beginning of the project rather than after the hardware is completed, as is a common practice. Engineers are often unaware of the complexity involving the power source, especially when charging under adverse conditions.

2. LITERATURE SURVEY

R. Kushwaha et al., [1] this work deals with the design and implementation of a new charger for a battery-operated electric vehicle (EV) with power factor improvement at the front end. In the proposed configuration, the conventional diode converter at the source end of existing EV battery charger is eliminated with the modified Landsman power factor correction (PFC) converter. The PFC converter is cascaded to a flyback isolated converter, which yields the EV battery control to charge it, first in constant current mode then switching to constant voltage mode.

The proposed PFC converter is controlled using single sensed entity to achieve the robust regulation of dc-link voltage as well as to ensure the unity power factor operation. The proposed topology offers improved power quality, low device stress, and low input and output current ripple with low input current harmonics when compared to the conventional one. Moreover, to demonstrate the conformity of the proposed charger to an IEC 61000-3-2 standard, a prototype is built and tested to charge a 48 V EV battery of 100 Ah capacities, under transients in input voltage. The performance of the charger is found satisfactory for all the cases.

M. Gjelaj et al., [2] Widespread use of electric vehicles (EVs) requires investigating impacts of vehicles' charging on power systems. This study focuses on the design of a new DC fast-charging station (DCFCS) for EVs combined with local battery energy storages (BESs). Owing to the BESs, the DCFCS is able to decouple the peak load demand caused by multiple EVs and decrease the installation costs as well as the connection fees. The charging system is equipped with a bidirectional alternating current/direct current (DC) converter, two lithium-ion batteries and a DC/DC converter.

The introduction of BES within the DCFCSs is investigated with regard to operational costs of the CSs as well as the ability of a BES to mitigate negative impacts on the power grid during congestion hours. The proposed solution is shown to reduce not only the installation costs, but also the charging time and it facilitates the integration of fast chargers in existing low-voltage grids. A cost-benefit analysis is performed to evaluate the financial feasibility of BES within the DCFCSs by considering the installation costs, grid connection costs and battery life cycle costs.

A. Taylor et al., [3] As two exemplary candidates of wide-band gap devices, SiC MOSFET s and GaN HEMT s are regarded as successors of Si devices in medium-to-high-voltage (>1200 V) and low-voltage (<650 V) domains, respectively, thanks to their excellent switching performance and thermal capability. With the introduction of 650 V SiC MOSFETs and GaN HEMTs, the two technologies are in direct competition in <650 V domains, such as Level 2 battery chargers for electric vehicles (EVs).

This study applies 650 V SiC and GaN to two 240 VAC/7.2 kW EV battery chargers, respectively, aiming to provide a head-to-head comparison of these two devices in terms of overall efficiency, power density, thermal performance, and cost. The charger essentially is an indirect matrix converter with a dual-active-bridge stage handling the power factor correction and power delivery simultaneously. These two chargers utilize the same control strategy, varying the phase-shift and switching frequency to cover the wide input range (80–260 VAC) and wide output range (200 V–450 VDC).

Experimental results indicated that at the same efficiency level, the GaN charger is smaller, more efficient and cheaper, while the SiC charger has a better thermal performance.

M. Truntič et al., [4] this study discusses a converter structure appropriate for charging the batteries of an electric vehicle (EV). The structure is obtained by a transformation of a conventional three-phase inverter, which is already present in an EV's power-train system. Since the motor inverter's semiconductor components and the electric motor's windings form the battery charger's circuit, a reduction in the power-train system's size and weight is achievable.

The proposed fully integrated battery charger operates alternately in two modes, buck and boost, while providing power factor (PF) correction capability continuously. This study also proposes an input current control strategy that ensures smooth operating mode transitions, which occur during the operation of a battery charger. The control is entirely implemented within a microcontroller and ensures operation with a high PF and low total harmonic distortion of the input current. The performance of the discussed converter using the proposed control scheme was verified experimentally.

S. Faddel et al., [5] the penetration of electric vehicles (EVs) is expected to increase in the future. With more EVs on the road, more loads will be added to power systems, which will impact the system voltage and loading. This work studies the impact of the EVs on the distribution system and provides an automated controller that satisfies the customer requirements and mitigates the negative impacts of the charging of EVs on the system. The controller takes into consideration the system voltage, the customer requirements, and the state of charge of the battery.

The controller is tested using a large-scale distribution system in MATLAB Simulink. It is also validated using a small-scale four-bus experimental system. To show the interaction between local distributed generations (DGs) with the EV charging, the controller is tested in the presence of DG units. The results showed the superior performance of the controller in charging the EVs smoothly and mitigating the negative impacts of the grid.

G. Hilton et al., [6] High rate (<;100 kW) electric vehicle chargers (HREVCs) are crucial for achieving the benefits of reduced CO_2 and particulate emissions promised by EVs by enabling journey distances greater than the range of the vehicle. A method for predicting the expected demand pattern at these HREVCs is presented in this work. This is critical to plan a network of chargers. This novel method uses the freely available traffic flow data and travel patterns extracted from the Open Street Map combined with a novel EV battery capacity prediction method, to find future HREVC usage patterns in the U.K. and their dependence on location and EV characteristics.

This planning method can be replicated to find HREVC power demand for any location on the strategic road network in the U.K. and can be used in the analysis of the role of high rate EV charging in the wider energy system.

J. Lu et al., [7] This work presents a method for efficiency estimation of boost-derived continuous conduction mode power factor correction (CCM-PFC) converters for electric vehicle (EV) onboard chargers. The proposed methodology incorporates converter non-idealities, especially caused by magnetic components. The value of magnetizing inductance in an inductor or transformer core does not remain constant over variable current levels, which causes non-uniform power losses at different current levels.

The method proposed in this work considers a time-variant inductance over various current levels and accordingly establishes a dynamic model of loss estimation. As a proof-of-concept verification, the approach is applied to three different PFC topologies for EV applications and the estimated conversion efficiencies exhibit good agreement with experimentally obtained efficiency values over a wide range of load power from 400 W to 4.6 kW. The deviation of the efficiency predicted from the experimental data is considerably.

J. Lu et al., [8] an indirect matrix converter is employed directly converting the grid ac to the battery voltage, with the dual-active-bridge taking care of the power factor correction and power delivery simultaneously. Such circuit is regarded as one candidate of the high-efficiency and high-power-density electric vehicle onboard chargers, if the double-frequency current ripple to the battery is tolerated.

Instead of optimizing the overall charger, this work is focused on adopting variable switching frequency with multiple phase shifts to accommodate the wide input range (80-260 V_{ac}) and output range (200 V-450 V_{dc}). In addition to the phase shift between the transformer primary-side and secondary-side voltage, one extra phase shift is added to the primary-side H-bridge when the instantaneous input voltage is higher than the reflected output, otherwise, to the secondary side. The goal is to secure zero-voltage-switching for all switches at all voltage range. Such control strategy is further optimized incorporating with the switch parasitic capacitance and dead band settings. To further enhance the charger performance, GaN HEMTs are equipped to the on-board charger aiming at higher efficiency and higher power density than Si devices. Experimental results indicated that such charger with proposed control strategy embraces the peak efficiency of >97% at 7.2 kW and a power density of ~4 kW/L.

B. Lee et al., [9] this work suggests another candidate for isolated/bidirectional dc/dc converter in electric vehicle on-board charger based on PWM resonant converter (RC). The PWM-RC has good switching characteristics but it is not adequate for bidirectional applications because it is always operated under “buck type” operation regardless of power flow directions.

This problem can be solved by structure change method, which increases the converter gain into double. Also, additional technique to increase the converter gain during discharging operation is suggested by analysis of the gain characteristics. The feasibility of bidirectional PWM-RC is verified with a 6.6-kW prototype charger.

N. Bodo et al., [10] A fully integrated on-board battery charger for future electric vehicles (EVs) has been recently introduced. It reutilizes all the propulsion components of an EV in charging/vehicle-to-grid (V2G) modes, it does not require any additional components or hardware reconfiguration, and charging/V2G modes are realized with zero electromagnetic torque production. Both fast (three-phase) and slow (single-phase) chargings are possible, with unity power factor operation at the grid side. The solution is based on the use of a triple three-phase machine and a nine-phase inverter/rectifier.

This work reports on the results of efficiency evaluation for the said system. Testing is performed using both a nine-phase induction machine and a nine-phase permanent magnet machine for a range of operating conditions in charging/V2G modes, with both three-phase and single-phase grid connection. Additionally, the impact of converter interleaving on the losses and efficiency is also studied. Losses are separated for different subsystems, thus providing an insight into the importance of optimization of different EV power train components from the efficiency point of view. Promising efficiencies, in the order of 90%, are achieved although none of the system components have been optimized.

M. A. Awadallah et al., [11] this work presents a study of the impact of the electric vehicle (EV) charger load on the capacity of distribution feeders and transformers of an urban utility. A residential neighborhood of the city of Toronto, Canada, is selected to perform the study based on survey results that showed a high tendency for EV adoption. The two most loaded distribution transformers of such a neighborhood are studied along with their cable feeders via steady-state simulations in CYME software. A worst case scenario of full EV penetration is studied, where all chargers are connected to the system simultaneously at the peak summer or winter load. The effect of increasing the rate of EV adoption on the performance of distribution networks is examined with correlation to the ambient temperature. Finally, the impact of increasing the charger size on system performance is explored.

The results send a few warning signals of potential equipment overload to utility companies under certain system loading and EV charging levels as EV use grows, impacting utility future planning and operation. This will assist utilities in taking appropriate measures with respect to operating the existing system and also planning for the future.

X. Wang, C et al., [12] It is expected that wide-band gap devices like silicon-carbide MOSFETs and gallium-nitride HEMTs could replace Si devices in power electronics converters to reach higher system efficiency. This work adopts the conventional half-bridge LLC topology to realize a 10-kW all-SiC bidirectional charger used in electric vehicles. Though it is a well-known topology for the unidirectional charger, it has not been comprehensively explored for the bidirectional energy flow yet. A double-pulse-test (DPT) platform is utilized to provide accurate power losses.

A state-space model is built to obtain accurate switching current waveforms, which is eventually combined with the DPT results to accurately predict the system efficiency. Based on this model, to further enhance the system efficiency, the dc-bus voltage is varied with LLC dc/dc converter running at the resonant frequency through the whole power range. Experimental results validated that the proposed approach could realize the bidirectional power flow. By varying the dc-bus voltage, the V2G and G2V modes reach ~96 % wall-to-battery efficiency.

M. S. Diab et al., [13] this work presents a new configuration for integrated on-board battery chargers of electric vehicles (EVs) incorporating symmetrical six-phase machines. The configuration proposes an exclusive utilization of a nine-switch converter (NSC) along with the machine windings during both propulsion and charging of EVs.

The proposed configuration has the advantage of employing a reduced number of components in both the EV (on-board) and charging station (off-board), with the privilege of avoiding machine electromagnetic torque production during charging/vehicle-to-grid (V2G) mode of operation. During charging/V2G mode, the NSC is turned into a conventional three-phase pulse width modulation rectifier and is directly connected to the three-phase mains through the machine windings. Conventional three-phase transformers can be employed for galvanic isolation. Switching between propulsion and charging modes is carried out using a simple hardware reconfiguration.

Control schemes for both propulsion and charging/V2G modes are elaborated, along with the principles of operation of the NSC. Experimental results are provided to validate the theoretical deductions for the different operating modes.

S. Moon et al., [14] this work proposes a high-efficiency wireless power transfer system with an asymmetric four-coil resonator. It presents a theoretical analysis, an optimal design method, and experimental results. Multicoil systems which have more than three coils between the primary and secondary side provide the benefits of a good coupling coefficient, a long transfer distance, and a wide operating frequency range.

The conventional four-coil system has a symmetric coil configuration. In the primary side, there are source and transmitter coils, and the secondary side contains receiver and load coils. On the other hand, in the proposed asymmetric four-coil system, the primary side consists of a source coil and two transmitter coils which are called intermediate coils, and in the secondary side, a load coil serves as a receiver coil. In the primary side, two intermediate coils boost the apparent coupling coefficient at around the operating frequency. Because of this double boosting effect, the system with an asymmetric four-coil resonator has a higher efficiency than that of the conventional symmetric four-coil system. A prototype of the proposed system with the asymmetric four-coil resonator is implemented and experimented on to verify the validity of the proposed system.

The prototype operates at 90 kHz of switching frequency and has 200 mm of the power transmission distance between the primary side and the secondary side. An ac-dc overall system efficiency of 96.56% has been achieved at 3.3 kW of output power.

I. Subotic et al., [15] The work considers integration of multiphase (more than three phases) machines and converters into a single-phase charging process of electric vehicles (EVs) and, thus, complements recently introduced fast charging solutions for the studied phase numbers. One entirely novel topology, employing a five-phase machine, is introduced and assessed jointly with three other topologies that use an asymmetrical nine-phase machine, an asymmetrical six-phase machine, and a symmetrical six-phase machine.

In all topologies, both charging and vehicle-to-grid (V2G) mode are viable. Moreover, all are capable of unity power factor operation. A torque is not produced in machines during charging/V2G process so that mechanical locking is not required. Hardware reconfiguration between propulsion and charging/V2G mode is either not required or minimized by using a single switch. Theoretical analysis of operating principles is given, and a control scheme, applicable to all topologies and which includes current balancing and interleaving strategy, is developed. Finally, operation of all topologies is compared by means of experiments in both charging and V2G mode, with a discussion of influence of current balancing and interleaving strategy on the overall performance.

G. Buja et al., [16] the work deals with wireless battery chargers (WBCs) for plug-in electric vehicles (PEVs) and analyzes two arrangements for the receiver of a series-series resonant WBC. The first arrangement charges the PEV battery in a straightforward manner through a diode rectifier. The second arrangement charges the PEV battery through the cascade of a diode rectifier and a chopper whose input voltage is kept constant. Figures of merit of WBCs such as efficiency and sizing factor of both the power source and the transmitter/receiver coils are determined. Afterwards, they are discussed and compared with reference to the case study of WBC for an electric city car. A proposal to optimize the efficiency of the second arrangement by a suitable selection of the chopper input voltage is presented. Measurements on the efficiency of the two arrangements are included to support the theoretical results.

J. Park et al., [17] this study proposes an electric vehicle (EV) battery charger with a fixed frequency zero-current-switching (ZCS) series loaded resonant converter (SRC). Owing to the proposed fixed frequency operation the SRC is capable of operating under ZCS turn on and turn off regardless of voltage variation or load variation, and the magnetic components and the electromagnetic interference (EMI) filters can be optimized.

The proposed battery charger has minimum component count, which makes it possible to achieve low cost and high reliability. Also, it is insensitive to resonant component tolerances and therefore suitable for high volume manufacturing. Experimental results are provided from a 3.3 kW prototype which was built for 2011 Future Energy Challenge Competition.

J. Deng, S. Li et al., [18] In this work, an inductor-inductor-capacitor (LLC) resonant dc-dc converter design procedure for an onboard lithium-ion battery charger of a plug-in hybrid electric vehicle (PHEV) is presented. Unlike traditional resistive load applications, the characteristic of a battery load is nonlinear and highly related to the charging profiles. Based on the features of an LLC converter and the characteristics of the charging profiles, the design considerations are studied thoroughly.

The worst-case conditions for primary-side zero-voltage switching (ZVS) operation are analytically identified based on fundamental harmonic approximation when a constant maximum power (CMP) charging profile is implemented. Then, the worst-case operating point is used as the design targeted point to ensure soft-switching operation globally. To avoid the inaccuracy of fundamental harmonic approximation approach in the below-resonance region, the design constraints are derived based on a specific operation mode analysis. Finally, a step-by-step design methodology is proposed and validated through experiments on a prototype converting 400 V from the input to an output voltage range of 250-450 V at 3.3 kW with a peak efficiency of 98.2%.

T. Mishima et al., [19] A new prototype of a secondary-side phase shift soft-switching PWM dc-dc converter suitable for electric vehicle battery charging systems is presented in this work. Wide range soft-switching operations are achievable from full load to no load by effectively utilizing the parasitic inductances of the high frequency transformer in the proposed dc-dc converter. In addition, no circulating current occurs in both of the primary and secondary side full-bridge circuits; thereby, the related idling power can be minimized.

As a result, high efficiency power conversion can be maintained owing to the full range soft-switching operation and wide range output power and voltage regulations. Its operating principle is presented on the basis of theoretical analysis and simulation results, and the design procedure of the circuit parameters of the proposed dc-dc converter is described.

The essential performance and its effectiveness of the proposed dc-dc converter are originally demonstrated from a practical point of view in an experiment using a 1 kW-50 kHz laboratory prototype.

A. Kuperman et al., [20] this work presents the functionality of a commercialized fast charger for a lithium-ion electric vehicle propulsion battery. The device is intended to operate in a battery switch station, allowing an up-to 1-h recharge of a 25-kWh depleted battery, removed from a vehicle. The charger is designed as a dual-stage-controlled ac/dc converter. The input stage consists of a three-phase full-bridge diode rectifier combined with a reduced rating shunt active power filter. The input stage creates an uncontrolled pulsating dc bus while complying with the grid codes by regulating the total harmonic distortion and power factor according to the predetermined permissible limits.

The output stage is formed by six interleaved groups of two parallel dc-dc converters, fed by the uncontrolled dc bus and performing the battery charging process. The charger is capable of operating in any of the three typical charging modes: constant current, constant voltage, and constant power. Extended simulation and experimental results are shown to demonstrate the functionality of the device.

H. H. Wu, A et al., [21] this work presents the design of a 5 kW inductive charging system for electric vehicles (EVs). Over 90% efficiency is maintained from grid to battery across a wide range of coupling conditions at full load. Experimental measurements show that the magnetic field strength meets the stringent International Commission on Non-Ionizing Radiation Protection (ICNIRP) guidelines for human safety.

In addition, a new dual side control scheme is proposed to optimize system level efficiency. Experimental validation showed that a 7% efficiency increase and 25% loss reduction under light load conditions is achievable. The authors believe this work is the first to show such high measured efficiencies for a level 2 inductive charging system. Performance of this order would indicate that inductive charging systems are reasonably energy efficient when compared to the efficiency of plug-in charging systems.

J. C. Gomez et al., [22] A summary of the actual state of battery charger harmonics is presented. The effect of harmonic distortion on the distribution system, especially on distribution transformers, is analyzed. A program was developed, which allows the consideration of the transformer life consumption as function of the battery charger characteristics and charging algorithm. The program is considered a distribution planning and management tool.

The proposed tool can be easily applied to determine the optimum charging time as function of the existing load, ambient temperature, and time of day. From the study, it can be deduced that direct connect-and-charge scheme can be detrimental to the transformer life, especially under high temperature and large load. Calculations show the existence of a quadratic relationship between the transformer life consumption and the total harmonic distortion (THD) of the battery charger current. Furthermore, the current THD should be limited to 25-30% in order to have a reasonable transformer life expectancy.

3. Electric Vehicle Battery Charger

In recent years the problems of "range anxiety" associated with electric vehicles (EVs) have been alleviated by the introduction hybrids (HEVs) and plug in hybrids (PHEVs) and the development of higher energy density batteries capable of storing more energy in the same space. With the increasing popularity of electric vehicles, "range anxiety" is now being replaced by "charging anxiety". This page addresses the issues associated with providing suitable chargers and the charging infrastructure necessary to support the growing population of EVs.

It takes about three minutes fill up a petrol or diesel engine car at a filling station with enough fuel to travel about 300 miles, costing about $35 in th USA and about £52 ($80) in the UK. To travel 300 miles in a small EV passenger car would need three full charges of a typical 25kWh battery used to power these vehicles costing about $2.50 per charge in the USA with electricity priced at $0.10 per unit (kWh) and £2.50 ($3.90) in the UK with electricity priced at £0.10 per unit. The low energy cost is one of the attractions of owning an EV.

Unfortunately to put the 25 kWh of energy needed to travel each 100 miles into the battery in the same time (1 minute) that the equivalent amount of diesel fuel is pumped into the tank would require a power supply capable of delivering a power of 1.5 Megawatts. To put this into perspective, 25 kWh is the amount of energy an average household consumes in a whole day. Providing electrical distribution facilities to allow users to consume this amount of energy from the electricity grid in one minute is not practical and even if it was, no EV battery could accept energy at this rate. On the other hand neither is it practical to take 24 hours to charge the battery in a passenger electric vehicle.

The solutions don't just involve the development of chargers, they involve the design and roll out of a network of public and private charging stations with associated user authentication and billing systems, public safety and planning issues, the negotiation of international standards and beefing up the electricity grid to carry the increased load. There are no single answers to these issues. On the one hand, national and international standards organizations attempt to find definitive solutions to these issues, but there are so many competing national standards. On the other hand commercial enterprises attempt to leapfrog the competition by coming up with new and unique innovative solutions to differentiate their offerings. Some of these issues are explored here.

Charger Requirements

First we need to scope out the requirements of the vehicles we are trying to accommodate and the batteries they use. The range is very wide with energy storage requirements ranging from 0.5 kWh to 50 kWh and current carrying capacity ranging from 20 Amps to 200 Amps requiring chargers purpose built to suit the applications. Chargers provide a DC charging voltage from an AC source whether from a common socket outlet or more recently from a purpose built DC charging station. Most important are the methods of controlling the charge and protecting the battery from over-voltage, over-current and over-temperature. These charger functions are integrated with and unique to the battery.

Chargers for electric bikes are usually low cost, separate units. To save weight they are not usually mounted on the bike and charging takes place at home. Their power handling capacity is only sufficient for charging the relatively low power bike batteries and entirely unsuitable for passenger car applications.

Chargers for passenger cars are normally mounted inside the car. This is because the vehicle may be used a long way from home, further than the range possible from a single battery charge. For this reason they have to carry the charger with them on board the vehicle. Charging can be carried out at home from a standard domestic electricity socket outlet but the available power is very low and charging takes a long time, possibly ten hours or more depending on the size of the battery. Since charging is usually carried out overnight this is not necessarily a problem, but it could be if the car is away from its home base.

Such low power charging is normally used in an emergency and most cars are fitted with a higher power charging option which can be used in commercial locations or with a higher power domestic installation. In many countries this higher power facility is implemented by means of a three phase electricity supply. Commercial electric vehicles need bigger batteries which need higher power charging stations to achieve reasonable charging times but they also have extra options. Many of them follow prescribed delivery routes within a limited range from base and return to base in the evening.

In these cases off board charging is possible saving weight and space on the vehicle. Such applications can also be adapted to battery swap options. Each vehicle may have two batteries with one being charged while the other is in use. When used in long distance shuttle applications this can double the effective range of the vehicle. The vehicle depletes the battery during each journey and picks up a fully charged battery at the terminus leaving the discharged battery to be recharged ready for the next trip. This shuttle option however needs three batteries per vehicle.

Early HEVs used Nickel Metal Hydride batteries, but they are mostly being superseded by a range of variants of Lithium ion batteries which is the technology of choice for most new EV applications since they can store more energy and deliver higher power. For this reason most EV chargers are designed to work exclusively with Lithium ion batteries.

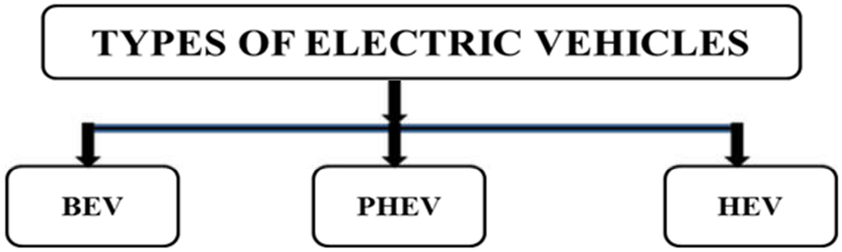

Figure 1: Classification of EV

There are three main types of electric vehicles (EVs), classed by the degree that electricity is used as their energy source. BEVs, or battery electric vehicles, PHEVs of plug-in hybrid electric vehicles, and HEVs, or hybrid electric vehicles. Only BEVs are capable of charging on a level 3, DC fast charge.

BATTERY ELECTRIC VEHICLES (BEV)

Battery Electric Vehicles, also called BEVs, and more frequently called EVs, are fully-electric vehicles with rechargeable batteries and no gasoline engine. Battery electric vehicles store electricity on board with high-capacity battery packs. Their battery power is used to run the electric motor and all on board electronics. BEVs do not emit any harmful emissions and hazards caused by traditional gasoline-powered vehicles. BEVs are charged by electricity from an external source. Electric Vehicle (EV) chargers are classified according to the speed with which they recharge an EVs battery.

The classifications are Level 1, Level 2, and Level 3 or DC fast charging. Level 1 EV charging uses a standard household (120v) outlet to plug into the electric vehicle and takes over 8 hours to charge an EV for approximately 75-80 miles. Level one charging is typically done at home or at your workplace. Level 1 charger has the capability to charge most EVs on the market.

Level 2 charging requires a specialized station which provides power at 240v. Level 2 chargers are typically found at workplaces and public charging stations and will take about 4 hours to charge a battery to 75-80 miles of range.

Level 3 charging, DC fast charging, or simply fast charging is currently the fastest charging solution in the EV market. DC fast chargers are found at dedicated EV charging stations and charge a battery up to 90 miles range in approximately 30 minutes.

PLUG-IN HYBRID ELECTRIC VEHICLE (PHEV)

Plug-in Hybrid Electric Vehicles or PHEVs can recharge the battery through both regenerative braking and “plugging in” to an external source of electrical power. While “standard” hybrids can (at low speed) go about 1-2 miles before the gasoline engine turns on, PHEV models can go anywhere from 10-40 miles before their gas engines provide assistance.

HYBRID ELECTRIC VEHICLES (HEV)

HEVs are powered by both gasoline and electricity. The electric energy is generated by the car’s own braking system to recharge the battery. This is called ‘regenerative braking’, a process where the electric motor helps to slow the vehicle and uses some of the energy normally converted to heat by the brakes.

HEVs start off using the electric motor, then the gasoline engine cuts in as load or speed rises. The two motors are controlled by an internal computer, which ensures the best economy for the driving conditions.

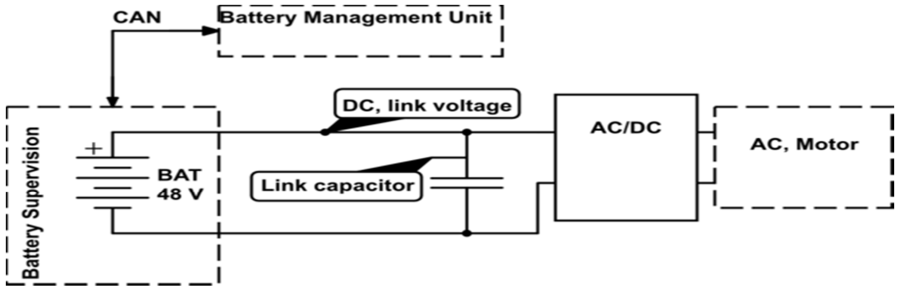

Figure 2: Block Diagram of General HEV

4. Bridgeless Landsman Converter

This work presents a modified bridgeless Landsman converter-fed power factor correction (PFC) for light emitting diode (LED) driver. The application is targeted for high brightness (HB) projection applications with brightness control of high brightness red-green-blue (HB-RGB) LEDs. The pulse width modulation (PWM) technique is used for current control to achieve effective brightness control of LED driver without compromising the efficiency.

The modified BL- Landsman PFC converter is used to feed a dual fly back DC-DC converter which supplies power to the forced LED cooling unit and the LED lighting module with a galvanic isolation. The brightness control of LED is performed by synchronous-buck converter with current modulation. The proposed PFC based modified BL- Landsman converter design is based on discontinuous conduction mode of output inductor current for high power factor (PF). A hardware prototype of the LED driver is verified experimentally.

The proposed LED driver performance evaluation at full and light load conditions is good for universal AC mains (90V-265V). The power quality parameters measured with calibrated instruments are within the acceptable limits of standard IEC 61000-3- 2 Class C for lighting systems.

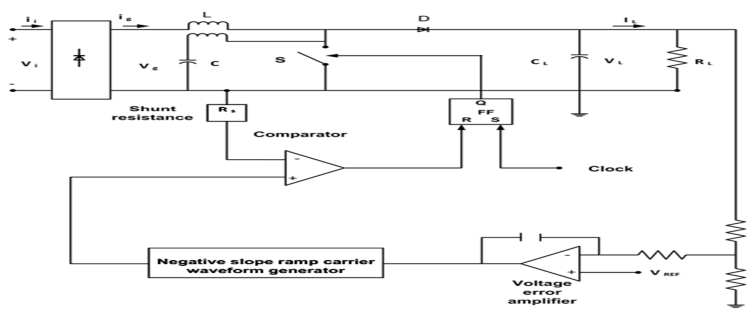

Figure 3: Bridgeless Landsman Converter

A power factor correction (PFC) based Landsman converter in bridgeless (BL) configuration feeding a brushless DC motor (BLDCM) drive is proposed for low power household appliances. The speed of BLDCM is controlled by varying the DC bus voltage of the voltage source inverter (VSI) feeding to a BLDCM. Switching losses of six solid-state switches of VSI are reduced by the use of low frequency switching signals in electronic commutation for the motor.

The front-end bridgeless PFC based Landsman converter operating in discontinuous inductor current mode (DICM) is used for DC bus voltage control and PFC is achieved inherently with reduced conduction losses and switch stress. The DC bus voltage of drive is sensed by a single DC voltage sensor. A prototype is developed for performance evaluation of the drive for speed control over a broad range. The experimental performance of BLDCM is presented for its functions at wide voltages of AC mains (90V-265 V) to adhere the limits of standard IEC 61000-3-2.

The Landsman converter based on a power factor correction (PFC) in bridgeless (BL) configuration feeding a brushless dc motor (BLDCM) drive is proposed for low-power household appliances. The conduction losses associated with diodes are reduced by BL configuration and switching losses of solid-state switches of voltage source inverter are reduced by the use of low frequency switching signals in electronic commutation for the BLDCM. The front-end BL PFC based Landsman converter operating in the discontinuous inductor current mode is used for controlling the dc link voltage, and PFC is attained naturally with reduced conduction losses and switch stress. A single voltage sensor is used for controlling the dc bus voltage.

A prototype is developed to study performance of the system for wide range speed control and power quality improvement. The experimental performance of BLDCM is presented for its functions at varying voltages of ac mains (90-265 V) to adhere to the limits defined by IEC61000-3-2 standard.

The air-conditioning is energy intensive application which normally uses single phase induction motors for driving its compressor and fans. The efficiency of these motors is between 70-80%. More over the on-off control employed for the temperature control is not energy efficient and introduces many disturbances in the distribution system along with increased wear and tear of the motor and reduce power factor. The use of PMBLDCM for driving the compressor results in energy efficiency improvement of the Air-Con. Moreover, the temperature in the air-conditioned zone can be maintained at these references smoothly while operating the Air-Condenser speed control. This paper presents to improve the power factor using Landsman Converter for PMBLDC motor application.

Mainly in air conditioning systems to achieve the below, which is difficult in conventional system. Smooth start-up of air conditioning systems without fluctuations in input voltage .Achieve the study and smooth speed control to maintain the constant Room temperature. Avoid the Harmonics in the power system due to the continuous switching millions of Air conditioners and main higher efficiency.

5. Modified Bridgeless Landsman Converter

This work deals with power factor correction (PFC) in high-brightness (HB) light emitting diode (LED) module using a bridgeless canonical switching cell (BL-CSC) converter. This application is designed for large area LED projection application with full brightness control of HB red-green-blue LED module. A PWM technique is used for brightness control of LED driver. This BL-CSC PFC converter is used to feed dual fly back DC-DC converter which supplies power to the cooling unit and the LED module with galvanic isolation. Synchronous buck converters are used for brightness control using PWM dimming technique of the multiple LED strings.

The BL-CSC PFC converter is designed for discontinuous inductor current mode operation to provide natural PFC at AC mains. A working prototype of the proposed LED driver is developed for experimental verifications. The performance parameters of the proposed HB LED driver is evaluated for a full brightness control capability with high power factor at universal input AC (90–265 V). The improved power quality parameters observed at AC mains are found within the acceptable limits of international power quality standard IEC 61000-3-2.

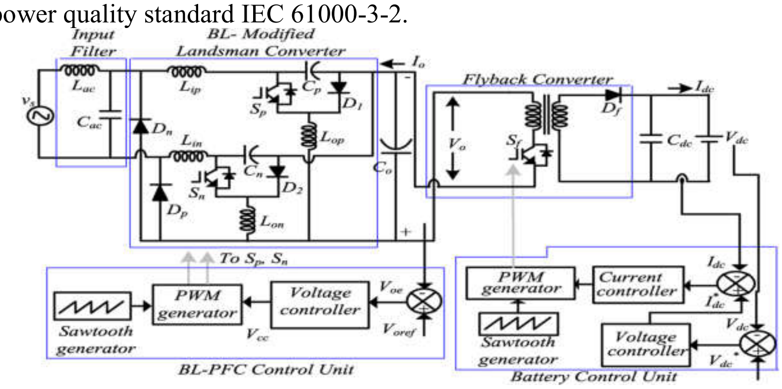

Figure 4: Modified Bridgeless Landsman Converter

When switch (Sw) is on, an energy from the supply and stored energy in the intermediate capacitor (C1) are transferred to input inductor (Li). The output inductor (Lo) starts discharging and the voltage of intermediate capacitor (vC1) starts reducing while DC-link voltage (Vdc) starts increasing. The value of intermediate capacitor is large enough to store required energy such that the voltage across the capacitor does not become discontinuous. Mode-2 In this mode of converter operation, switch is turned-off. An intermediate capacitor (C1) and DC-link side inductor (Lo) are charging through the supply current while output inductor (Li) starts discharging. Hence, vC1 starts increasing in this mode.

Moreover, the voltage across the DC capacitor (Vdc) decreases. Mode-3 is the DCM for converter operation as the input inductor (Li) is discharged completely and current iLi becomes zero. The current of DC bus side inductor (iLo) starts increasing and the voltage of intermediary capacitor (vC1) continues to decrease in this mode.

This work deals with the design and implementation of a new charger for a battery-operated electric vehicle (EV) with power factor improvement at the front end. In the proposed configuration, the conventional diode converter at the source end of existing EV battery charger is eliminated with the modified Landsman power factor correction (PFC) converter. The PFC converter is cascaded to a flyback isolated converter, which yields the EV battery control to charge it, first in constant current mode then switching to constant voltage mode. The proposed PFC converter is controlled using single sensed entity to achieve the robust regulation of dc-link voltage as well as to ensure the unity power factor operation.

The proposed topology offers improved power quality, low device stress, and low input and output current ripple with low input current harmonics when compared to the conventional one. Moreover, to demonstrate the conformity of the proposed charger to an IEC 61000-3-2 standard, a prototype is built and tested to charge a 48 V EV battery of 100 Ah capacities, under transients in input voltage. The performance of the charger is found satisfactory for all the cases.

The experimental set-up consists of four components. They are MOSFET control inverter, BLDC Motor, fluffy rationale controller and RF Transmitter and Receiver units. The BLDC engine is an electronically commutated engine. The inherent lobby sensors produce three signs as indicated by the rotor position. Here the information is given as accessible single-stage AC source. It been passed to stage controlled rectifier where it is changed over from AC to DC. The channel exhibit is utilized to expel the sounds in the DC source. At that point it is gone through the single stage to three stage inverter where the uncontrolled DC is changed over to throbbed or controlled DC.

The throbbed DC current is utilized to begin or run the BLDC engine. The rotor position is sense by the Hall Effect sensor and the flag is been opened up by the flag condition. The opened up flag is passed to the microcontrollers. Utilizing implanted c coding program is scorched in the IC 16F877A by utilizing CCS complier. The set speed is transmits by the RF transmitter and at the less than desirable end, the beneficiary gets this simple incentive on a solitary information line and passes this information to the decoder. It changes over the single piece information into eight piece information and offers it to the microcontroller which does the further preparing. Here the controller compares the reference set speed and the real speed and it varies according to it and determines the error speed and produces the control signal which sends them to the MOSFET inverter circuits. These signals are energize the appropriate windings by switching the appropriate switches in the power inverter. Thus the speed of the BLDC motor is controlled by using the microcontroller.

6. Fly back Converter

A fly back converter with an output voltage of 65V is designed to provide the isolation to the battery as well as to control the charging current in two charging modes. The selection of optimum switch rating and the magnetizing inductance L mag are the significant criteria for the fly back converter. For the required stepping down of the input voltage to 65V, a duty ratio (Dif) of 0.394 is selected to provide the necessary charging voltage to the battery. Therefore, the turn’s ratio (Nsec/Npri) is calculated.

$$V_{dc} = \frac{N_{sec}}{N_{pri}} \frac{D_{if}}{1-D_{if}} V_o$$

$$\frac{N_{sec}}{N_{pri}} = \left(\frac{1-D_{if}}{D_{if}}\right) \frac{V_{dc}}{V_o} = \left(\frac{1-0.394}{0.394}\right) \frac{65}{300} = 0.333$$

During ON time of switch S_f, the current in the magnetizing inductance of the transformer, starts increasing as described in mode-I of the flyback converter operation. The inductor current I_{Lmagf} is expressed

$$I_{Lmagf} = \frac{2 \times P_i}{V_{dc} \times D_{if}} = \frac{2 \times 850}{300 \times 0.394} = 14.38\,A$$

Where, Vdc is the output DC voltage of the PFC bridgeless converter that powers up the fly back converter. ILmag f denotes the current in the primary of the fly back transformer during ON state of switch Sf. Moreover, the size of the transformer is minimized using 50 kHz switching frequency, f_{sf} for fly back converter. The output charging voltage to the battery, corresponding to the full SOC value to near 60% SOC, is provided by wide variation in duty cycle Dif.

7. Fuzzy Logic Controller

Fuzzy logic or fuzzy set theory was introduced by Lotfi Zadeh, a computer scientist at the University of California, Berkeley, in 1965, as a means of representing and manipulating data that is not precise, but rather fuzzy or vague. In the beginning he was censured by the professional community, but progressively, Fuzzy logic (FL) captured the mind's eye of the professional society and in due course emerged as an utterly new discipline of Artificial Intelligence. The FL became a fascinating area of research because it does a good job of trading off between significance and precision – something that humans have been managing for a very long time.

The FL provides an inference that facilitates approximate human reasoning capabilities to be applied to knowledge-based systems. The theory of FL provides a mathematical strength to capture the uncertainties allied with information, such as thinking and reasoning. The classical set theory is based on Boolean logic, where a particular object or variable is either absolutely belongs to a set $\left(\mu(x)=1\right)$, or absolutely does not belong to the set $\left(\mu(x)=0\right)$. On the other hand, in fuzzy set theory based on FL, a particular object has a degree of membership in a given set that may be anywhere in the range of 0 (absolutely does not belong to set) to 1 (absolutely belong to set).

For this reason, FL is often defined as multi-valued logic (0 to 1), compared to bi-valued Boolean logic. Therefore, the approaches based on FL do provide an appropriate conceptual framework for dealing with the representation of common sense knowledge.

Over the past few decades, fuzzy logic has been used in a wide range of problem domains. Although the fuzzy logic is relatively young theory, the areas of applications are very wide. In 1965, L.A. Zadeh laid the foundations of fuzzy set theory [1] as a method to deal with the imprecision of practical systems.

Bellman and Zadeh write: "Much of the decision making in the real world takes place in an environment in which the goals, the constraints and the consequences of possible actions are not known precisely". This "imprecision" or fuzziness is the core of fuzzy sets or fuzzy logic applications.

Fuzzy sets were proposed as a generalization of conventional set theory. Partially as result of this fact, fuzzy logic remained the purview of highly specialized and mathematical technical journals for many years. This changed abruptly with the highly visible success of several control applications in the late 1980s. Heuristics, intuition, expert knowledge, experience, and linguistic descriptions are obviously important to power engineers. Virtually any practical engineering problem requires some "imprecision" in the problem formulation and subsequent analysis.

Conclusion

This research study shows the study of a new charger for battery operated electric vehicle (BEV) with power factor enhancement at the frontend. The conventional diode converter at the source end of existing electric vehicle (EV) battery charger is eliminated with modified Landsman power factor correction (PFC) converter.

References

[1] R. Kushwaha and B. Singh, "Power Factor Improvement in Modified Bridgeless Landsman Converter Fed EV Battery Charger," in *IEEE Transactions on Vehicular Technology*, vol. 68, no. 4, pp. 3325-3336, April 2019.

[2] M. Gjelaj, S. Hashemi, C. Traeholt and P. B. Andersen, "Grid integration of DC fast-charging stations for EVs by using modular li-ion batteries," in *IET Generation, Transmission & Distribution*, vol. 12, no. 20, pp. 4368-4376, 13, 11 2018.

[3] A. Taylor, J. Lu, L. Zhu, K. (. Bai, M. McAmmond and A. Brown, "Comparison of SiC MOSFET-based and GaN HEMT-based high-efficiency high-power-density 7.2 kW EV battery chargers," in *IET Power Electronics*, vol. 11, no. 11, pp. 1849-1857, 18 9 2018.

[4] M. Truntič, T. Konjedic, M. Milanovič, P. Šlibar and M. Rodič, "Control of integrated single-phase PFC charger for EVs," in *IET Power Electronics*, vol. 11, no. 11, pp. 1804-1812, 18 9 2018.

[5] S. Faddel, T. Youssef, A. T. Elsayed and O. A. Mohammed, "An Automated Charger for Large-Scale Adoption of Electric Vehicles," in *IEEE Transactions on Transportation Electrification*, vol. 4, no. 4, pp. 971-984, Dec. 2018.

[6] G. Hilton, M. Kiaee, T. Bryden, B. Dimitrov, A. Cruden and A. Mortimer, "A Stochastic Method for Prediction of the Power Demand at High Rate EV Chargers," in *IEEE Transactions on Transportation Electrification*, vol. 4, no. 3, pp. 744-756, Sept. 2018.

[7] J. Lu, A. Mallik and A. Khaligh, "Dynamic Strategy for Efficiency Estimation in a CCM-Operated Front-End PFC Converter for Electric Vehicle Onboard Charger," in *IEEE Transactions on Transportation Electrification*, vol. 3, no. 3, pp. 545-553, Sept. 2017.

[8] J. Lu *et al*., "Applying Variable-Switching-Frequency Variable-Phase-Shift Control and E-Mode GaN HEMTs to an Indirect Matrix Converter-Based EV Battery Charger," in *IEEE Transactions on Transportation Electrification*, vol. 3, no. 3, pp. 554-564, Sept. 2017.

[9] B. Lee, J. Kim, S. Kim and J. Lee, "An Isolated/Bidirectional PWM Resonant Converter for V2G(H) EV On-Board Charger," in *IEEE Transactions on Vehicular Technology*, vol. 66, no. 9, pp. 7741-7750, Sept. 2017.

[10] N. Bodo, E. Levi, I. Subotic, J. Espina, L. Empringham and C. M. Johnson, "Efficiency Evaluation of Fully Integrated On-Board EV Battery Chargers With Nine-Phase Machines," in *IEEE Transactions on Energy Conversion*, vol. 32, no. 1, pp. 257-266, March 2017.

[11] M. A. Awadallah, B. N. Singh and B. Venkatesh, "Impact of EV Charger Load on Distribution Network Capacity: A Case Study in Toronto," in *Canadian Journal of Electrical and Computer Engineering*, vol. 39, no. 4, pp. 268-273, Fall 2016.

[12] X. Wang, C. Jiang, B. Lei, H. Teng, H. K. Bai and J. L. Kirtley, "Power-Loss Analysis and Efficiency Maximization of a Silicon-Carbide MOSFET-Based Three-Phase 10-kW Bidirectional EV Charger Using Variable-DC-Bus Control," in *IEEE Journal of Emerging and Selected Topics in Power Electronics*, vol. 4, no. 3, pp. 880-892, Sept. 2016.

[13] M. S. Diab, A. A. Elserougi, A. S. Abdel-Khalik, A. M. Massoud and S. Ahmed, "A Nine-Switch-Converter-Based Integrated Motor Drive and Battery Charger System for EVs Using Symmetrical Six-Phase Machines," in *IEEE Transactions on Industrial Electronics*, vol. 63, no. 9, pp. 5326-5335, Sept. 2016.

[14] S. Moon and G. Moon, "Wireless Power Transfer System With an Asymmetric Four-Coil Resonator for Electric Vehicle Battery Chargers," in *IEEE Transactions on Power Electronics*, vol. 31, no. 10, pp. 6844-6854, Oct. 2016.

[15] I. Subotic, N. Bodo and E. Levi, "Single-Phase On-Board Integrated Battery Chargers for EVs Based on Multiphase Machines," in *IEEE Transactions on Power Electronics*, vol. 31, no. 9, pp. 6511-6523, Sept. 2016.

[16] G. Buja, R. K. Jha, M. Bertoluzzo and M. K. Naik, "Analysis and comparison of two wireless battery charger arrangements for electric vehicles," in *Chinese Journal of Electrical Engineering*, vol. 1, no. 1, pp. 50-57, Dec. 2015.

[17] J. Park, M. Kim and S. Choi, "Zero-current switching series loaded resonant converter insensitive to resonant component tolerance for battery charger," in *IET Power Electronics*, vol. 7, no. 10, pp. 2517-2524, 10 2014.

[18] J. Deng, S. Li, S. Hu, C. C. Mi and R. Ma, "Design Methodology of LLC Resonant Converters for Electric Vehicle Battery Chargers," in *IEEE Transactions on Vehicular Technology*, vol. 63, no. 4, pp. 1581-1592, May 2014.

[19] T. Mishima, K. Akamatsu and M. Nakaoka, "A High Frequency-Link Secondary-Side Phase-Shifted Full-Range Soft-Switching PWM DC–DC Converter With ZCS Active Rectifier for EV Battery Chargers," in *IEEE Transactions on Power Electronics*, vol. 28, no. 12, pp. 5758-5773, Dec. 2013.

[20] A. Kuperman, U. Levy, J. Goren, A. Zafransky and A. Savernin, "Battery Charger for Electric Vehicle Traction Battery Switch Station," in *IEEE Transactions on Industrial Electronics*, vol. 60, no. 12, pp. 5391-5399, Dec. 2013.

[21] H. H. Wu, A. Gilchrist, K. D. Sealy and D. Bronson, "A High Efficiency 5 kW Inductive Charger for EVs Using Dual Side Control," in *IEEE Transactions on Industrial Informatics*, vol. 8, no. 3, pp. 585-595, Aug. 2012.

[22] J. C. Gomez and M. M. Morcos, "Impact of EV battery chargers on the power quality of distribution systems," in *IEEE Transactions on Power Delivery*, vol. 18, no. 3, pp. 975-981, July 2003.