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An integrated controller for power quality enhancement in plug-in electric vehicle charging applications

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ABSTRACT: The plug-in electric vehicle is going to be the dominant part of transportation within a few years in which this charging of many vehicles with proper time and without delay is one of the main tasks that need to be fulfilled, like with minimum time the vehicle should be fully charged. The main disadvantages of charging a plug-in electric vehicle are emi issues, power quality distortion and lack of efficiency. The proposed systems are sophisticated and improve the overall efficiency of the system. The power factor correction circuit in the proposed system and the emi filter and DC/DC voltage controller together goveries the overall system performance. The battery which is inside the vehicle and a port is connected to the vehicle. The overall circuit will act as a board charging circuit thus the vehicle does not require any specified supply for the charging purpose. It can be directly connected to any supply voltage, ranging from (110-250)V AC source. The power quality is enhanced with reference to the store of charge of connected vehicles like scooter, car etc. The proposed system can be connected to two wheeler and four wheeler vehicles because the controller it sets will maintain the charging voltage and charging current.

KEYWORDS: Power factor, DC/DC converter, THD, BMS, power management.

I. INTRODUCTION

Electricity is the most efficient means of obtaining energy from the sun and wind. To put it another way, a sustainable transportation system requires the vehicle to be powered by an electric energy source. A vehicle that is powered at least partially by electric force obtained from electric motors or traction motors is known as an electric vehicle (EV). A charging system is a mechanism that forces electric current through a rechargeable battery to supply energy to it. Varying batteries require different amounts of power and take different amounts of time to charge.

An on board charger that can be used to recharge a car battery for plug-in technology. This charger can regulate the load's voltage and current values and keep them there. The grid's 50 Hz electrical values are converted into dc quantities using the first converter [1]. A second converter provides galvanic isolation while also adjusting the levels to the battery's specifications. It explains why the components and the structure were chosen.

As the world moves toward reducing carbon pollutants and oil dependency, which are destructive to the climate and raise greenhouse gas emissions, electrification of vehicles has gained relevance since it would also reduce other harmful pollutants such as ozone and particulate matter. Battery electric vehicles have the potential to utilize fewer fossil fuels overall than hybrid electric vehicles, which are only partially powered by electricity [2]. To make them as excellent as or better than a regular vehicle, numerous technologies are applied, including regenerative braking, an autopilot system, auto start and shut-off, and even more sophisticated technology.

The most essential type of recharge system is the wireless charge system, which delivers electricity from transmitter to receiver without any contact in addition to playing a crucial function in providing a vehicle with the necessary power [3]. The wireless charging method for electric vehicles is disclosed.

The primary goal of achieving Car to Grid (V2G) and Grid to Vehicle (G2V) applications, describes a bidirectional on-board single-phase electric vehicle charger. A buck converter and a high gain boost converter combination make up the majority of the bidirectional charger configuration. Based on the battery's state of charge, the battery is charged and discharged. To verify the bidirectional on-board charging capability with a high gain boost

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converter, simulation is done using the Matlab Simulink software. Bidirectional converter topology, converter design and battery working algorithm are discussed in this work. The grid can exploit the electrical car to its advantage thanks to the bi-directional power flow. The charger has two modes of operation: G2V and V2G. The charger consists of a cascaded DC-DC converter and a bidirectional AC-DC charger [4]. The integrated DC-DC converter is made up of a high gain boost converter for V2G operations and a buck converter for G2V operations.

An onboard battery charger for plug-in electric vehicles that are versatile (PEVs). Three H-bridge modules, which include a selective switch, a high-frequency transformer, and inductors, make up the proposed battery charger. When a PEV connects to the ac grid, the proposed charger's primary function is to charge the propulsion battery [on board charger (OBC)] Ac-to-dc conversion with power factor correction is accomplished in this case by the suggested charger. Occasionally, the propulsion battery can send extra energy to the grid [vehicle to grid (V2G)]. As more charging stations were connected to the power system and electric vehicles were charging under base load and peak load situations, it was noticed that the input power factor values rapidly decreased [9]. With the installation of charging stations during base loads, it was discovered that total harmonic distortions increased. During high loads, the THD values do not significantly change.

II. TOPOLOGY

The battery is the energy source for the plug-in electric vehicle. Thus the charging of the battery is the main concern about the development of a control system for the application of charging and pev. The proposed system is of two parts one is PFC (power factor correction circuit) consists of a bridge rectified and a DC DC converter. The second part is the DC/AC inverter or simply a boost convertor. Fig 1 shows the block diagram of the proposed system.

The battery which is placed inside the vehicle, the charging controller, is an off on-board vehicle charger. The lid is connected with AC input and the parametric of the battery is being monitored continuously for the safe operation of the proposed system. The voltage source interior is included in the system which enables the charging voltage of the battery. A flyback transformer is inserted between the DC voltage source and battery, which will provide electrical insulation and higher efficiency to the system. A LC filter is introduced in order to filter the unwanted components from the DC voltage supply. The power quality enhancement is the main objective of the proposed system which is achieved through two stages. One from the PFC correction circuit and other in the flyback transformer.

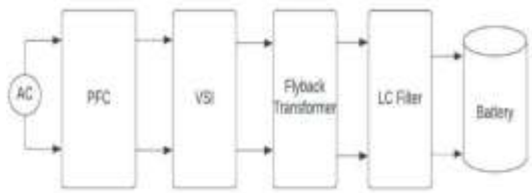

Figure 1: Block Diagram of the Proposed System

III. OPERATING PRINCIPLE

The proposed system has two stages. One from the power factor correction section which includes the AC voltage input, bridge rectifier and boost convertor. In this stage the PFC is carried out with a high end power factor which is around o. T9 is obtained. The pulse signal is provided by the closed loop PS controllers by governing the DC-link voltage of a constant voltage.

In the second stage the dc-voltage is converted into a high frequency AC voltage which is fed to the primary of the flyback transformer. The pulse generated for the VSI is governed by the controller by considering the AC and DC voltages. The high switching frequency flyback transformer is transferring the power from the input side to output. The battery charging voltage and current is monitored continuously and the robust controller generates the switching pulse with varying duty cycle in accordance with land conditions. Figure 2 shows the control system of the proposed converter.

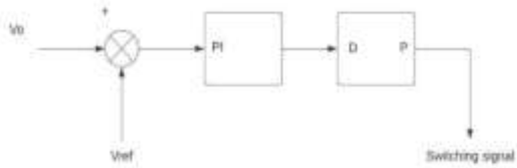

Figure 2: Modelling of Power factor corrector

Over the stages, irrespective of the voltage of the battery the charging voltage and current are governed by the control scheme; the power factor and the THD are monitored over the period. For analysing the performance of the proposed system.

IV. PROPOSED SYSTEM

The battery is being charged by the AC supply. The battery control, grid connection and the PFC control are the components of the system.

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A. Grid connected PFC circuit

When connecting a DC supply circuit to a battery these will be changing and discharging losses that will be leading to distortion in the power factor of the system and overall efficiency of the system will be reduced. Table 1 shows the parameter of the component used in the PFC circuit. It is basically a boost converter with a bridge rectifier. Once the AC voltage is rectified into a DC voltage it is being boosted up to a voltage level that is sufficient enough to charge the flyback transformer for the charging purpose.

After the voltage link capacitor is charged to a position level of voltage then the flyback transformer starts working and zero voltage switching and zero current switching are achieved leading to more efficiency by reading the THD figure 3 shows the PFC of the proposed design.

Table 1: PFC circuit parameters

Sl No	Parameter	Value
1	L	1 mH
2	C	1000 µf
3	fs	1 KHz
4	Input V	230,50 Hz

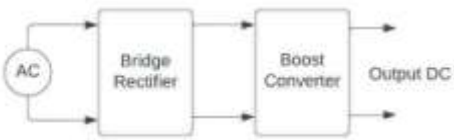

Figure 3: PFC of the proposed system

B. Charging circuit / Charging controller

The charging controller works based on the requirement of charging voltage and charging current. The voltage source inverter is governed by the closed loop controller which will vary the duty cycle of the system in accordance with the CV and CC. The voltage generated at the Dc link capacitor is fed to the input of the flyback transformer figure shows the structure of a flyback transformer figure 4 shows the structure of a flyback transformer.

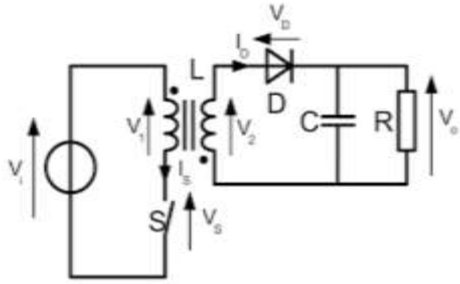

Figure 4: Flyback Transformer Design

The switching pulse for the application is developed for maintaining the voltage to the input of the capacitor. The flyback transformer will act as an isolation transformer. And transfer the power only when the switching pulse is off. For The duty cycle which is in the off the off condition the stored energy in the transformer transferred to the output of the battery connected upto a charging voltage level. The transformer itself doesn't have a switching controller but the voltage source inverter itself produces enough switching pulse and duty cycle for the application.

C. LC Filter

The purpose of the LC filter is to maintain the output voltage level at a fixed point for the charging of the battery. The voltage level may fluctuate with the state of charge of the battery. So the unwanted component should be removed by the LC filter. Table 2 gives the parameters of LC filter and VS1

Table 2: LC Filter

Sl.no	Parameter	Value
1	L	1mH
2	C	1000μf
3	fs	10KHz
4	RL	100Ω

D. Battery Control

The battery connected to output terminals of the LC Filter the Parameters of the battery given in Table 3.

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Table 3: Battery Parameters

Sl.no	Parmeter	Value
1	V Normal	240V
2	Ah	24Ah
3	SOC	30-90%

V. RESULTS AND DISCUSSION

A 10 kW system with 24hr battery is simulated and analysed using MATLAB/Simulink. Figure 5 shows the simulation diagram of the proposed system in which the grid is used as the power source for the system.

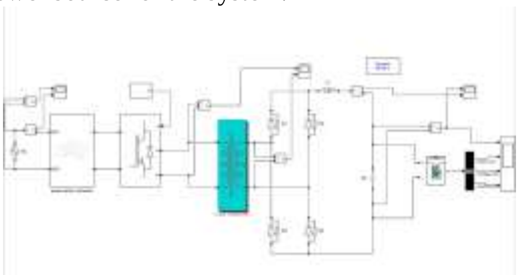

Figure 5: Simulation Diagram of the proposed system

The figure 6 shows the VI characteristics of the battery with time and ampere - hour from the figure it is clear that the optimum points where battery working are between (300 - 350)V and 13A is 2.5 hr.

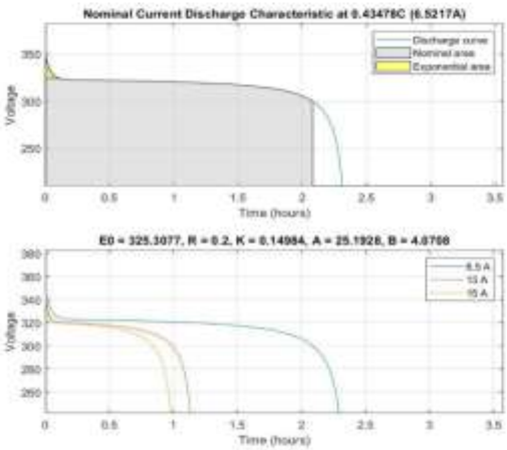

Figure 6: Battery properties in hours

The modified system reduces the charging time of the battery by around 1.3 Ar with power factor improvement. The power factor throughout the experiment is 0.99 and THD is equal to zero.
Figure 7 shows the power factor cmd frequency of the system the frequency is constant at 50Hz and the power factor is very closed to 1 by measurement it shows between (0.96-0.99) which is high efficient

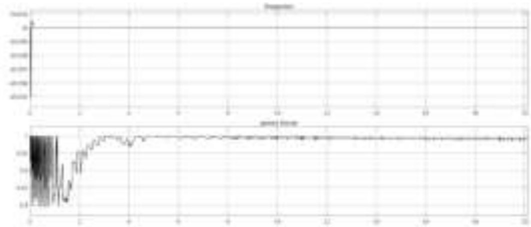

Figure 7: Frequency and Power factor measurement

Figure 8 shows the grid voltage and grid current used for the proposed system in which by controlling the switching pulse the voltage and current are taken.

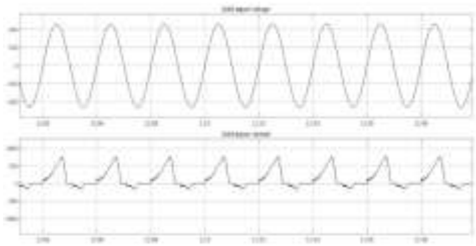

Figure 8: Grid input voltage and current waveform

By using a PFC circuit the power factor will be high enough without the PFC circuit the pf will be less that is the current will not start at the beginning itself; this will be a delay in the development of current through the circuit.

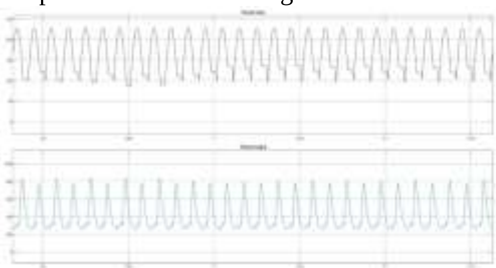

Figure 9: Input and output voltage of boost converter

Figure 9 shows the input and output of the boost converter. From the figure it is clear that the voltages are verified in accordance with the switching pulse used for the proposed system. The mean input voltage will be 150 and output will be 400V. Thus it will be switched enough to charge the fly back transforms.
The active and reactive power of the system should be regulated in the proposed range for the smooth

operation of the system. Figure 10 shows the active and reactive power of the proposed system.

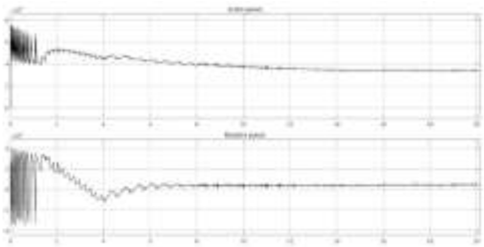

Figure 10: Active and Reactive Power waveforms

From the figure it is clear that the active power is off 30kw constant alter 10s and the reactive power is around zero not equal to the active power. The concern is that the active power should be enough to charge the battery upto the normal value.

Figure 11 shows the input and output voltage of the flyback transformer; the voltage will be switching with the high switching frequency. From the figure it is clear that input and output voltage are the same with a time period of 50 ms i.e. 5KHz switching frequency and the flyback transformer will work well.

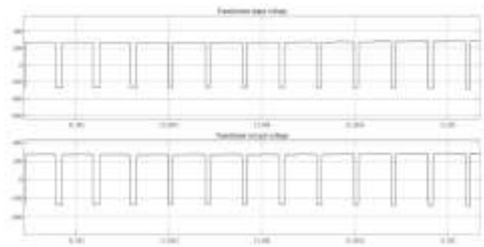

Figure 11: Input and output voltage of the transformer

The charging of the battery is the main task that needs to be achieved by using the proposed design. Figure 12 shows the battery parameters used in the proposed system.

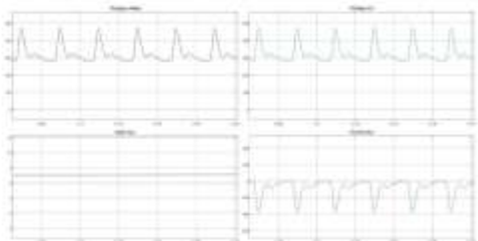

Figure 12: Battery Parameters

The parameters measured are charging voltage state of charge battery voltage and charging current. From the graph it is clear that even if there is a fluctuation in the input voltage the system is stable and shows the efficiency will be enough to get high efficiency. The proposed controller has the advantage that the input voltage varies from the range (200 - 250)V AC. That will not distract the output charging voltage. The possession of flyback transfer leads to the advantage that it will not attend to any faults from source side to load side and load side due to the isolation transformer. This proposed system can be off 720w charging system for the usage purpose.

VI. CONCLUSION

The power quality improvement of plug-in electric vehicle charging systems has importance due to vast usage and power dispersion due to the charging of pov using on grid chargers. A 720w grid connected charging controller is used in the proposed system. The proposed system is designed and developed in the MATLAB/Simulink from the analysis. It's clear that the proposed system has improved the power factor when compared with the conventional charging system where the power factor i.e. very less than 0.6 the proposed also has the advantage that it will value the THD in the frequency components which will reduce due efficiency and be removed and diminished. The frequency is kept at 50 Hz throughout the operation. The power factor obtained is around 0.99.

The proposed system can be implemented in many applications where the battery recharging is on grid like the two wheeler four wheeler and even the heavy duty cracks can be charged are the charging voltage and charging current that can be monitored using the state charge of the battery that can be monitored continually using the proposed controller.

Electricity is the most efficient means of obtaining energy from the sun and wind. To put it another way, a sustainable transportation system requires the vehicle to be powered by an electric energy source. A vehicle that is powered at least partially by electric force obtained from electric motors or traction motors is known as an electric vehicle (EV). A charging system is a mechanism that forces electric current through a rechargeable battery to supply energy to it. Varying batteries require different amounts of power and take different amounts of time to charge.

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