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EV Charging Using PFC

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Abstract - At present, the automotive industry has equipped their electric vehicles with the on-board charger with PFC, where it converts the power in order to charge the high voltage battery. However, there is a demand to remove the on-board charger with PFC from the vehicle since it requires large space and weight. Therefore it is desirable to investigate if it is feasible to relocate and redesign the on-board charger with PFC to an external portable charger with PFC. Since this charger with PFC is suppose to be portable, it is essential that the design is lightweight and compact.

This research completed an analysis of a dissembled on-board charger with PFC, topolo- gies review of converters, components selection, loss calculations, electric circuits simulation and thermal simulation studies.

In this study it was demonstrated that it was feasible to design an off-board charger with PFC for electric vehicles. The charger with PFC was design for a current level of 10 A, which has a 30VDC Charging voltage, a weight of 2.8 kg.Forced cooling has been implemented, to prevent overheating of the power electronic components.

Key Words**:** On-board charger with PFC, Off-board charger with PFC, AC/DC converter, DC/DC con- verter, PHEV, Boost, Totem-pole, Full-bridge, Half-bridge and Cooling system.

1. INTRODUCTION

Today, consumer and automotive markets involve high-performance devices. Ideally, an infinite source of energy is desired from the end-user. True mobility is that the most engaging feature of both handheld devices and electric vehicles [1]. Academic and industrial research is really focused on accomplishing true portability while keeping high performances of devices. True portability while saving cost of energy from the electrical grid is that the key challenge to face with. within the last years, great efforts are made to both improve the facility conversion efficiency of the entire charging station and integrating within the charging equipment low-emission renewable energy sources, thus reducing the quantity and price of energy drawn from the electrical grid [2-9].

For years, powering handheld devices by renewable energy sources like fuel cells or micro photovoltaic generators are the leading research topic [10-14]. within the previous couple of years, European and worldwide research programs are dominated by cell and photovoltaic based applications. Accurate modeling of renewable energy sources remains an acknowledged open topic to shorten the general design process [15-19]. Today, several leading firms are investing on efficient energy harvesting solutions for handheld devices. Whereas within the past, PFC sensor networks and biomedical applications were the most application areas, today multi-sourcing techniques are investigated to supply efficient battery charging in handheld devices.

Supplying the standby power by harvesters is one among the foremost attractive research topics. within the past, main investments on power electronics research were focused on speeding up the transient response improving steady-state and dynamic load regulation keeping as a side effect the development of the facility conversion efficiency [20-21]. Nowadays, the facility conversion efficiency plays a key role in power supply system design to accomplish with modern trends in energy saving. within the literature, several innovative solutions to efficiency related issues are proposed for a good sort of research areas, from front-end to point of load converters [22-24].

Due to increasing oil price and heating , the electrical traction of transportation means represents a convenient solution in terms of cost and environmental cleanness. Therefore, the utilization of electrical power is especially compliant with urban mobility, since the distances covered by vehicles are relatively short inside cities. Among urban electric vehicles, bicycles are certainly the smallest amount noisy and polluting ones. Moreover, electric bikes are cheaper than the opposite electric vehicles. within the electric bicycle, so-called “E-bike”, a neighborhood of the classical energy source, that's muscle power, is replaced by electricity, providing the likelihood of an electrical assisted pedal [25-26].

In the near future, a rising number of electrical vehicles should move through the urban roads. during a similar scenario, new battery recharge stations are going to be necessary so as to supply all vehicles the quantity of electrical energy which is required for his or her traction. an electrical vehicle battery is usually recharged through the normal “plug-in” method that's a wired connection between the vehicle and a charging column which is linked to the electrical grid. Despite its simplicity, this charging method seems to be uncomfortable for the driving force , who has got to plug the cable into the socket, and unsafe, thanks to the electrocution danger arising from old power cords and even more likely in wet conditions. Furthermore, the presence of wires could bother, especially when tons of small vehicles are parked very on the brink of one another , as in parking lots. For this purpose, PFC battery charging is really investigated for automotive applications also.

Nevertheless, the normal energy sources still provide better performances in terms of auto autonomy and power conversion efficiency of the entire charging equipment. Conventional fuels or grid-connected wired charging still ensures higher performances.

In the literature, several innovative solutions for PFC power transfer which ensure complete mobility are proposed

[27-29]. Yet, if compared with their wired counterparts, power conversion efficiency is comparatively low. albeit PFC technology is already mature, the loss of a couple of percentage points of power conversion efficiency remains the main hindrance to a successful spread on the market. Since extremely low power levels are involved, handheld applications are less burdened by the loss of efficiency than automotive applications. Whereas prototypes of PFC

Research is therefore focused on efficiency related issues aiming at ensuring the very best mobility while reducing consumption from the electrical grid.

In this paper a PFC solution of E-bike battery recharge is proposed. Power transfer from grid to battery is achieved through magnetic coupling: a coil, connected to mains, transmits energy towards another coil, placed upon the bike and linked to its rechargeable battery. Cyclers should only park their bike and recharge will start automatically, without having to use bulky and dangerous power cords

2. E-BIKE CHARGING SYSTEM

Fig. 1 shows a diagram of the proposed recharging system, compliant with an E-bike battery. From the left to the proper , the subsequent parts are shown: the grid-connected subsystem, also mentioned as power transmitter; the resonant network, including a magnetic efficiently converts the AC signal into a 48V DC bus level; A battery charger, which controls the flow of charge from rectifier to battery; the E-bike LiFePO4 battery.

The following design procedure has been undertaken. consistent with the envisioned spatial constraints pertaining to an E-bike battery PFC recharge, the magnetic coupling structure has been selected and analysed through magnetic Prototype software. From the magnetic simulator analysis, inductive and resistive parameters values are obtained and consequently included within the circuit Prototype model of the entire charging equipment. supported the chosen coil length, wire section and material, electrical phenomenon losses versus operating frequency are modelled too.

In order to get the nominal 48V rectifier output voltage along side a high coupling efficiency value, a hard and fast and resonant operating frequency control has been implemented. Power load regulation is achieved by varying the duty-cycle of the inverter square wave. coupling structure; the load-connected subsystem, also referenced as power receiver, which supplies the ultimate rechargeable battery. Nowadays LiIon batteries are typically employed for E-bike supply. The proposed recharge system complies with a designed system envisions an about 100W recharge.

The grid-connected subsystem includes an AC-DC stage, which converts the grid AC low frequency voltage into a 36V DC voltage, and an inverter, which converts the DC voltage into a high frequency AC signal.

Due to the magnetic coupling inside the resonant network, a PFC power transfer occurs from power transmitter to power receiver, consisting of this AC signal flowing towards the load-connected subsystem.

The power receiver includes: a lively rectifier, which efficiently converts the AC signal into a 48V DC bus level; A battery charger, which controls the flow of charge from rectifier to battery; the E-bike LiFePO4 battery.

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The proposed rectifier, shown in Fig. 2, is implemented through an innovative “cross-coupled” topology and a correct driving network, consisting of two comparators (comp1-comp2) and two not logic gates (inv1-inv2). The cross-coupled configuration consists of 4 active switches: two enhancement pMOS (M1-M2) and two enhancement nMOS (M3-M4). The rectifier AC input , like the resonant network output , is applied between M1 and M2 gate terminals. The DC rectified output is sensed between M1- M2 common source node and ground. M1 and M3 drain terminals are connected, also as M2 and M4 drain terminals. M1 gate terminal is connected to M2-M4 drain terminals; M2 gate terminal is connected to M1-M3 drain terminals. All four gate MOSFETs don’t require any external signal to be driven by: pMOS gates are driven by the input AC signal polarities (-AC and +AC), while nMOS ones are driven by two signals which are obtained by processing the AC input through the driving network. The comparators convert the analog signals – AC and +AC into two digital signals, B1 and B2: when – AC (+AC) is positive to ground, B1 (B2) corresponds to logic 1; when –AC (+AC) is negative to ground, B1 (B2) corresponds to logic 0. The not gates haven't only a logic function, but also work as drivers, thus providing the required gate currents to both the nMOS. Therefore, when the AC signal is positive, G3 and G4 correspond to logic 1 and 0, thus turning M3 on and M4 off; since M3 is on, M2 gate terminal is tied to ground connections, thus driving M2 into conduction. When the AC signal is negative, G3 and G4 correspond to 0 and 1, thus turning M3 off and M4 on; since M4 is on, M1 gate terminal is tied to ground connections, thus driving M1 into conduction.

In brief, during the input AC signal positive half-wave, the height voltage is rectified by M2 and M3 while M1 and M4 are off; during the negative half-wave, the height voltage is rectified by M1 and M4 while M2 and M3 are off. Subsequently, an equivalent behavior of the normal

3. COMMUNICATION LINK

so as to properly fulfill the load power requirements, regulating the PFC transfer is important . A transmitter side control might be an appropriate technique to efficiently suits this goal. Therefore, a communication link between primary and secondary side is required , in order that the load-connected subsystem could inform the grid-connected subsystem about the specified power amount. The proposed channel is implemented through an amplitude modulated signal which is shipped from the facility receiver back to the facility transmitter. The AM is achieved by modulating the equivalent load of the secondary-side resonant tank. For this purpose, a further passive network

is alternatively connected to or disconnected from the resonant tank, consistent with a hard and fast communication protocol. The modulation frequency must obviously be less than the switching frequency so as to supply an actual AM signal. Then, the so-generated modulation signal is shipped back to the transmitter side by the mean of the magnetic coupling network. The modulated signal is monitored by the primary-side sensing network and a correct demodulation occurs by filtering the switching frequency harmonic. A microcontroller decodes this demodulated signal and generates the right inverter MOSFETs gates drive signals.

4. PROTOTYPE RESULTS

The Prototype model of the facility stage is implemented in SPICE-based Prototype environment. Note that SPICE-based Prototype environment is really considered the simplest option for circuit Prototype of such a system. because of the utilization of effective device models, the power conversion efficiency can be easily evaluated. the precise choice is further supported by considerations on the entire charging equipment. Designers aim at modeling the entire system as closely as possible to its effective behavior, including load and sources.

Besides the facility stage of both primary and secondary sides, the entire PFC battery charging station includes a digital section and an impact subsystem. MATLAB/Simulink Prototype environment is fairly considered the simplest option for every further subsystem. Note that to shorten the general design process, the entire charging station should be accurately modeled and tested since the Prototype stage. The Prototype of mixed analog-digital-power sections is achieved by SPICE-MATLAB-ALDEC co-Prototype toolboxes, powerfully integrated in Simulink environment. Such a co-Prototype procedure allows the designer to check power conversion efficiency of the facility stage, timing of the digital system, stability problems with the control subsystem in an unique Prototype setup. Accurate analysis of measured data is vital to reliability of measurements [33-36].

Although the experimental prototype will include charger and battery, in Prototype tests a continuing 2A current independent source has been connected to the rectifier output. An open loop configuration has been tested to guage the facility transfer efficiency.

where PLOAD and PRX are respectively the load power and therefore the receiver power losses. Therefore, a 98.5% value of the receiver efficiency is obtained. a rise of 5 percentage points of the facility conversion efficiency has calculated by the voltage on the facility battery divided by this flowing through it. Moreover, the full-bridge rectifier, its input inductance, output filter capacitor, and thus the load resistance ar along outlined as a results of the rectifier circuit. though subsequent analysis is conducted supported the precise system, it ar usually extended to applications on different rectifier and compensation network topologies.

been highlighted as compared with the traditional full-wave diode rectifier solution. Regarding the resonant network, a 91.6% coupling efficiency has been obtained.

The power conversion efficiency of the general PFC charging system 5MÆG&RX, including magnetic coupling and receiver section, is given by (10):

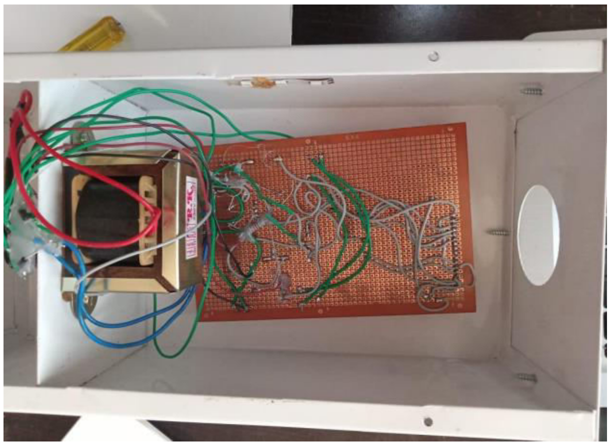

Fig. 9. Prototype results under 48V DC bus at the rectifier output. The switching period is set at 10µs.

CONCLUSIONS

In this paper, an innovative recharge system for E-bike batteries has been proposed. Power transfer from the grid to the load is achieved PFC through a magnetic coupling structure. Although an air gap occurs between grid-connected and battery-side coils, the proposed PFC solution allows an efficient recharge. Power transmitter, magnetic coupling and power receiver are accurately designed.

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